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Putting the learner into the Science of Learning and Development (SoLD)

Knowing, learning, deepening, transferring

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CSE CENTRE FOR STRATEGIC EDUCATION
Leading educational thinking and practice

Contents

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Introduction

Learning is a complex process. It has attracted the interest of theorists for millennia. Plato (c 428–347 BC) provided an early Western philosophical perspective in 'The Republic' and subsequent dialogues (Murphy, 2015; Scott, 1995).

Theories proliferated over the last two centuries, with the emergence of disciplines such as neuroscience, epigenetics, early childhood, the social and cultural sciences, psychology, education and psychometrics. In education in recent years this interest has crystallised in the *Science of Learning and Development* (SoLD).

The aim of SoLD is to identify evidence-based commonalities across the various theories, and to synthesise them into a set of propositions about how students learn, as well as the developmental, contextual and cultural factors that scaffold it. It also targets the implications for teaching and educational provision.[1]

The breadth of SoLD is immense. In this paper I examine one aspect – the evidence base for the role of an individual's knowledge in the learning process, and how this changes during learning. I explore learning in the context of formal educational provision, where provision is intended to guide students' learning to outcomes, usually decided by the student's culture. Learning is more likely when the provision matches how students implement these processes.

Education as 'leading learning' is indicated in its etymology. The word 'educate' derives from the Latin 'e+duco'. 'ducere' means 'to lead, guide, think' and 'e' means 'out of' or 'from'[2] (Bass and Good, 2004). The words 'educare', meaning to teach or bring up children and 'educere', meaning to bring out or 'lead forth', evolved from these roots. The two processes are complementary: teaching or raising by using what the student knows at any time.[3] Both words are based on the process 'to lead'.

In this paper I examine the evidence base for the role of an individual's knowledge in the learning process, in terms of three 'big ideas', which are

1. the contributions of the diverse perspectives on knowing and learning
2. the multiple ways in which we know an idea, and
3. how knowledge changes during learning.

The sequence of these ideas is shown in Schema 1.

Learning as adaptation

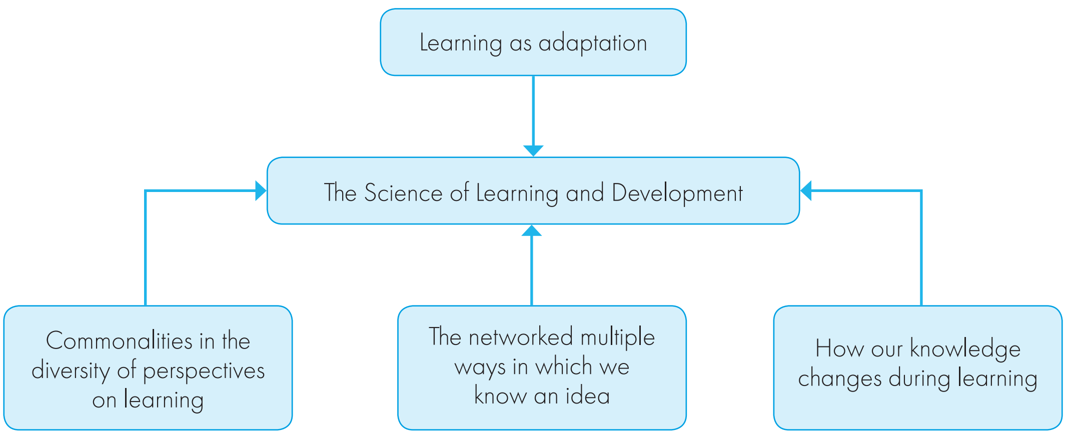
Our world today is arguably changing faster now than at any earlier period in history. This applies to every aspect of our lives: how we communicate and interact socially; how we manage our everyday lives; how we manage our health and wellbeing; how we work; and how we recreate. The capacity to adapt is increasingly demanded.

Learning is the means through which we adapt to our world and changes in it. Interactions with one's environment are associated with changes within the individual and lead to more effective interactions in the future.

The adaptation process draws on qualities both in the individual and in the environment. It begins with informal learning in the infant years. For example, the two-year-old learns to say 'doggie' for familiar animals and 'more' when they want more juice. It extends with access to formal education. Children learn to read and do maths. They learn a range of daily living skills and how to socialise. In adolescence they begin to form a social identity.

Adaptation extends over the course of adulthood. Individuals learn to manage the complexities of family and community life and work. They learn how to use new mobile phones. Over their lifespan they continue to learn about who they are, how they relate to others and their place in the world.

Schema 1. Big ideas about knowledge in the learning process



The Science of Learning and Development (SoLD)

SoLD examines learning in terms of four dimensions (Darling-Hammond et al, 2020), which are

1. the environmental conditions that foster strong relationships and learning communities,
2. effective teaching provision,
3. emotional and social aspects of learning, and
4. the system of supports that optimise learning.

Underpinning the four dimensions is the concept of 'learning students' operating as 'integrated wholes' in their environmental interactions.

SoLD describes the learning process in terms of three key processes, which are

1. encoding,
2. consolidation, and
3. retrieval (Van Hoof and Doyle, 2018).

This paper shows how these processes link with a student's knowledge. Encoding involves using one's existing knowledge to interpret the teaching information. Consolidation involves synthesising what has been learnt with existing knowledge. Retrieval involves recalling and using the new knowledge (Yonelinas et al, 2019).

the study of learning would benefit from a framework that could organise, consolidate and integrate the outcomes from the various disciplines.

This focus is supported by SoLD researchers. Calcagni and Lago (2018) note that, from an educational provision perspective, the study of learning would benefit from a framework that could organise, consolidate and integrate the outcomes from the various disciplines.

This paper offers an exploration of such a framework. It has, at its core, the student engaged in the adaptation process, as they interact with the teaching in formal education to learn. I investigate the possibility of a common learning model (CLM) that describes the set of activities employed by all school students to learn successfully, and which is independent of the content, the purpose and the context for learning. The activities are a version of learning 'universals'. An advantage of such a model is that it offers a common language for talking about learning within a school context.

The framework has a dynamic dimension that takes account of developmental trends in the adaptation. Its characteristics change over the lifespan. An infant's response to an environmental challenge will likely differ from that of an adult. The interactions both initiate learning and change what the person knows. In this way the outcomes of learning at any time influence future learning activity.

A characteristic of a scientific study of any domain is the identification of key concepts and variables that affect it. The scientific study of learning is complicated by several factors, including variation in how it is defined, and its implication of 'invisible' or inferred phenomena, such as knowledge and memory.

Key terms in the study of learning are defined in different ways. As well, the phenomena and mechanisms to which they refer are described in multiple ways and researched separately. This paper begins with an examination of some of these factors, to see what they have in common and how they can fit together in a theory about learning.

Big Idea 1.
Commonalities in the diversity of perspectives on learning

The first big idea is the contribution to SoLD of the diverse range of perspectives on learning. In this section I unpack the ideas shown in Schema 2.

The study of learning is characterised by diversity in its conceptualisation, the characteristics of its outcomes and the theories proposed to explain it. A key goal of SoLD is to examine the evidence base for this diversity.

Barron et al (2015)[4] note the challenges in defining learning and how different disciplines define it, as

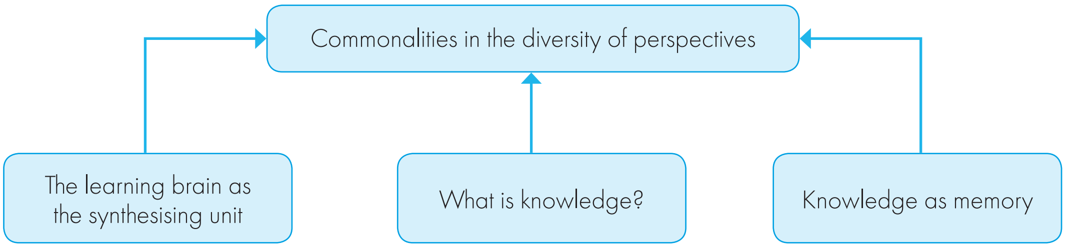
- the processing of information or experience,
- behavioural change, and
- changes in mechanisms that underpin behavioural change.

Malamed (2021) lists ten definitions of learning used in education. These definitions cover the different aspects noted by Barron et al (2015). Most refer to a permanent or persisting change or gain in knowledge, capability, performance or behaviour, due to experience or interactions with one's environment, rather than to maturation or the development and growth of the nervous system. They distinguish learning from constitutional or developmental changes due to ageing or 'wired in' maturational changes.

Over the 20th century we have seen the emergence of a range of 'public domain' theories of learning. They are 'public domain' in that they have been researched, published and are readily available. They have emerged largely in the West. The majority of ethnic or racial cultures have not published universally their theories. It is only recently, for example, that we have access to 'First Nations' theories of learning. The theories in the public domain have come from a restricted range of cultures.

Richard Millwood in 2013 listed 24 major theories of learning. They emerged at different times over the 20th century. Each built on earlier theories and developed in a particular domain in a particular culture at a particular time. Each was influenced by cultural factors at the time and was intended to respond to particular issues. They differ in the extent and quality of research that supports them.

Schema 2.



This diversity has both values and limitations. It offers inclusion and breadth. It can also be overwhelming and daunting for educators interested in planning and implementing educational practice that is based on a theory of learning. It is possible for example, for educators discussing learning to use the same words but mean different things. When they are aware of these differences, they are more able to manage them in their practice.

The diversity prompts several questions, including the following.

- What does having so many learning theories say about teaching and education as evidence-based practice?
- What does each theory assume about knowledge and knowing?
- What do they have in common and how they differ?
- Are some more applicable to particular learning outcomes?
- To what extent are they context-specific?
- How does each one match with what we know about how the brain learns?

It is possible ... for educators discussing learning to use the same words but mean different things. When educators are aware of these differences, they are more able to manage them in their practice.

One reason for this diversity is that learning has been investigated by multiple disciplines. Each targets aspects of the process from within its domain. The research outcomes in each discipline have largely developed separately and independently, and remained within the discipline. As a consequence, their contributions to more general provision have been limited (Fedyk, 2015).

As noted earlier, in this paper I explore a framework for identifying shared aspects of learning. The diverse range of perspectives on learning either explicitly or implicitly imputes the roles of the brain, knowledge and memory. I examine here these perspectives on learning.

The learning brain as the synthesising unit

The role of the brain, interacting with its environment or context, is important for any discussion about learning. The brain manages all aspects of the adaptation process. This includes the biological and physiological functions necessary for learning and for using what we have learnt about the world, how we think about it, our earlier social interactions, our emotions and our place in it. We use what we know to interpret information at any time, to act intentionally and frame up goals, to initiate and control behaviours and to change what we know. What we know at any time determines what we learn or how we adapt.

Brain activity during learning has been described in various ways – for example, at the individual microscopic brain cell or neuronal level, and at the more macroscopic functional level. At the microscopic level, learning is explained in terms of the formation of new brain cells, hippocampal activity and changes in the links between brain cells.

Macroscopic descriptions of brain activity during learning identify the simultaneous activation of multiple functional areas. These neural networks link specific functional areas, mutually interact and lead to a synthesised outcome.

The networks have been described in various ways. One approach identifies seven functional networks, each responsible for various aspects of brain functioning, which underpin knowing and learning (Tomasi and Volkow, 2011).

from a brain perspective, learning is associated with forming new links or associations that change one's existing or prior knowledge. Two brain networks do this.

The integrated activity of the seven networks during learning can be described in terms of two main types of neural networks. At any time, an individual can learn either by interpreting and responding to environmental information or by reflecting on and re-organising what they already know; the task-positive network (TPN) and the default mode (DMN) networks respectively (Kim, Daselaar and Cabaña, 2010; Spreng, 2012; Yeo et al, 2011).

