4. GUIDANCE FROM LEARNING RESEARCH

In recent decades, significant research has been undertaken into human learning and the conditions that promote successful learning. This research has spanned a range of disciplines, including neuroscience, cognitive science, educational psychology, educational research and sociology, and has resulted in a relatively new interdisciplinary field of inquiry commonly referred to as the 'science of learning' or the 'learning sciences'. Several major reviews have summarised the state of knowledge in this field. Many of the field's research findings have implications for learning in schools. A few of these findings are summarised here.[28]

> New developments in the science of learning raise important questions about the design of learning environments – questions that suggest the value of rethinking what is taught, how it is taught, and how it is assessed.[29]

Deep understanding

One group of research studies has explored the characteristics of 'experts' in various fields such as mathematics, chess, science, medicine and history in an effort to identify what develops as people become more expert in their fields and so to establish what distinguishes experts from novices.

A general conclusion from these studies is that experts have a great deal of knowledge in their fields. Their extensive factual and procedural knowledge is an important component of their expertise. However, importantly, this knowledge does not exist in the form of disconnected facts; expert knowledge is interrelated and organised around deep understandings of important concepts and principles of the field.

Experts' deep understandings of their field make their factual and procedural knowledge more 'usable' in the sense that it can be transferred and applied more readily to new and unseen situations. Experts are better able to make sense of new information, including by recognising features, patterns, relationships and discrepancies that are less obvious to novices. Research shows that novices in a field are more likely to represent newly encountered problems in terms of their surface features, while experts attend to deeper, more abstract concepts, principles and processes that underlie surface features. Other research has shown that novices tend to possess knowledge in smaller, disconnected pieces, while experts possess larger, more integrated 'chunks' of knowledge that assist them in identifying meaningful patterns in information.

Experts' deep understandings also provide them with better appreciation of the contexts to which knowledge can and cannot be applied (that is, their knowledge is 'conditionalised') and deep conceptual understanding enables them to retrieve facts more readily from memory, to learn related information more rapidly and to think about and solve novel problems in their field.

These expert/novice studies show that the simple accumulation of knowledge and the memorisation of facts and procedures are inadequate for analysing and solving significant new problems or tackling complex challenges. Activities of those kinds require deep understandings of a field developed over many years through exposure to a wide variety of related problems and challenges.

[28] This section draws on a paper prepared for the Curriculum Review by Ms Charlotte Waters titled *'Findings from the learning sciences: implications for curriculum, instruction and assessment'*, Australian Council for Educational Research, 2019.

[29] J Bransford, AL Brown, RR Cocking, MS Donovan & J Pellegrino (eds), *How people learn: brain, mind, experience, and school: expanded edition*, National Academies Press, Washington DC, 2000, p. 131.

This research also has shown that expertise in one field does not transfer readily to expertise in another, even when fields appear closely related. For example, it might seem that 'problem solving' should transfer across fields of expertise. But research has found that experts behave much like novices when faced with problems outside their fields. Expert problem solving appears to depend on understandings that are largely field-specific.

These findings have obvious implications for the school curriculum. Students' abilities to transfer and apply their factual and procedural knowledge to new contexts and problems depend on their grasp of underpinning concepts and principles in an area of learning, opportunities to apply their learning to a wide range of contexts and problem types, and extended time frames in which to do this.

> The fact that experts' knowledge is organised around important ideas or concepts suggests that curricula should also be organised in ways that lead to conceptual understanding. Many approaches to curriculum design make it difficult for students to organise knowledge meaningfully. Often there is only superficial coverage of facts before moving on to the next topic; there is little time to develop important, organising ideas.[30]

Motivation

A second body of research has explored the role of motivation in learning. These studies have investigated different ways of motivating learning; learners' varying reasons for engaging in learning; beliefs about personal capacity to learn; and conditions and teaching practices that enhance motivation to learn. The findings of these studies demonstrate the powerful impact motivation has on student engagement, persistence and learning outcomes.