Each network links together the brain parts that represent the relevant existing (or prior) knowledge, how we manage and direct the learning activity and the types of thinking used, and the emotional evaluation of the activity and feedback the individual receives, either from the environment for the TPN or self-evaluation from the individual for the DMN. The TPN includes additional functional areas that handle the perceptual and motor demands and linked emotional demands.

The two networks yield different outcomes. The TPN generates an essentially literal interpretation of the external information or the interaction with the environment. The DMN provides a more inferential or 'imagined' interpretation. It involves the individual reflecting on what they have learnt, looking for patterns and links and re-organising it into larger chunks, making links with other areas of their knowledge and generating possibilities for future activity, and evaluating themselves in various ways – for example, how they operate socially. It has been implicated in creativity.

Individuals use both networks and switch between them in a balanced way. We use cognitive control to manage this balance. Both networks share specific functional areas that help us to direct and focus our attention (the 'salience' network) and to manage and direct our thinking activity (the 'executive-control' network). These mechanisms provide flexibility by facilitating goal-directed actions and suppressing irrelevant ones

The outcomes generated by each network have components from each of the functional areas. These include cognitive, social, environmental and emotional experiences. The brain has the capacity to organise and manage its activity; it operates as a 'self-organising' system.

In summary, from a brain perspective, learning is associated with forming new links or associations that change one's existing or prior knowledge. Two brain networks do this. Each draws on multiple functional areas that are activated simultaneously and selected according to the specific tasks. Each comprises multiple sub-networks. Both networks link emotion, social awareness, abstract or episodic knowledge, thinking and how we manage it. The TPN manages directly the individual's interaction with their environment.

The integrated 'brain learning in context' perspective provides a starting point for unpacking a model of learning in the classroom. It highlights the key mechanisms and variables the model needs to target.

What is knowledge?

In any discussion about learning, it is also necessary to clarify what we mean by knowledge. Knowledge has been conceptualised in a plethora of ways (for example, Bolisani and Bratianu, 2018; Ichikawa and Steup, 2018). Learning is frequently defined in terms of acquiring or gaining knowledge (for example, Malamed, 2021).

In the present paper, 'knowledge' refers to the capacity to interact with and adapt to one's environment at any time; to say 'doggie' or 'more', to read and do maths, to socialise, or to manage the complexities of family life and work. We explain these adaptations by assuming that our brains can represent aspects of our environmental interactions. Through progressive adaptation, we construct increasingly complex and sophisticated mental models of our world.

We noted before that the brain generates learning outcomes. We infer the quality of a person's knowledge from the outcomes they display. In this sense, knowledge is a mental construct that we use to explain observed outcomes. Knowledge is assumed to underpin and inform goal-oriented or intentional behaviours. Siemens (2004), for example, describes learning as 'actionable knowledge'.

Descriptions of knowledge differ. Some models, for example Anderson's ACT-R theory (Anderson et al, 1998) distinguish between 'the what' and 'the how' of knowledge. Declarative knowledge refers to a person's factual, conceptual and experiential knowledge. Procedural knowledge is goal-oriented; it is the repertoire of skills an individual can use to achieve goals. The theory proposes a production system that retrieves relevant parts of an individual's declarative knowledge and maps them into procedural knowledge, which in turn generates behaviours. Each production comprises both an action and when it is appropriate to use (that is, a set of conditions).

Other models have used the various types of learning outcomes to impute knowledge in one or more of three major domains: cognitive, affective and psychomotor (Haghshenas, 2015; Hoque, 2016). Gagné, for example, developed a sequence of frameworks for categorising learning outcomes. His most recent taxonomy identified five types of knowledge: verbal information; intellectual skills; cognitive strategies; attitudes; and motor skills. (Driscoll, 2005).

The terms 'knowledge' and 'information' are often used interchangeably in discussions relating to learning. In the present paper I believe that it is necessary to distinguish between them. The distinction is exemplified in situations in which two or more people are exposed to the same situation, that is, information, and interpret it differently – for example, fourth graders reading the same text, or adults witnessing an accident. In each situation the participants were exposed to the same information. They interpreted it differently, that is, formed different knowledge of it.

Individuals differ in how they represent or interpret the same information. Many educators will be familiar with this observation. Students differ in the knowledge they form or what they learn from the same teaching information.

What do we do to learn from information?

We can examine how we use information and knowledge interactively during learning, by working through the following learning activity. The text in Diagram 1, titled *The family outing*, contains (hopefully) some ideas that many readers will find unfamiliar. These are in boxes in the margins of the text.

Please, read the information in the text and use it to infer the meaning of each one. Also, monitor the knowledge and thinking that you use to work out each of them.

What do you need to do/know to work out each idea? You may have

- planned how you will think about it, for example, you decided that it is essentially a vocabulary elaboration task that draws on reading comprehension,
- recalled the abstract meanings of ideas, such as **orchard**, **berry pickers** and **worked**, sequenced them and linked them into relationships,
- formed a place and time mental image of the berry pickers working in the orchard, perhaps using your earlier experiences of what usually happens in an orchard,
- imagined doing the actions mentioned in the information,
- thought about the ideas in various ways, for example, you inferred the possible gist of the text and synthesised the text information with what you already knew,
- linked either positive or negative emotions with the activity. You may enjoy this type of challenge. Alternatively, you may link feelings of fear, panic or boredom with it. You may have needed to manage and regulate your emotions during the learning.
- engaged willingly with the task of discovering new concept meanings. Alternatively, you may not value this type of activity and believe it was a waste of time; you could have simply located the meaning of each concept in a dictionary.
- had particular beliefs about whether you could complete this task successfully or not (your self-efficacy) and whether you were intrinsically motivated to work out each meaning, or
- believed that cultures to which you belong, for example, your collegiate peer group, values this type of learning activity and would give you worthwhile feedback for it.

Diagram 1. The family outing: A learning activity

bacciferous

baft

The bushes in the orchard were bacciferous. The berry pickers worked without pause. The baskets of baft into which they deposited their conquests abraded their bare arms. If only the farmer had invested in containers made of more expensive and softer fabric.

baragouin

batrachophobia

barbigerous

batrachian

Conversation with the other pickers was difficult. Their baragouin was largely incomprehensible. However, there was no mistaking the batrachophobia shown by the barbigerous giant nearest to them. The first sight of the tree frogs froze him to paralysis. Even his well-endowed beard failed to mask the intense fear the batrachian creatures induced in him.

What you now know about **bacciferous**, baft and the other unfamiliar ideas, is a consequence of this set of activities. Each makes a unique contribution to what you now know about **bacciferous**. You now may know that **bacciferous** means 'laden with berries', visualise an instance of it, link it with holding a load of berries, feel positive about it, recall the thinking you used to work it out and feel positive about learning similar ideas. Each is a 'way of knowing' **bacciferous**. We can know and learn any idea in this range of ways.

How is your knowledge organised?

We noted earlier the self-organisational activity of the brain. This provides an insight into how a person's knowledge is organised and how separate ideas are linked in networks.

Young children form networks of ideas that represent particular events or contexts they experience. These include the idea's place and time, such as hearing a dog called 'doggie', and they gradually begin to use it.

> Each way of knowing develops along its trajectory, simultaneously and in parallel with the other ways of knowing.

As they develop, their brains organise ideas in more complex networks. For example, we organise ideas around topics or themes. One model of the network of ideas around a topic is the schema (McClelland and Rogers, 2003; Roe, Stoodt-Hill and Burns, 2007). Your schema for any topic guides how you interpret information about it, how you infer from it and expect particular ideas. Your schema for 'bacciferous', for example, includes the range of aspects described earlier. Your set of schemata comprises your knowledge at any time, your model of your world.

What we know about any idea

The assumption in this paper is that our knowledge of any idea is all that we know about it. This includes what we know about its abstract features; its experiential and imagery properties; the action repertoires that characterise it; the feelings and emotions we link with it; our attitude to it; how we think about it; our self-efficacy as a learner of it; and its relevance to the cultures to which we belong.

These multiple ways or 'forms' of knowing each idea are in functionally separate areas of the brain. Each way of knowing constructs an aspect of the new knowledge during learning. These are linked in a network or 'web' that spans these areas. The individual's knowledge of the idea is the synthesis of these aspects.

Each way or form of knowing develops along its trajectory, simultaneously and in parallel with the other ways of knowing. Progress along each pathway is partly independent of the other pathways and partly affected by them, through the network or web.

The new knowledge comes from interactions between the individual's learning capacity and the learning environment or context. It is the synthesis of the cognitive, social, learner identity, attitudinal, cultural and emotional contributions provided by the ways of knowing interacting with the context. The individual's attitude to the idea, for example, influences the goals they set for themselves and the quality of their engagement with the idea.

This notion of learning outcomes being a consequence of multiple ways of knowing, which develop partly independently, is useful for explaining both differences between individuals in their learning outcomes and differences within an individual (Lerner, 2017; Rose, 2016).

Some approaches to the analysis of knowing and learning restrict their focus to abstract knowledge or procedural knowledge, for example what is known factually. They do not identify an individual's bank of experiences, self-identity or the emotions linked with a topic as aspects of what the individual knows about it. Some use it to refer to what you know automatically.

In summary, the adult brain organises ideas around topics or themes in schemata. You can now define **bacciferous**, **baft** and the other new ideas, visualise instances of them, describe the thinking you used to learn them and reflect on what they mean for you as a learner. We form new knowledge by making new links between the ideas we recall. We can then add the new ideas to our existing knowledge or memory. Later we can recall and apply them and use them to build new knowledge.

> Some approaches to the analysis of knowing and learning ... do not identify an individual's bank of experiences, self-identity or the emotions linked with a topic as aspects of what the individual knows about it.

Any topic can be represented in all of the ways of knowing. Your knowledge includes the relevant abstract concepts, your experiences, actions, feelings, attitudes and thinking, and your self-efficacy and cultural interpretations of it. As noted earlier, each way of knowing can potentially change as a result of a learning activity.

Knowledge as memory

The change in knowledge in the scenario can be described in terms of how we use memory. Memory, like knowledge, is a hypothetical concept or construct that we have created to account for what humans can do. There are two states of knowledge or memory we need to examine.

Long-term retention

First, there is the knowledge we retain over time. It has the quality of permanence; our 'long-term memory'. This is what you recalled to help you work out the meanings of bacciferous and baft. We retain multiple types of knowledge. You may have recalled the abstract meanings of orchard and berry pickers, images of them and the actions that typify working and depositing.

Cultures differ in the dominant forms of memory they value. Some value storing knowledge in imagery forms, while others value more abstract forms (Chan, 1999). They also differ in how the processes of memorising and understanding new ideas are integrated (Kember, 1996; Marton, Watkins and Tang, 1997).

Short-term retention

Second, there is the knowledge that we are thinking about at any time. For example, when learning about bacciferous, we converted the teaching information to knowledge (that is, interpreted it) and linked it in the intended ways. We used knowledge stored in long-term memory to do this.

We say that this knowledge is retained in 'short-term memory' and manipulated in 'short-term working memory'. We can attend to or handle only a limited amount of knowledge in this memory at any one time. It is useful to talk about the amount of thinking space or mental attention the ideas we are thinking about take up. More familiar ideas take up least space. The more strongly two or more ideas are linked, the less attentional space each idea needs.

Third, some memory theories propose a 'sensory memory', in which information is retained briefly before it is interpreted (the 'short-term sensory storage'). At any time, individuals attend to some ideas and keep other ideas in a 'holding bay'. The information is stored here in its perceptual form.

> teaching students how to retrieve knowledge from long-term memory can improve learning outcomes

These retention phenomena have been explored in terms of various models of memory, for example, the 'multistore', 'modal' or 'stages' models (Malmberg, Raaijmakers and Shiffrin, 2019; Marx and Gilon, 2022), the 'levels of processing' models (Craik, 2002), the 'working memory' models (Baddeley, 2017) and the 'individual differences-attentional control' models (Engle, 2002). The models differ in how they conceptualise short-term and long-term retention and continue to be investigated.

Implications for understanding learning

This research has direct implications for understanding learning and teaching. A goal of education is to optimise knowledge acquisition and retention. During a learning session, students need to retain and manipulate relevant ideas. The site of learning is the short-term working memory or 'thinking space'. Incoming teaching information is converted to knowledge here and triggers the multiple ways of knowing.

Each way of knowing interprets or encodes part of the information in its own way, simultaneously with the others. Metacognition manages this activity. Students use various cognitive strategies to 'keep ideas alive' during learning. They can repeat the ideas, paraphrase, or visualise them or enact them.

In addition, teaching students how to retrieve knowledge from long-term memory can improve learning outcomes (Weinstein, Madan and Sumeracki, 2018).

Some memory processes can disrupt learning. One relates to how we value some bits of knowledge more than others. Those we value are easier to retrieve (or 'stimulate'). A second relates to new knowledge detrimentally displacing existing knowledge from working memory ('*catastrophic forgetting*'; Rolnick et al, 2019). This affects how well we transfer and generalise knowledge. Revisiting and rehearsing relevant past experiences can support retention.

Outcomes from this research can inform

- how the teaching information can most easily be interpreted (memory encoding),
- the maximum amount of knowledge students can retain briefly (short-term memory capacity and cognitive load),
- how short-term retention of knowledge can be extended (elaborative rehearsal and chunking),
- how the new knowledge can be encoded for long-term retention,
- how knowledge can be recalled most easily (knowledge search and scanning, fixed and queued recall conditions), and
- the conditions for optimal recall (using memory images and the use of retrieval cues).

The distinction between recognition and recall memory retrieval (Malmberg, Raaijmakers and Shiffrin, 2019), and its links with knowing implicitly or intuitively versus knowing explicitly and objectively or logically, is relevant to educational provision.

We noted earlier the focus in SoLD on the encoding, consolidation and retrieval processes in learning. In the following sections, I unpack how the eight ways of knowing can contribute to understanding these processes.

Big Idea 2.
The networked multiple ways in which we know an idea

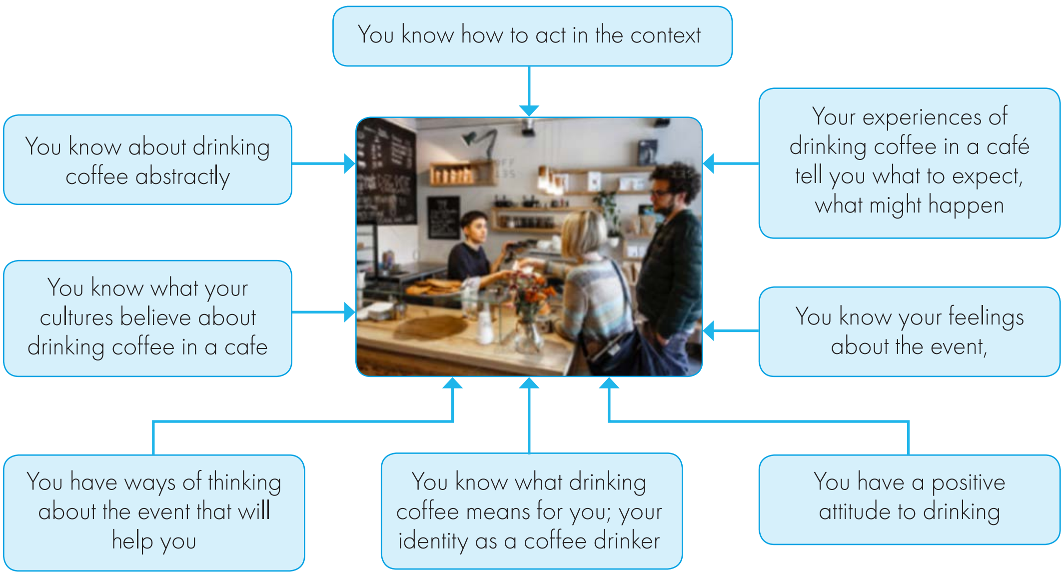
All learning begins with what and how we know (Mayer, 2019; Witherby and Carpenter, 2022). The second big idea relates to the multiple ways in which we know a topic, that is, the various forms of knowledge or memory we have of it.

Imagine you visit an unfamiliar coffee shop. How do you know what to do and what to expect? You draw on a range of ways of knowing or types of knowledge that inform how you interpret the event, the decisions you make, what you do and what you learn. Multiple ways or types of knowing interact in this network, and each way influences the others (see Diagram 2). You synthesise the outcomes from these multiple ways of knowing.

What we know at any time is influenced by this range of ways of knowing. We use this range to interpret information about most topics we encounter. Each way or form of knowing delivers a unique aspect of knowledge that we link to our overall interpretation. Our understanding is the synthesis of the eight aspects.

In the following subsections of this paper I unpack how each way of knowing works. We then examine how the various ways interact synergistically and contribute to the overall knowledge outcome.

Diagram 2. Multiple ways or types of knowing, in interaction



Experiential or episodic way of knowing

First, we all have a bank of stored experiences, our experiential or episodic knowledge. You might see a picture and recognise it as a coffee shop. Alternatively, a friend mentions a new coffee shop they have found. You have not been to this coffee shop, but you can predict events that might happen: a customer asking for a flat white; people sitting and chatting; an espresso machine hissing and bubbling. This is your experiential or episodic way of knowing at work. It is initiated or triggered by information from your current context.

Each experience records a specific event in which you have engaged. It tells you perceptual information about the event, such as a learning task, when and where it happened and what you and others did. It is your perspective on the event and includes what you thought and how you felt; it is personal, subjective and unique to you. We can 'see', 'hear', and 'feel' the event again. We recall these as images (Tulving, 2002).

We can use this knowledge to interpret information in a current situation. Your past experiences tell you what to expect, what might happen next and how to act to deal with challenges.

> Whenever we learn a new idea, we note and store place and time information about the context

We often recall and apply our experiential knowledge 'unconsciously'; we use it tacitly or implicitly. You may have difficulty explaining why you acted in a certain way or expected an event to occur; you 'just knew'. We might take a particular stance on an issue without being aware of it. This leads to a 'cognitive bias' that can restrict or slant our interpretation and how we think about it (Hallihan, Cheong and Shu, 2012; Menne-Lothmann et al, 2014).

We sometimes use our experiential knowledge consciously. You may have a problem and consciously 'run through' or scan your earlier experiences to recall what worked best. You may not be able to recall the name of someone or something and you try to recall the context in which you last heard it.

Your episodic knowledge contributes to the sense of time in your life. It is your awareness of you in time, your 'subjective time' or 'chronesthesia' (Tulving and Kim, 2007). When you saw the photograph of the unfamiliar coffee shop you may have recalled the last time you were in a place like that. Your brain organises your experiences in order of occurrence. You can go forwards or backwards in time and decide when one event happened relative to another.

Your experiential knowledge is 'future-oriented' – it tells you what to do and expect, as long as the new situation matches, in important ways, your stored experiences.

We can also form 'virtual experiences' by imagining. We can infer how our experiences may have been different or imagine them changing in particular ways. We can visualise possible outcomes or solutions to a problem or issue. When we visualise a text as we read or listen, we can often understand it, think about it and use it more easily.

Whenever we learn a new idea, we note and store place and time information about the context (Smith and Mizumori, 2006). The episodic image may initially be incomplete and is sharpened, with repeated exposures (Raaijmakers and Shiffrin, 2002).

Episodic knowledge is formed simultaneously with learning in the other ways of knowing in the network.

This leads to contextual knowledge being linked with outcomes from the other ways. As a consequence, contextual cues can trigger and facilitate the recall of knowledge.

Our brain organises our experiences into categories, based on similarities. We form 'typical' experiences that cover or 'summarise' a range of specific experiences (Gee, 2015). These become our stereotypes and prototypes. As teachers we have general experiences that include what we see as typical activities that occur in classroom. Our students, as well, form general classroom experiences that include the regular routines and procedures. These stereotypes shape our expectations.

Experiences allow students to think in wholes that hold a lot of information at once. They can manipulate the items by moving them around, imagining how they change over time.

The abstract way of knowing

Second, abstract knowing is knowing beyond a single episode or experience. Think back to the example of abstract knowing that you read in the text of *The family outing* (Diagram 1). There you recalled the meanings of its vocabulary and used these to interpret it. You knew the meaning of each word in a general or abstract way. The words 'orchard' or 'worked' do not apply to one experience in a single context but to a group or category of items that share a property.

> Every topic that you teach comprises concepts. They are its vocabulary or building blocks.

Concepts

One component of abstract knowing is the concept. 'Orchard' and/or 'worked' each has a dictionary definition that tells us what qualifies for inclusion in the respective category.

Abstract knowing uses symbols to communicate meanings. Those words, 'orchard' or 'worked', do not resemble what they mean. They are not images of each meaning. Each word is a symbol for a category or concept. Our brains form and use symbols such as words, mathematics symbols, icons and gestures to represent conceptual categories.

We form concepts by recognising and inferring patterns and generating rules of inclusion and exclusion, initially from specific experiences. We infer, for example, the concept of 'carry' from the functions performed by a camel, a van and a tram. The shared feature here is abstract rather than perceptual. Later we learn to form concepts about concepts. We can identify, for example, the feature shared by democracy, theocracy, dictatorship and republic.

Every topic that you teach comprises concepts. They are its vocabulary or building blocks. Examples are: 'walk', 'electron', 'car', 'tomorrow', 'yellow', as well as H_2O and $.

Propositions

Another component of abstract knowing is the proposition or semantic relationship. Each proposition links two or more concepts to form a meaning association. Each sentence in *The family outing* for you is a proposition.

Other examples include the following.

- *The car hit the power pole* (a relationship describing a specific event).
- *Plants need water to grow* (a cause-effect relationship).
- *People started writing about 3000 BC* (a generalisation).
- $E = mc^2$, $A = \varpi r2$ (formulae).
- 4+6=6+4 (a mathematical relationship).
- If the shape has three joined sides and is flat, it is a triangle (a definition of a concept).

Every topic you teach is made up of propositions. Some subjects have their own ways of talking about ideas and often the subject's symbolic language.

Conceptual networks

Most concepts can be linked with more general concepts, more specific concepts and mutually exclusive concepts, around topics or themes in 'semantic networks' (Lerner, Liben and Mueller, 2015). They are parts of schemata. Semantic networks are believed to model how concepts are organised in the brain (Ralph, Lowe and Rogers, 2007; Wixted, 2018). We often expect students to learn to link concepts in this way.

> The abstract way of knowing allows us to organise concepts into hierarchies based on inclusion and generality.

We use our semantic networks to interpret spoken and written texts. Once you know the topic of a text, you can access likely relevant networks of ideas in your semantic memory. You can scan them, note how each fits and predict what might come up next (McNamara and Holbrook, 2003). Our teaching often requires students to develop 'conceptual awareness', to know how to put ideas into categories, to transfer knowledge to new situations and to change the boundaries of a concept.

The abstract way of knowing allows us to organise concepts into hierarchies based on inclusion and generality. We use it to communicate using spoken and written texts, such as fiction and nonfiction. It allows us to identify in texts the main ideas (or topics), the subordinate ideas (the meanings of paragraphs, sections and chapters) and the details (the sentences and vocabulary). It equips us to comprehend symbolism used in other domains, such as mathematics.