Studies of different ways of motivating learning show that praise, recognition, rewards and reprimands (often referred to as 'extrinsic' forms of motivation) are all capable of encouraging learning. However, external motivators of these kinds often are less powerful than internal ('intrinsic') motivators of learning such as the desire to learn something because it is interesting, enjoyable or inherently useful, or because it relates to personal long-term goals. Research suggests that intrinsic motivation often is related to the desire to be in control of one's own life, to become more competent or to be connected with or care for others.

In general, learners are more intrinsically motivated if they are pursuing a topic of personal interest, responding to a challenge that they believe is within their capabilities, and feel a sense of autonomy and control over their learning. There is some evidence that, if people are extrinsically rewarded for their performance or for things they would have done anyway, persistence and performance can decline – perhaps in response to a perceived diminution in control.

Closely related to these studies is research into reasons for learning. Researchers have described two broad motivations for learning: 'performance' and 'mastery'. Learners with a performance orientation often are focused on competition, satisfying others, achieving recognition and avoiding negative judgements. Learners with a mastery (or learning) orientation usually are motivated by a desire to develop their competence in an area of learning and to achieve personal learning goals.

These different motivations for learning are reflected in learner behaviours. Learners with a performance orientation tend to focus on learning isolated pieces of information to improve speed of learning and recall. They typically avoid challenging tasks or areas in which they may perform less well than other learners, and may perceive failure as a matter of personal shame. Learners with a mastery/learning orientation tend to enjoy challenging tasks, are more willing to persist and make an effort, and tend to have more positive attitudes to failure.

Other research has studied conceptions of learning ability. Some learners see the ability to learn as 'fixed'. They believe people differ in their ability to learn, meaning that there are better and worse learners. From their point of view, there is little that poor learners can do to change the hand they have been dealt; additional effort may be largely pointless. Others see learning as 'incremental' (also referred to as a 'growth mindset'). They believe that every learner is at some point in their learning and is capable of further progress with effort and appropriate support.

[30] eds Bransford et al., *How People Learn*, p. 42.

Learners' views of their own ability to learn have a direct impact on motivation. When learners believe they are capable of success, they are more inclined to make an effort and to persist with their learning, and so are generally more successful. The opposite is true of learners who doubt their ability to learn and have low expectations of success. This can be a particular issue if the learning environment is not seen as welcoming and a place where they belong – for example, if they sense that they are cultural outsiders.

Learning environments can be designed to encourage motivation. One way to do this is to provide learners with a sense of control over their learning, enabling them to pursue personal interests and strengths.

Research suggests that even small meaningful choices can promote a sense of autonomy and control, enhance motivation and lead to improved outcomes. When learners have a degree of control over their own learning, they also are more likely to take on and persist with challenging problems.

Motivation is also enhanced when the learning environment sparks interest and curiosity, and arouses learners' interests to know more. Researchers refer to this as 'situational interest' or interest in specific situations or phenomena. Project-based and problem-based learning can be effective in building situational interest and encouraging perseverance. Motivation is also increased when learners see value and practical relevance in learning, and when it is aligned with their interests and long-term aspirations.

Teachers can promote motivation by connecting with learners' interests and passions; making clear how new learning builds on what learners already know; directing learners' attention; encouraging a focus on learning rather than performance; explaining the meaning and utility of what is being learnt; ensuring that challenges are at a manageable level of difficulty; and providing learners with the ability to monitor the progress they are making and to appreciate the relationship between effort and success.

Educators may support learners' motivation by attending to their engagement, persistence, and performance by:

- helping them to set desired learning goals and appropriately challenging goals for performance
- creating learning experiences that they value
- supporting their sense of control and autonomy
- developing their sense of competency by helping them to recognise, monitor, and strategise about their learning progress
- creating an emotionally supportive and nonthreatening learning environment where learners feel safe and valued. [31]

Progress in learning

A third body of research has explored the developmental nature of learning, addressing questions of how expertise typically unfolds in particular fields, including how new learning builds on prior learning and lays foundations for future learning; common sequences in the development of competence; the impacts of prerequisite knowledge, preconceptions and misconceptions on learning success; and the teaching implications of learners' pre-existing understandings, beliefs and backgrounds.