We learn the various types of symbolism from the cultures to which we belong.

Procedural or action ways of knowing

A third way of knowing and learning about any idea is through the actions we link with it. You may know how to use an app on your mobile, how to prepare a meal, or how to research a topic. You probably know these both as sequences of physical actions and as mental simulations of actions. This knowledge is encoded in your 'procedural memory' (Johnson, 2003).

Think of something you learned recently, for example, how to use an app or how to operate a new television, or how to improve your golf swing. You now know the idea abstractly. Your learning began with you thinking 'just show me what to do'. You did not want an abstract explanation at that time. Learning the actions gave you a 'cognitive feel' for the ideas. Learning to drive a car is an example of this. When you first learned to drive, you focused on the specific actions to use. Now you can probably think abstractly about driving.

Thinking in actions is not limited to learning how to do something. As you listen to or read a complex explanation or a dense argument, you might find yourself acting out the information. You might be moving your hands or acting mentally. You know that doing actions will often help you remember ideas.

This is 'embodied cognition' (Marshall, 2016). You learn 'with your body', by 'doing' parts of the idea, whether it relates to the new computer program or the new television. You form a 'mechanical' or 'practical' knowledge of a topic (Sternberg, Wagner and Okagaki, 2018).

Action knowing is the first phase of learning a topic

Action knowing is often the first phase of learning a topic, skill or new idea at any age (Commons et al, 2014; Fischer, 2008; Piaget, 1936; Wertsch, 1981). What begins as physical actions becomes mental actions and ways of thinking.

We observe this with students learning. Some find it easier to understand new ideas when they have the opportunity to learn them first as actions. They learn the meanings of rotating and revolving in the solar system by pretending to be a planet or a moon and doing the two actions. They learn about graphs by moving their finger to map out a straight line, parabola or circle (Bouck and Park, 2018). They learn the meaning of 'schemer' in 'Lady Macbeth was a schemer' by doing scheming actions.

This can be explained, at least in part, because procedural cues such as gestures facilitate recall from long-term memory Actions trigger and facilitate the recall of knowledge from long term memory and support working memory processing (Sepp et al, 2020). Students recall ideas by using characteristic actions or gestures that represent the ideas.

The time needed for teaching an action understanding of an idea is often brief. Students rapidly internalise the physical actions as mental actions. Without this opportunity, some may never learn the idea. They are more able to show their emerging understanding of the new idea by acting it out rather than talking about it. They often need time to translate their action knowledge into other forms.

Learning a new action sequence

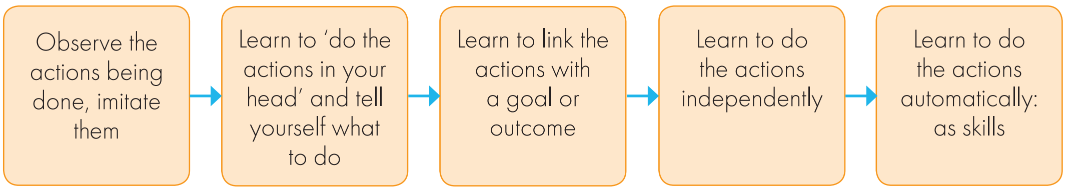
We learn new action sequences in several ways. You can imitate a modelled action sequence (Bandura, 2001). Alternatively, you can convert descriptions to actions. Noting how the actions are similar to actions that you already know can help.

You can also create new actions by modifying existing sequences of actions in order to achieve a goal or intention. You will probably use trial and error to modify the sequence and monitor the outcomes in order to 'tune' the sequence to the goal.

You may describe each action in a sequence and visualise doing it. Verbalising the sequence facilitates application and helps you to use it more generally. Visualising assists in learning the contexts or experiences in which it might be appropriate. Simultaneously, you learn the purpose of the action sequence. Together these allow you to use it selectively and independently in a goal-oriented way. Practice improves automaticity. This enhances the transferability of the action sequence.

A sequence for learning a set of actions (Dave, 1970) is as shown in Diagram 3.

Diagram 3. A sequence for learning a set of actions



An action understanding of wellbeing and values

Action knowing can be used to teach the behaviours usually associated with student wellness. Some contemporary curricula target this through domains such as personal and social capability (for example, victoriancurriculum.vcaa.vic.edu.au/personal-and-social-capability/curriculum/f-10#level=1-2).

> Teaching ideas as actions can make them more 'visible' and unambiguous to all students.

Teaching that largely talks about these aspects is insufficient for many students. They learn this capability more effectively when they are taught directly how to do aspects of it – for example, how to act optimistically, empathetically or respectfully; how to behave in threatening situations; and how to act resiliently and constructively in challenging situations.

Similarly, students are often told that they need to be more responsible, honest, reliable, trustworthy or self-disciplined … As noted before, for many students, being told is not enough. They need to know how to act to achieve each attribute, to tell themselves to do the actions and to practise doing them.

These actions or behaviours allow individuals both to interact more functionally in their world and also to let the world 'see' or 'know' them. They are the actions that we use to achieve our goals in social contexts.

Teaching the actions for the assessment verbs

Many students have difficulty using the 'assessment verbs' such as evaluate, explain, recount, describe, compare, estimate, infer, relate or summarise. They do not know how to act on what they know to generate the required outcome. They do not know what an evaluation or an explanation actually 'looks like', nor the difference between a summary and a discussion. They need to learn how to act on what they know in the specified way. It is recommended that you teach students explicitly how to do the action associated with each of these verbs.

Summary: Actions as a way of knowing

Teaching ideas as actions can make them more 'visible' and unambiguous to all students. The key ideas that comprise any topic can be taught in ways that give students the opportunity to 'do' or 'enact' them.

Students can do them physically with their hands or other parts of their bodies or see class peers do them (that is, do the actions 'vicariously').

Knowing through how we think

A fourth way of knowing relates to what you know about how to think. Thinking is the set of 'mental actions' that we use to interpret information as knowledge and to manipulate what we know in various ways. We refer to these mental actions as thinking strategies and thinking skills.

Thinking means linking

How we think determines the links we make between bits of knowledge. We form concepts, relationships, and patterns when we link together separate ideas. The brain is programmed to look for similarities and differences between separate items, and to identify patterns (National Research Council, 2000). Our thinking allows us to form, analyse and use patterns.
We know that ten people can detect the same information and form ten different interpretations or understanding. This is due in part to the thinking actions they apply.

There are two types of thinking activities: the actions we apply to information and knowledge; and the actions we use to manage this activity so that we can achieve our goals (Apaydin and Hossary, 2017; Wu and Peng, 2016). The first type is cognitive strategies, and the second type is metacognitive strategies.

An example of each type would be a person reading *The family outing* and visualising what it says. The cognitive strategy is the set of actions that leads to forming the mental picture or virtual experience of a sentence. It includes recalling and synthesising the images linked with vocabulary in a sentence. The metacognitive strategy that you as a reader used, involved knowing that visualising was a useful way of thinking to use here, and monitoring how you used it.

> The cognitive strategies you use at any time influence the quality of your learning outcomes

Cognitive strategies

We have a set of cognitive strategies that we use selectively and in combination, in a range of ways, to interpret information and form patterns. We can think about our concepts, propositions, experiences, images and action sequences in these ways. We can, for example,

- look for similarities and differences between items and form categories of more complex ideas,
- examine an idea from a range of perspectives,
- visualise propositions and action sequences and create virtual images for further analysis,
- notice an attribute changing and form a pattern,
- extend or extrapolate a pattern,
- infer, anticipate, predict and form possibilities, as an aspect of creative thinking,
- generalise, summarise and form more general ideas,
- synthesise ideas,
- evaluate and compare experiences and propositions, using various criteria and ideas from a range of perspectives, and
- transfer and contextualise what we know, thinking by making analogies.

Our strategies differ in their complexity, the amount of knowledge they can transform at once and their relevance or appropriateness in particular contexts. The cognitive strategies you use at any time influence the quality of your learning outcomes (Swanson, Lussier and Orosco, 2015). This contribution is independent of your motivation to learn (Murayama et al, 2013).

Metacognitive thinking

Our metacognitive thinking allows us to manage and direct our thinking and to learn independently. It includes what we know about when and how to use cognitive strategies selectively (Pintritch, 1995). In any successful learning activity, we

- plan how we will learn, what the outcome might look like and how we might think about the ideas; that is, the cognitive strategies we will use,
- monitor our learning progress, evaluate how well it is working and decide, if necessary, to change direction and use other strategies, and
- reflect on what we learned and what worked for us.

Our metacognitive knowledge also includes what we know about knowing and knowledge, and when and why to use it.

We manage and direct our metacognitive activity through our self-talk or ‘inner language’. Learners first show metacognitive ability when they distinguish between ‘the knower’ and ‘what is known’, often towards the end of the preschool years (Kuhn and Dean, 2004). They learn to reflect upon and evaluate how they learn in particular situations, as well as the language for monitoring and analysing this.

Thinking in the classroom

Teaching usually requires students to think about the content using particular strategies and with a particular level of efficiency. This may, for example, require the students to recall automatically a set of ideas, identify similarities and differences between previously unrelated ideas, and recognise and use the main ideas to organise the details.

Cognitive and metacognitive strategies predict successful academic outcomes. Students achieve enhanced outcomes in any domain when they improve how they think about its ideas. Teaching explicitly the relevant cognitive and metacognitive strategies improves students' outcomes for reading comprehension, writing and mathematics (de Boer et al, 2018; Davis, 2010; Fadlelmula, Cakiroglu and Sungur, 2015; García and Cain, 2014; Gu, 2019; Suggate, 2016; Thiessen and Blasius, 2008). The teaching can include

- scaffolding explicitly the relevant thinking strategies at any time. This is working in the students' zones of proximal development or ZPD.
- building students' awareness of how they learn and think at any time, and what their knowledge 'looks like', as well as teaching the language students can use to talk about their thinking,
- teach students to select relevant thinking strategies in domain-specific ways, and
- teaching them to use self-talk to guide their thinking and learning – for example, plan how they will learn or work through a task and monitor their progress towards their goal for learning.

Knowing through our emotions

A fifth way in which you know any topic is through the emotions or feelings that you link with it. You may recognise ideas in a novel or maths as interesting, challenging, boring or perhaps frustrating. You link this with your understanding of the idea.

The emotional way of knowing (also called the affective or mood way of knowing) is the 'feeling lens' through which we interpret the idea. When you recall this knowledge later, you also remember the feelings you experienced. What you remember influences your motivation to learn more about the topic and how you learn it (King and Areepattamannil, 2014).

Where do our feelings come from? Let's say you and your friend are watching a football grand final. You passionately support one team. Your friend supports the other. The winning goal is kicked and the game over. What caused each of you to have opposite feelings? It could not have been the event itself; you both witnessed the same event. You differed in what you told yourself about it. You told yourself: 'We've lost. That shouldn't have happened. It is awful'. Your friend told themselves the opposite.

That football scenario can be generalised to other events in our lives. Our emotion at any time is linked both with what we tell ourselves about an event and also with our biochemistry. We tell ourselves something positive and the physiological activity in our body induces a positive feeling. We perceive ourselves to be threatened and our biochemical activity induces a negative feeling. How we perceive the event – that is, what we tell ourselves about it and the biochemical activity – is aligned with the feeling. The emotional way of knowing tells us how to respond appropriately in situations. It is a type of decision making. It tells us to feel joyful, guilty, compassionate, pensive or sad.

We can also infer the feelings of others in a situation and act accordingly. Being able to read the emotions of others in social interactions allows us to operate in socially functional ways.

How emotions develop

An individual's set of emotions gradually broaden and differentiate as they develop. While researchers differ in how they describe this development and categorise the various emotions, most propose three stages of development (Ekman and Cordaro, 2011; Shaver et al, 2001) as follows.

1. Primary, primitive or basic emotions of love, joy, surprise, anger, sadness and fear. These are the building blocks for more complex emotions.
2. Secondary emotions that children and teenagers form by elaborating the primary emotions, through their interactions with others and their language learning.
3. Tertiary emotions of adults. These comprise up to 150 complex or deeper emotions.

> The extent to which students achieve their educational goals is affected by their ability to display the skills of emotional competence in the classroom

This trend has been linked with brain development (Tracy and Randles, 2011). The primary emotions are genetically determined processes and are managed by subcortical structures. They are necessary for early survival The development of the neocortex provides higher-order processes that link with our emotional functioning. This allows us to regulate and manage how we think about our emotions, and how we behave emotionally. This regulation is linked with our use of self-talk, which we noted earlier.

Our emotional state at any time has a function; it affects how we interpret and interact with our world by linking with our thinking and the actions we take (Dalgleish and Bramham, 1999). It also impacts on our social functioning, our moral reasoning and our activity during learning (Immordino Yang and Damasio, 2007). A low level of anxiety can keep you focused on an activity, while fear can restrict focus. Linking positive emotions with a topic leads to stronger motivation and the belief that you can learn it successfully. Educators need to understand this link and how it can be used in teaching.

How our emotions affect classroom learning

The extent to which students achieve their educational goals is affected by their ability to display the skills of emotional competence in the classroom (Buckley, Storino and Saarni, 2003). Their emotional development has implications for learning and for social relationships.

Our emotions affect what we remember. Our emotional state at the time of learning affects how well we encode and recall the new knowledge (Brown and Kulik, 1977). We retain and recall better those events in which we invest more intense emotion (MacKay et al, 2004). We recall specific details about an event better when we put ourselves into the mood we felt when we witnessed the event. You may have experienced recalling where you were when a significant event happened. These are called 'flashbulb memories'.

We tend to forget memories that have negative emotions more than memories which are more positive: the 'fading affect bias' (Walker et al, 2009). This tendency increases as we age (Kennedy, Mather and Cartensen, 2004). The older we get, the more we may see the past through 'rose-tinted glasses'. Freud reported that memories of traumatic or distressing events may be repressed, although they could be recalled under hypnosis with free association.

Why do emotions influence memory? First, fear and anxiety may be inherited traits which have a survival advantage; they signal impending environmental dangers (Öhman and Mineka, 2001). Second, these emotions focus and direct our attention to significant knowledge (Schupp et al, 2007). Third, you recall knowledge better if your mood when you recall matches the emotions you linked initially with the content: the mood congruence effect (Bower, 1981). You recall better a negative newspaper report if you are feeling low rather than happy when you read it.

Suppressing your emotions can impair your recall later (Richards and Gross, 2000). Your mood when recalling events later can affect how well you can recall. If you are feeling happy at recall, you remember better past events that brought you happiness. This is mood-state dependent memory (Laird et al, 1989).

Knowing through our attitudes and dispositions

A sixth way of knowing an idea, topic or situation is how much we value it, how useful we think it is, how important it is to us, and how much we prefer it over other options. You may have either a positive or negative disposition towards a type of art, music, sport, pets or cars. This is your attitude or disposition to each (Perkins, Jay et al, 1993). It affects how prepared you are to engage with it and learn about it. When individuals learn a topic, part of what they learn is its comparative usefulness or value.

The term 'attitude' has been interpreted in different ways. In this paper I use it to mean how disposed you are to something. it is the intensity of your commitment to it and your engagement with it. It precedes how you respond to the item; it is your 'behavioural intention' (Simmons and Maushak, 2001) We cannot directly observe a person's attitudes; we infer them from the behaviours the person displays (Bednar and Levie, 1993).

Your attitude to something is different from the emotion you link with it. Even though your football team might lose, and you link negative emotions with this, you can still value the team and remain positively disposed to it. This is not restricted to sport. Students may have a negative attitude to a subject such as maths even though they sometimes have success and link positive emotion with it.

It is your attitude or disposition to an idea, situation or a topic, that leads to the consistency in how you behave towards it. While you retain an attitude towards something, your behaviour towards it will be consistent. You can, of course, change your attitude towards the object.

Attitudinal knowing in the classroom

A systematic way of describing how strongly students engage with a topic has been provided by Krathwohl, Bloom and Masia (1964). They propose five levels of engagement organised in a taxonomy. These are summarised as follows.

- Receiving – the student shows a willingness to attend to the teaching information or listens with an open mind.
- Responding – the student participates actively or responds to information and chooses to continue to respond voluntarily.
- Valuing – the student shows they value an idea, topic or behaviour.
- Organisation – the student relates the idea to their life and to other ideas. They advocate for the idea.
- Characterisation – the student forms a value system around the idea that shapes how they see the world. They use the idea to shape their world view and live their life through it.

The levels indicate a progressively higher commitment to a topic and a greater internalisation of behaviour. Students' attitudes to an idea are indicated by where their behaviours are on the continuum. Each level is linked with indicative behaviours. Educators can use it to identify students' current disposition or commitment to topics they are learning and to monitor changes in their attitudes.

All of the attitudes in the taxonomy have a positive orientation or direction. We know that some students may show strongly negative dispositions to aspects of academic learning and school phenomena (Simmons and Maushak, 2001; Zimbardo and Leippe, 1991). It seems reasonable to have a means of describing systematically such negative attitudes, in order to reduce their intensity.

In summary, Krathwohl et al's (1964) taxonomy provides a systematic framework for setting goals and monitoring changes in student attitudes.

Knowing through our cultures

A seventh way of knowing is through the cultures to which we belong. Most of us belong to several cultures: our family, our peer group, our workplace or classroom group, our leisure and friendship groups, gender, ethnic and community cultures. Through their collaborative interactions with significant others in each cultural and social groups students learn the knowledge valued by that culture (Cole, 1998; McLeod, 2018; O'Donnell et al, 2016; Valsiner and van der Veer, 2000). They use the 'cultural' knowledge to reference and evaluate their understanding in terms of its acceptability to each group.

> Successful learning requires students to learn how to interact socially in their cultures.

All aspects of knowledge have both cultural-general and specific components (Heyes et al, 2020). The culture-general components include the capacity to reflect on and evaluate how one thinks and learns and an awareness of what one knows. In terms of formal education, the cultures can differ in how they value a topic, how they believe it is learnt and the aspects they value or prioritise (Hodges,1998).

Bronfenbrenner's Bioecological Model of Human Development provides a framework for understanding the critical role of the culture in learning (Bronfenbrenner and Morris, 2007; Hamwey et al, 2019). It identifies the types of interactions children have with various levels of their culture. What we learn from these cultural interactions becomes our cultural way of knowing. It is inextricably linked with experience, self-identity and socialisation (Tomasello, 2016). It influences how we interact in the classroom.

Social cognition: How students form social and cultural knowledge

Successful learning requires students to learn how to interact socially in their cultures. This includes learning to use the plethora of social cues and signals used by members of each culture, and to interact and behave in socially acceptable ways.

The process individuals use to learn about their cultures in these ways is referred to as 'social cognition' (Arioli, Crespi and Canessa, 2018), a key aspect of the cultural way of knowing. As with the other ways, it is acquired developmentally.

Our social cognition determines how we interpret and evaluate our interactions with others and the social feedback we receive. What we know about our cultures and how members operate in them has a major impact on how we think, feel and interact with our world. (Kaneko, Asaoka, Lee and Goto, 2021). We make inferences about the feelings, dispositions and knowledge of others from the behaviours they display; that is, we have a 'theory of mind' (Schaafsma et al, 2015). How we 'read' social interactions at any time impacts, for example, on how we evaluate and value what we know, how we feel, and the decisions we make.

Cultures differ in the social cognition they teach (Legare, 2019). Two individuals can interpret the same social situation quite differently. In addition, the same social behaviour can have different meanings and purposes in different cultures.

Social cognition in the classroom

Formal educational provision usually requires students to learn in groups. In interactions they interpret or 'read' the behaviours of others, using their social cognition, and act based upon their interpretations. They use the range of social cues, infer the feelings and perspectives of others, behave in socially acceptable situations and display prosocial behaviours. The feedback they receive for their behaviour informs both how they perceive themselves as learners and the cultural norms of the classroom.

Students bring to the classroom aspects of what they learn from their other cultures. Their cultural knowledge can influence how they approach learning and interact with the teaching. The classroom culture can differ from the student's other cultures in

- how it defines concepts and propositions, and how it uses knowledge to make decisions, solve problems and achieve goals,
- the typical experiences it fosters and values,
- the beliefs it fosters about learners and learning, what it means to be a student and a teacher, and how it scaffolds learning and the learning strategies it prioritises (Swanson and Hoskyn, 1999). One culture may encourage students to question ideas while another may discourage this. A student's family may believe that reading is learnt in ways that differ from those taught in the classroom. Cultures differ in how they perceive the roles of students and teachers and the expectations they have of each role. These beliefs influence how students interact in the classroom and the trust they have in their teachers and themselves when learning. They store their perceptions of the social and instructional climates of the classroom, how the roles of 'teacher' and 'learner' are constructed, and the types of permitted interactions (Hofman et al, 2001).
- the dominant forms of memory it values. Some cultures, for example, value storing in imagery forms, while others value more abstract forms (Chan, 1999).
- who is prioritised to learn what. Some cultures, for example, believe that males have a greater right to learn science or mathematics, while others do not prioritise access based on gender.
- how to communicate ideas. Cultures differ, for example, in how they structure argumentative essays (Pritchard, 1990) and this influences the genres they use to read and write.

These aspects of a classroom culture are communicated through interactions between students and teachers. Students need the necessary social cognition to learn them. Cultural mismatches between teachers and students in these aspects can restrict the effectiveness of learning and teaching if they are not recognised. School and classroom culture and climate influence student achievement (Dumay, 2009; Gruenert, 2005; MacNeil, Prater and Busch, 2009; Tan, Dimmock and Walker, 2021).

> Formal educational provision in Western cultures preferences the abstract way of knowing and objective analytic-sequential thinking.

The socioeconomic status of student cohorts and schools influences individual academic outcomes (Koza and Melis 2017; Perry and McConney, 2010). The teaching may need to acknowledge and respect the cultural relevance of students' knowledge and teach students how to 'code switch' where necessary.

Unpacking social cognition in the classroom

We have noted that successful classroom learning requires effective social interaction skills. Some children bring to school cultural and social interactional skills that are less appropriate in the regular classroom. Some display immature or dysfunctional interaction skills. Goleman's (2006) theory of social intelligence provides a framework for unpacking these in the classroom. It comprises two dimensions, which are

1. a student's social awareness ability, to: infer accurately and understand or feel how others feel in particular experiences (empathic accuracy and empathy); respond appropriately to someone's emotional state (attunement); and think about and understand social interaction (social cognition[5]),
2. a student's ability to act in socially acceptable ways, to: be a cohesive group member (synchrony); to communicate about themselves and match the expectations of others (self-presentation); to respond functionally to how others affect their emotions, opinions and behaviours (influence); and to regulate how they respond to spontaneous acts of courage, tolerance or compassion.

Educational provision often neglects this way of knowing and, in particular, social cognition. The longer it is neglected, the bigger the problem becomes and the greater the need for interventions that teach socialisation skills explicitly.

Provision often also ignores differences in the types of thinking valued by cultures. Western cultures, for example, tend to value the abstract way of knowing and analytic-sequential thinking, more than the episodic and action ways. Other cultures use imagery and body language to communicate more broadly. Formal educational provision in Western cultures preferences the abstract way of knowing and objective analytic-sequential thinking.

Knowing through our self-identity as a learner

In an eighth way of knowing, we also know through our self-identity as a thinker and a learner. This refers to our 'learning personality': what we know about ourselves as learners, both generally and for specific domains or topics. It defines who we believe we are, and who we can become. We usually use it tacitly or implicitly. It includes

- how we see ourselves and others ('I'm the sort of person who …'),
- the standards and rules we set ourselves ('I wouldn't do that because …'),
- how we define our world ('I think it is important that …),
- how we self-evaluate ('I can do … well' or 'I'll never be good at …'),
- our expectations, and
- our motivations.

One aspect of our self-identity is our 'mindset'. This refers to the beliefs that underpin how we interact with our world. We have multiple domain-specific mindsets, for example, about intelligence (Dweck, 2006) and about teaching (Frondozo et al, 2020). They provide personal models for us to interpret structure, events and situations in consistent, systematic and stable ways, to generate goals[6] and plan courses of action.

The foundations of a self-identity

Erikson's psychosocial theory of identity development (Erikson and Erikson, 1998) provides a framework for unpacking the elements that inform an individual's self-identity. It proposes that an individual's identity develops gradually through various phases of social and cultural interactions. Each phase adds an element. These elements are learnt in the following order, building the capacity to

- trust or to mistrust themselves and others,
- exert self-control and autonomy over aspects of our world, versus perceptions of inadequacy and self-doubt,
- take initiative; to set and pursue goals, explore our abilities, and develop a sense of direction in our interactions,
- take pride and self-efficacy in our accomplishments and abilities, and acquire a sense of proficiency and self-belief in these areas, and
- form an integrated sense of who we are as individuals in our cultures and social groups and our 'place in the world'.

Key dimensions of a self-identity that influence learning

In this paper I examine the following five dimensions of a student's self-identity that influence their learning activity for any topic or domain.

1. ***What they believe about how they learn.*** Students' self-identity includes what they believe about how they learn. Some for example, believe that learning involves internalising or imitating the teaching information. Others believe that learning involves forming their own, unique interpretation of it. These perspectives lead to different expectations of the teaching and different approaches to learning.

   Independently of student beliefs, the teaching usually makes assumptions about students' beliefs about learning. A mismatch between teacher and student beliefs can lead to learning problems, student management and social and emotional adjustment issues. Students might become stressed, confused, angry, impatient, frustrated and annoyed with themselves, or show low self-esteem. They might not be sure of how to act in various situations. It can influence their social identity in the classroom and how they interact with peers.

2. ***How they attribute success as learners.*** Students can attribute their level of success as learners on a task either to themselves, (the effort they invest, their intelligence and ability) or to sources over which they have no control (high-quality teaching, easy tasks, a supportive environment, luck or chance). These are the 'adaptive' and 'helpless' profiles respectively (Núñez et al, 2005).

   Underachievers typically show the helpless profile. Their attributions suggest low self-agency and restricted metacognitive thinking. Explicit teaching of learning strategies, such as on-task persistence and appropriate self-talk, can enhance their academic learning.

3. ***What you believe about your likelihood of success as a learner.*** Your identity as a learner also tells you whether you expect to learn successfully in particular contexts. This is your self-efficacy (Nichols and Utesch, 1998). It affects your approach to learning a topic and the level of achievement you think you can achieve. It limits the decisions you make, how you act and how you interpret the actions of others.

   We make self-efficacy judgements before we decide the effort to invest in an activity and how to approach it. This includes the thinking we will use. We make this judgement quickly, unconsciously and independently of our actual level of ability. We base the judgement on

   - our evaluations of past performance,
   - our observations of how peers approach and complete tasks,
   - our emotional arousal; anxiety linked with earlier experiences of the topic can lead to low self-efficacy, and
   - the verbal persuasion we get from others that tells us we can achieve particular outcomes.

4. ***The goals students set themselves.*** Students' self-efficacy affects the goals they set and their persistence. Those with higher self-efficacy set goals, which target changing what they know or can do, and show task persistence in pursuing these. They are 'challenge seekers' (Dweck, 2006; Rebolledo-Mendez, du Boulay and Luckin, 2006). Those with lower self-efficacy set goals that target showing what they know or can do. They prefer easy tasks and are the 'challenge avoiders' (Brookhart, Walsh and Zientarski, 2006). Self-efficacy predicts academic success better than ability; the higher a student's self-efficacy, the greater their effort and persistence.

5. ***Intrinsic motivation to learn.*** Motivation and engagement are related to self-efficacy and influence learning outcomes (Green et al, 2007; Liem and Martin, 2012). Self-efficacy judgements influence whether and how students are motivated to pursue the goals and the learning strategies they use.

Teaching to improve students' self-identity

A disorganised or negative self-identity can restrict learning and lead to self-management, social and emotional adjustment issues. As mentioned earlier, students may seem stressed, confused, show low self-esteem, become angry, impatient, frustrated or annoyed with themselves. They may not know how to act in some situations or worry about events beyond their control.

Students can improve their self-identity when they are scaffolded to make explicit their tacit beliefs, to monitor and control their learning activity and to learn how to deal with learning challenges and difficult tasks. Teacher practice influences students' beliefs in their ability and their approach to learning. The frequency of positive teacher comments and feedback predicts positive student self-talk. These increase positive self-efficacy and higher-level goals in the future. Learning experiences judged to be unsuccessful have the opposite outcome.

Why are the multiple ways of knowing relevant to effective educational provision?

Each of the eight ways of knowing makes a unique contribution to a student's learning and to their knowledge of a topic at any time. When educators are aware of the eight ways and what they 'look like' in the classroom, they are better equipped to target them explicitly in their teaching.

The eight ways of knowing model contributes an explicit evidence-based dimension of learner activity to SoLD. It provides a means for understanding classroom interactions in terms of individual or personal learning factors.

Our ways of knowing and learning are networked

So far, we have looked at each way of knowing separately. The ways of knowing are linked in networks and operate as integrated knowledge systems. Each way or form makes a unique contribution to your understanding at any point. It gives you part of the story. The parts are synthesised or combined into an overall interpretation. They provide the contents for the TPN and the DMN described in an earlier section.

The contributions interact synergistically as a networked system (Griffiths and Hochman, 2015, p 2; Lickliter and Witherington, 2017). Each way of knowing 'talks with' and is influenced by the other ways. An idea you know in one way can stimulate linked ideas in other ways. You may, for example, 'see' an idea and then recall how to say it, how you feel about it and how to 'do' it.

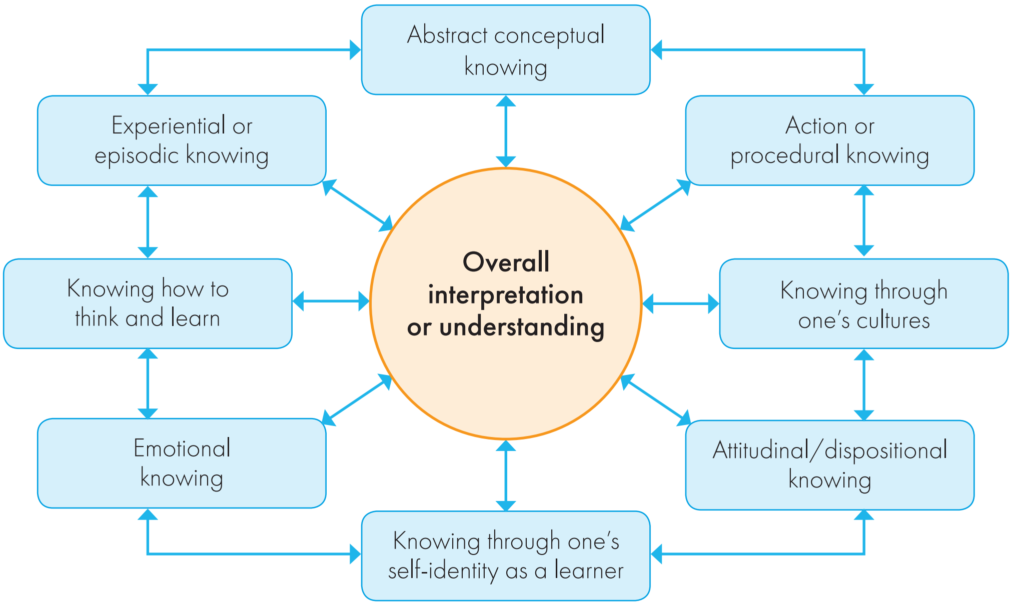
Suppose you plan to buy a pair of shoes online. Your attitude to purchasing online tells you it is worth pursuing. You can read and understand what relevant web pages advertising shoe sales say. You also recall your earlier experiences that tell you it worked out well. You know the actions to take to make the purchase. You link positive feeling with doing it. Your identity says you can do it successfully, even though it did not work in your last experience. All of these aspects interact or 'talk with' each other. Their synthesis underpins your online purchase.

One way of understanding how the multiple ways of knowing interrelate at any time is through the concept of the 'perezhivanie' (Vygotsky, 1994). This is the lens through which an individual interprets their interactions with their environment at any point and draws on the interactions between cognition, emotional, attitudinal and self-identity aspects, both during an initial learning episode and in later reflective activity when they may re-interpret their earlier activity (Cong-Lem, 2022).

Knowing and learning are underpinned by networks that link the multiple aspects of what you know at any time (see Diagram 4). These combine to form your understanding. An analogy is a synergistic symphony, where the musicians work together to produce the outcome with each instrument interacting with others. Paivio (2014) uses the term 'synergistic interactivity' (p 141) to describe how abstract (or verbal) and episodic and procedural (or nonverbal) ways of knowing interact during cognitive activity.

The synergistic networked system changes over time (Griffiths and Hochman, p 2; Lickliter and Witherington, 2017).

Diagram 4. How the ways of knowing operate as an interaction network



Skills are one aspect of knowledge

Educators frequently refer to 'knowledge and skills'. The OECD defines a skill as 'the ability to perform tasks and solve problems' (Ananiadou and Claro, 2009, p 8). The present paper classifies them as one type of procedural knowledge. Skills are action sequences we use relatively automatically to achieve particular outcomes. They are part of an individual's overall knowledge.

Skills are learnt as action sequences. A skill is learnt first as an action sequence in particular contexts to achieve specific goals or purposes (Mascolo and Fischer, 2015). It builds on the synthesis of prerequisite skills (Heckman and Masterov, 2007), and requires the investment of cognitive or mental attention. Through practice it is strengthened and 'sharpened' and the level of cognitive attention needed decreases. Feedback shapes its efficacy. It can be gradually generalised, automatized and transferred to a broader range of contexts.

The multiple ways of knowing are implicated in the learning trajectory of an action sequence becoming a skill. The sequence is linked with particular contextual or experiential knowledge. Students infer the applicability or transfer of the skill and evaluate its use in various contexts and cultures. This leads to the skill becoming generalised and abstract. The students link emotions and attitudes progressively with it. As well, the feedback they receive about applying it at any time informs the self-efficacy they link with it and their self-identity as a user of the skill. Together, these factors influence student's future use of the skill.

Teaching for skill development may need to target all of these aspects. Locating skill acquisition within the broader knowing or knowledge network draws attention to this need.

Examples of the knowing network in action

Returning to the example we used of buying a pair of shoes online, suppose while you were making the purchase that something went wrong after you entered your credit card details. This experience could lead to different emotional responses, depending on what your thinking and self-identity ways of knowing tell you. If your thinking says ‘Danger’ because you do not think you have skills to deal with this, you might try to scan your abstract knowledge to decide how to act. If your thinking enables you to unpack the issue and solve it, you will have different emotions. Evidence for the synergistic links between the multiple ways of knowing is shown in how the emotional, thinking, abstract, episodic and procedural ways of knowing interact (Immordino-Yang and Damasio, 2007).

Suppose instead you see yourself as an unsuccessful maths student. You cannot escape the maths teaching sessions. Your brain has linked maths experiences with fear and anxiety. You know how important and useful it is, but you just cannot learn it. As soon as the maths information starts, the voice in your head starts again: ‘I’m hating it. I hope she doesn’t ask me’. It seems to block out anything you learned recently about maths or how to do it. As the session goes on, your identity is confirmed.

Many students have this network of reactions to what we teach. It can be in any domain. To change their outcomes, we need to ‘break into the network’. For a short period, we may need to work on each way of knowing separately. It is not sufficient to simply ‘re-run’ the teaching information that did not work.

How can we conceptualise competencies in terms of knowledge?

The OECD defines a competency as the overall capacity to adapt to the challenge and demands in a particular context (Ananiadou and Claro, 2009). It includes cognitive, personal, social and communication aspects. This conception of competencies matches the perspective presented here of the multiple ways of knowing each contributing separately to a synthesised or overall understanding. In the purchasing on-line example, your competency is a synthesis of your relevant attitudes and feelings, your abstract knowledge of buying shoes on-line, your social and communication skills, your stored experiences, your purchasing skills, your identity and motivation.

The ‘multiple ways of knowing’ perspective has implications for teaching competencies. It suggests that competence in an area grows out of knowing the domain in each way and then explicitly synthesising this knowledge in networks. The knowledge transitions that lead to competence are discussed later in the paper.

Big Idea 3.
How our knowledge changes during learning

The third big idea in this paper relates to how our knowledge changes during learning (see Diagram 5). You are probably aware that earlier in your reading you needed to act on the information in *The family outing* to work out each novel idea. The information did not become knowledge automatically. You interpreted bits at a time, converting them to meanings. You used your existing knowledge to do this and modified it to form the new ideas.

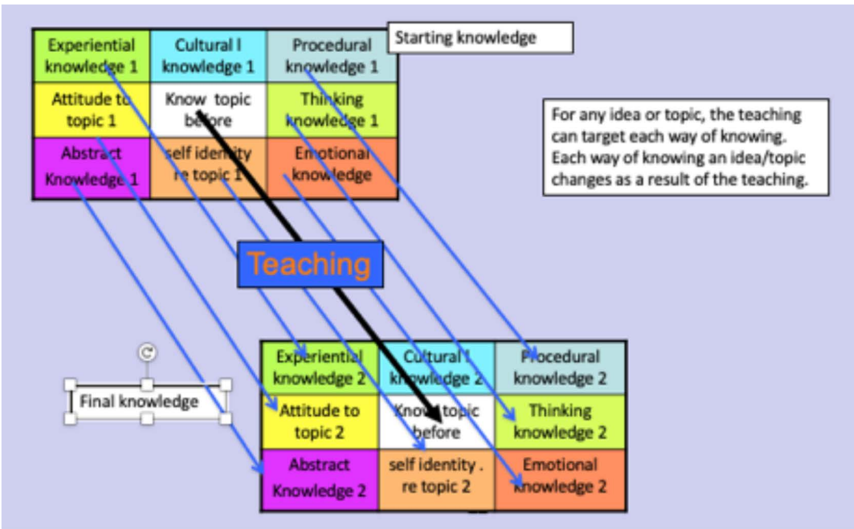
Students learn by interacting with the teaching information to form novel links or associations between ideas that can be modified by subsequent classroom feedback. For any topic, new links can be made within and between all of the ways of knowing, as shown in Diagram 5.

Explaining learning in terms of the multiple ways of learning

A student's knowledge of a set of ideas changes qualitatively. A learning event is proposed to proceed through the following phases of knowledge enhancement.

- The student stimulates what they already know about the topic that is relevant to the focus of the learning (Phase 1).
- They learn the new idea in a restricted, limited way (Phase 2).
- They learn the idea more broadly or abstractly across a range of contexts and link the multiple forms of the idea, (images, actions, and symbolic forms) into schemas (Phase 3).
- They link the new idea with related ideas and organise them around big ideas or topics in a semantic hierarchy (Phase 4).

Diagram 5. Changes in each way of knowing during teaching.



Source: J Munro

Across all phases they

- review and consolidate what they have learnt and store it in long-term memory, link it with what they already knew about the topic and extend that knowledge, and
- retrieve the new ideas, practise and apply them and gradually automatise them.

Particular ways of thinking are appropriate for forming new knowledge at each phase of learning. The phases differ in the thinking on which they draw. The thinking strategies are learnt through social and cultural interactions.

Students make links or 'associations' using what they know to form new knowledge or understanding. Their understanding initially, is limited.

Students learn to manage their activity as they move through the phases. They can learn to use self-talk to do this. Their metacognitive knowledge helps them to set goals for learning and to select and apply the appropriate thinking strategies to achieve them (Pintritch, 2002).

At each phase, the thinking strategies help students retain ideas long enough to form new knowledge, to reduce or minimise the 'learning attentional load' of a set of ideas, to encode the new knowledge in long-term memory and to recall from long-term memory.

Phase 1. What one knows: the starting point for knowledge enhancement

Learning begins with what you know. A person's existing (or prior) knowledge provides the starting point for knowledge enhancement. It provides the 'platform' or 'codes' for interpreting or 'encoding' the teaching information at any time and for learning the ideas or meanings encoded in the information.

You interpreted the information in *The family outing* using your existing knowledge. An initial interaction between the information and what you knew allowed you to select or stimulate part of your knowledge that you used for more in-depth interpreting. In addition to activating the relevant content (experiential, abstract and action), you probably decided whether you could be successful with activity, how you might manage it, your feelings about it, your engagement with it and what you believed the group culture would think appropriate.

The Phase 1 thinking strategies help students link the teaching information with what they know, recall their imagery, abstract and action knowledge of a topic, and decide what the learning outcome might 'look like' and the learning pathway they might follow.

Phase 2. You form new links in specific contexts

Students make links or 'associations' using what they know to form new knowledge or understanding. Their understanding initially, is restricted. They know it or can do it in particular situations; it is essentially episodic. It is often 'partial'; students understand parts or separate components but have not linked or integrated them. It may comprise, for example, a set of actions learnt through imitation of a model in specific contexts.

Phase 2 understanding is formed using learning strategies that link the ideas into place and time experiences. Students may, for example, visualise, act out or paraphrase the teaching information. They know it intuitively and agree that it 'seems reasonable' but may not be able to justify it or see its implications or inconsistencies.

They store this new knowledge as experiences in long-term episodic memory (Tulving, 2005). It includes what they now know about a topic in particular contexts, the emotion they link with it, the ways of thinking they used to learn it and self-efficacy they link with it.

Students can practise recalling the new ideas, replicating and applying them, first in similar contexts and then gradually transferring them more broadly. This allows the students to form increasingly stronger links between the ideas and ultimately to automatise them.

Phase 3. You 'deepen' and broaden what you know

Students begin to 'disentangle' or 'decontextualise' the idea from specific contexts. They identify its common properties and features across several specific instances. The shared or general features are what they know about it abstractly. These features are often represented symbolically, using words, other symbolic systems, visual icons or actions.

The thinking that leads to Phase 3 understanding involves manipulating patterns, identifying common or shared features, synthesising, classifying and generalising. This type of understanding helps them transfer the new ideas by making analogies between sets of ideas within a topic and to recognise an abstract idea in different contexts.

Students can use the abstract form to refer to the idea, learn its logical aspects, predict when it is relevant, analyse how it is used in various contexts, transfer it and identify its boundaries. Conventional symbolism equips students to communicate their understanding more easily and to test it by receiving and using feedback. The symbolism allows them to deal with more topic knowledge and to 'compress' it. They can interact with more knowledgeable partners about the topic and participate in co-operative learning activities with peers.

The students link the imagery, actions and abstract-symbolic forms of the idea into a schema (Diakidoy and Kendeou, 2001; Vosniadou, Ioannides et al, 2002) and move between the forms. They can, for example, imagine the abstract form of an idea in specific situations and then infer from the image.

They store the synthesised schemata in long-term memory. The storage and retrieval processes, unlike episodic or experiential storage, often require an investment of cognitive attention.

As they continue to recall, practise and use the new idea, students need to invest less thinking space or 'cognitive attention' in them. They now have more attention to allocate to making links with related ideas. They can question ideas, identify more general links between them and test these.

Phase 4. Deepening and broadening further the understanding

Students can be guided to further transform or re-organise their Phase 3 knowledge of a topic into 'layers', or 'tiers' of main and subordinate ideas. They become aware that, for any topic, some abstract ideas and relationships are more general or inclusive than others, and others more specific (Bransford, Brown and Cocking, 2004). They re-prioritise, elaborate and differentiate further the meaning networks.

The links between the various ways of knowing a topic are stronger and more automatised. Students can move between the multiple forms more easily and strategically. This provides a broader understanding that they can use and apply to think more deeply. This level of knowing is a competency.

The thinking that leads to Phase 4 understanding includes Phase 3 thinking applied to the more complex abstract forms of the ideas. The student analyses more complex patterns and relationships about the new idea, questions them, classifies them using shared and contrasting abstract features, synthesises and links them in more complex ways, summarises and generalises. It also includes inferring patterns of inclusion among abstract ideas – that is, thinking 'hierarchically' or hierarchical abstraction (Haupt, 2018). This equips students to organise the ideas in a domain into 'clusters' or networks of knowledge.

Phase 4. Understanding facilitates transfer

Educators can enhance the transferability of knowledge by implementing provision that targets Phase 4 understanding. This includes

- providing opportunities for student thinking that is self-driven, with the motivation to explore, infer possibilities and reflect on aspects of the new ideas from multiple perspectives. This is characteristic of the default mode network activity.
- scaffolding students to use 'if X then Y' conditional thinking and to link parts of their knowledge with 'conditional tags'. This helps them recall specific aspects to solve problems and resolve issues.
- guiding them to transfer ideas by making analogies between topics and to recognise an abstract idea in different contexts or topics. Phase 4 knowledge is easier to search systematically. This helps students match their knowledge with a problem, search what they know and retrieve selectively what is relevant to the problem (Ericsson and Staszewski, 1989).
- scaffolding them to retain the imagery, action and abstract forms of an idea simultaneously in working memory, and to switch seamlessly between them. They can also monitor and change the thinking strategies they are using at the time. They can manage their emotions and evaluate their activity in terms of its cultural appropriateness at the time.
- guiding students to use their clustered knowledge to chunk and interpret information rapidly and efficiently. Phase 4 knowledge makes less demand on short-term working memory and attentional resources than the cognitively simpler forms. It frees up the thinking spaces for more sophisticated thinking about the topic. The clusters help them recognise features and patterns and to analyse a topic from multiple perspectives.

It also frees up thinking space for more effective metacognitive activity. When solving a problem at Phase 4, for example, they more easily interpret the problem, plan how they will solve it, monitor the effectiveness of their activity, modify or re-direct it, re-question what they know and review what they have learnt.

Knowledge in this form facilitates open-ended creativity, innovation and transfer (Urban, 2004). Students can move easily between multiple forms of a set of ideas (for example, between symbolism and imagery), infer and generate possibilities, construct multiple interpretations and evaluate them. They can think divergently by making 'far transfer' analogies and contemplate unusual possibilities for the ideas and evaluate them in terms of both their logic and their relevance to the culture. They can create new 'virtual episodes' of the possibilities using creative imagery thinking.

Changes in long-term memory over the phases

Students review and consolidate what they have learnt at each phase and store it in long-term memory, by linking it with what they already know about the topic and extending that knowledge. They can link emotion or affect, ways of thinking and self-efficacy, with the new ideas at each phase. They retrieve the new ideas, practise and apply them in a range of contexts, including problem solving and gradually automatise them.

From a long-term memory perspective, our representation of a new idea changes from primarily episodic to more abstract as we forge new links and re-arrange others (Conway et al, 1997). Formal education usually favours the retention of conceptual or procedural knowledge. The episodic knowledge linked with them facilitates the application and transfer of the knowledge and its use in creativity.

> A student's beliefs about how they operate as a learner influences their progress

Learning a disposition or attitude to a topic

When individuals improve their understanding of a topic, they may also confirm or change their disposition or attitude to it. The values they link with the new ideas influences subsequent learning.

The level of organisation of the student's topic knowledge can be linked with the increasingly more complex disposition to a topic proposed by Krathwohl et al's (1964) taxonomy, which is that

- the restricted understanding in specific situations in Phase 2 can be linked with being prepared to receive and a willingness to respond to the topic,
- the deeper, decontextualised Phase 3 understanding can be linked with the topic being increasingly valued, and
- the 'big idea' automatised understanding of the topic in Phase 4 can be linked with a worldview disposition to the topic. The attitudes are fused with the other ways of knowing so that they operate as an integrated meaning-processing unit.

Learning the emotions linked to a topic

Students link emotions with topics they learn (Schiefele, 1996). The emotions are embedded in individual experiences. When students recall a topic on later occasions, they also recall the linked emotion. This influences their motivation to learn more about it and how to do this. Interest, although often overlooked in teaching (Boekaerts and Boscolo, 2002), accounts for about 10 per cent of the variance in student achievement scores (Schiefele, 1996).

Students' emotions influence their progress through the phases. Positive emotions and feedback increase the likelihood that they will continue and persist. Negative emotions restrict this progress, both in the knowledge they retrieve and the learning strategies they use. During Phase 2 activity, emotions are often linked with experiences as implicit feelings. As the learning progresses to Phases 3 and 4, they become more explicit, and students link self-talk with them.

Students are more likely to link positive emotion with new knowledge when they believe that they managed the learning activity and see that their activity led to learning (McPhail et al, 2000) and deep processing is encouraged (Schraw,1998).

Knowledge of one's identity as a learner across the phases

A student's beliefs about how they operate as a learner influences their progress through the phases. This progress requires motivation, a belief that the goal of learning is appropriate and acceptable to them and that they can be successful as a learner. They need to persist and sustain the learning activity, including when they encounter apparent barriers.

- During Phase 1 their self-identity leads them to decide if and how they will engage with the teaching. This is influenced by their self-efficacy.
- During Phases 2–4 their self-identity influences the level of motivation and effort they invest in the learning activity, the control they exert over it and how they interpret the feedback as they progress. It influences how they monitor their progress and how to continue in the immediate future.

Across the phases it is influenced by how they perceive their learning success and how the knowledge gained is 'theirs'; that it is 'part of them'.

Knowledge of the culture or context across the phases

Classroom learning is a social and cultural activity. Students progress by interacting socially with the teacher and with peers. We noted earlier that they form a set of beliefs about what it means to be a student and a teacher in that classroom, and the types of interactions that are permitted. These influence the goals that students set and their approach to learning.

Each phase involves particular learner and teacher roles. At Phase 1, for example, the culture needs to support students to recall what they know about a topic, demonstrate a respect for this and a valuing of diversity in it. It needs to encourage curiosity about what will be learnt and to optimise students' beliefs that they can learn it successfully.

> The importance of fostering the capacity for deeper learning has been identified internationally as a key goal for 21st century educational provision

For effective learning of any topic, the classroom culture needs to scaffold each of the ways of knowing to progress from a Phase 1 to a Phase 4 understanding.

How do we foster deeper learning?

The importance of fostering the capacity for deeper learning has been identified internationally as a key goal for 21st century educational provision (for example, OECD, 2018). Pellegrino (2017) defines it as

> *… the process through which transferable knowledge (ie, 21st century competencies) develops. Through deeper learning, individuals not only develop expertise in a particular discipline, they also understand when, how and why to apply what they know. They recognise when new problems or situations are related to what they have previously learned, and they can apply their knowledge and skills to solve them.*
>
> (p 228)

Deeper learning is possible only when an individual's knowledge or understanding of a topic is amenable to transfer. Pellegrino's description matches an integrated Phase 4 understanding. Provision that guides the knowledge transformations from Phase 1 to Phase 4 will achieve deeper understanding and the capacity for deeper learning.

Across this trajectory it is important that the provision scaffolds the gradual synthesis of the various aspects so that an increasingly integrated network is formed, that the student can use more seamlessly and automatically. Whether knowledge of a topic achieves Phase 4 status depends on the range of factors that impact on the quality of the learner's interactions with their culture at the time, These include the goals and motivation for interacting, their relevant existing knowledge and the scaffolding and feedback from the culture.

Common learning model: What might it look like?

At the outset I noted the SoLD focus on learning in terms of the encoding, consolidation and retrieval processes and the need for a framework that could organise, consolidate and integrate the outcomes from these processes to explain learning across the various disciplines and that would facilitate application in formal educational practice.

A goal of this paper is to explore such a framework. The multiple ways or forms of knowing model provides an evidence-based interpretation of the encoding, consolidation and retrieval processes. This section offers a possible mapping of the outcomes of the interpretation into a common learning model or CLM.

The CLM has, at its core, the student engaged in the adaptation process as they interact with the teaching in formal education. It examines the possibility of identifying a set of activities employed by all school students to learn successfully, regardless of the content, the context and their purpose for learning. The activities are a version of learning 'universals'. An advantage of such a model is that it offers a common language for talking about learning within a school context. It is proposed that classroom learning generally includes the following universals.

> The multiple ways of knowing model provides an evidence-based interpretation of the encoding, consolidation and retrieval processes.

1. Learning is stimulated by a perceived challenge or goal. Students learn when what they know/can do/believe is challenged and they frame up a goal or reason for learning. The challenge can come from environmental/cultural interactions or be self-generated.
2. All learning begins with what students know. Any idea can be represented in multiple forms in memory: as actions, as images in context, as symbols for concrete entities and as symbols for abstract entities. Thinking, emotions, attitudes, their identity and their cultural knowledge are linked with these forms.
3. An idea develops through a sequence of phases as it is learnt: through actions, specific episodic representations, abstract and symbolic representations.
4. At each phase learning involves re-organising, deleting and/or generating links between ideas. Students use a repertoire of thinking strategies that are learnt initially in domain-specific ways.
5. Ideas are linked in networks. The number of ideas linked with any idea affects the complexity and depth of understanding of the idea.
6. The thinking activity during learning is goal-oriented and can either be self-directed or scaffolded by others.
7. The thinking activity during learning uses cognitive attention. A 'thinking space' or 'short-term working memory' is attributed to this activity. It has

limited capacity. Components of the activity, for example – encoding different types of information, forming new links, and retaining briefly the new knowledge – are aspects of short-term working memory.

8. Learning usually involves forming a succession of interpretations or 'possible representations' of an idea. Students trial each interpretation and use evaluative feedback, either from the external context or internally, to decide whether it is acceptable, or needs to be modified or rejected.
9. A learning outcome does not automatically become stored as knowledge in all forms. Students may need to use retention and recall strategies to store and retain new knowledge in memory.
10. Networks of ideas can be re-organised as students learn more about them. As students continue to apply and practise an idea, its multiple forms and links with other ideas become linked. This can lead to an expert understanding of the set of ideas.
11. The cultures to which a student belongs affect what they know and learn. The knowledge valued by a culture, its preferred ways of thinking and its attitudes influence the learning activity.
12. Learning collaboratively or co-operatively can lead to enhanced outcomes.
13. Students link emotions or feelings with their knowledge. These emotions determine how students recall the ideas in the future and how they feel about them and can sustain or restrict learning progress.
14. A student's identity as a knower and learner affects how they learn. Their self-efficacy for learning the ideas, their intrinsic motivation to learn them, the relevance and the perceived value of the ideas, are aspects of this.

The universals are proposed to describe learning across the grades and the curriculum domains taught in formal education. The set can be differentiated or elaborated to account for personalised or individual ways of learning and for particular curriculum domains.

Teaching students how to unpack and interpret the complex world of the future

We also noted at the outset that educational provision needs to equip students to adapt to and transact optimally in an increasingly complex world. Learning is the means by which they will manage the adaptation. They will need to learn new disciplines, many of which will emerge through the multi-disciplinary fusion of existing disciplines. The capacity to transfer complex competencies will be important.

What types of knowledge do they need to adapt? The multiple ways of knowing describe the networked types of knowledge that students will use to adapt. The set of learning universals in the CLM are intended to contribute to the means by which students will enhance what they know.

So far, the focus of this paper has been on educational provision. It could equally have been on students learning to be self-teachers, learning to take increasing self-control and management of their learning activity. Educational provision could aim to teach students explicitly about how they can understand the various forms of knowledge described here, the value of each, and how they can use them interactively to optimise their learning activity. They could also learn how to use the learning universals in the CLM to acquire and enhance their knowledge in any discipline.

Conclusion

A science is a body of established, evidence-based knowledge. SoLD potentially offers much to educational provision in the future. This paper is an attempt to synthesise existing knowledge about one aspect of learning within the framework of knowing. I have used this synthesis to distil a set of propositions about learning.

This paper positions knowing in SoLD. We noted at the outset that SoLD describes learning in terms of the key processes of encoding, consolidating and retrieval. The synthesis of the three big ideas provides this positioning.

Learning is conceptualised as the bridge between phases of knowing. An individual's knowledge at any time provides an infrastructure for the interactions that lead to learning and is itself changed through these interactions.

Science is a social process through which scientists, individually and collaboratively, continually create, revise and elaborate their scientific theories and ideas. The science of learning exemplifies this. If the ideas in this paper elicit questions from educators and provoke reflection on provision, its goal will have been achieved. Without the inclusion of a focus on learner activity, SoLD will be neglecting a key variable in understanding and explaining the learning process. Our work, as we step into the future, is too important for this not to happen.

Endnotes

1. The approach has been exemplified by workshops beginning in 2012 and sponsored by the US-based National Science Foundation (blogs.commons.georgetown.edu/scil2012/report-1st-workshop/), the creation of Science of Learning Centres (tdlc.ucsd.edu/tdlc/index.php), the formation of Science of Learning: Collaborative Networks, nsf.gov/pubs/2015/nsf15532/nsf15532.htm and publications such as *The Encyclopedia* of the Sciences of Learning (Seel, 2012).
2. etymonline.com/word/educate
3. *Education as 'Educare' and Education as 'Educere'*. Downloaded from stagiritecorner.wordpress.com/2018/03/18/education-as-educare-and-education-as-educere/ on 3 March, 2023.
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5. Goleman uses the term 'social cognition' in a narrower sense than Arioli, Crespi, and Canessa.
6. For example, see psychologytoday.com/us/basics/motivation

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About the author

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About the paper

Dr Munro explains that the aim of SoLD is to identify evidence-based commonalities across the various theories of learning, and to synthesise them into a set of propositions about how students learn, as well as the developmental, contextual and cultural factors that scaffold it. He also comments on the implications for teaching and educational provision. In his paper he focuses on one particular aspect – the evidence base for the role of an individual's knowledge in the learning process, and how this changes during learning. He examines three 'big ideas' and discusses how, from an educational provision perspective, the study of learning would benefit from a framework such as SoLD to organise, consolidate and integrate the outcomes from the various disciplines.

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