Underpinning this research is recognition that most human learning does not involve learning discrete, isolated and more or less equivalent facts and skills. Learning is the process through which increasingly interconnected and sophisticated knowledge, skills and understandings in an area of learning are developed over time. The development of expertise involves more than mastering a growing number of facts and skills; it also involves increasingly deep understandings of the principles, ideas and ways of working at the heart of the field.

Research has explored the nature of developing competence in fields as varied as language learning, medical specialisations, classroom teaching, mathematics and history. The general aim of this research has been to describe and understand what it means to be increasingly competent and to elucidate pathways to greater expertise – often to inform teaching programs or professional development.

[31] National Academies of Sciences, Engineering, and Medicine, *How people learn II: learners, contexts, and cultures,* National Academies Press, Washington, D.C., 2018, p. 133.

Research into learning pathways has included studies of 'learning progressions', defined as descriptions and illustrations of increasing understanding or proficiency in an area of learning. Unlike sequences of proposed learning found in many curriculum frameworks, learning progressions are constructed from empirical evidence about how proficiency typically develops in practice. That is, rather than describing what 'should' occur, learning progressions attempt to describe how learning actually occurs. And because they are evidence-based, these descriptions can be tested and falsified.

Research studies have investigated progressions of developing understanding in areas such as science and mathematics. These studies sometimes have explored learners' increasing understandings of specific concepts such as buoyancy, atomic molecular theory and the flow of organic carbon through socio-ecological systems. The belief is that more explicit, evidence-based descriptions of how learning occurs in practice will provide an improved basis for structuring curricula and deciding appropriate instructional sequences, as well as better frames of reference for establishing where learners are in their learning and monitoring improvements over time.

Other research has highlighted the importance of identifying appropriate starting points for learners' next steps in learning. It is now well established that successful learning depends on connecting with learners' current knowledge, understandings and beliefs. In general, learning is most effective when it builds on, challenges and extends prior learning. Teachers need to be able to establish where students are in their learning, including by diagnosing preconceptions, incomplete understandings and false beliefs. This, in turn, requires a frame of reference against which learning progress can be monitored. Teachers also need to be able to connect with, and build on, the cultural knowledge and starting points of individual learners.

Research suggests that by establishing where learners are in their long-term progress in an area of learning, teachers are better able to provide guidance on appropriately challenging learning goals, provide feedback to inform next steps in learning, and assist learners to see and monitor the progress they make over time.

> There is a good deal of evidence that learning is enhanced when teachers pay attention to the knowledge and beliefs that learners bring to a learning task, use this knowledge as a starting point for new instruction, and monitor students' changing conceptions as instruction proceeds… Learner-centred teachers present students with 'just manageable difficulties' – that is, challenging enough to maintain engagement, but not so difficult as to lead to discouragement. They must therefore have an understanding of their students' knowledge, skill levels, and interests.[32]

Variability in student attainment

A fourth body of research has explored variability in students' levels of attainment in particular areas of learning and strategies for addressing the varying points learners have reached in their learning. This research has been made possible by advances in educational and psychological measurement and, in particular, by advances that have allowed the construction of measurement scales along which variability in learners' levels of attainment can be mapped and studied.

The use of modern measurement techniques to construct a scale for measuring student attainment is illustrated in Figure 8 which shows distributions of students' levels of attainment in reading based on NAPLAN. Distributions are shown for all Australian Year 3, Year 5, Year 7 and Year 9 students. From these distributions it can be see that there is significant variability in students' levels of attainment in each year level and significant overlap from one year of school to the next (noting that the distributions for Year 4, Year 6 and Year 8 are not shown here). The best readers in Year 3 are already reading at the level of the average Year 7 student.[32] The poorest readers in Year 9 are still reading at the level of the average Year 5 student. As a result, in any year of school, students differ widely in the kinds of texts they can read and the kinds of support they require to improve their reading. The picture is similar for numeracy, except that the variability in numeracy levels does not reduce over time (and there is some international evidence that students' levels of attainment in mathematics become more varied the longer students are in school).

[32] Department of Education and Training, *Through growth to achievement*, p. 29.

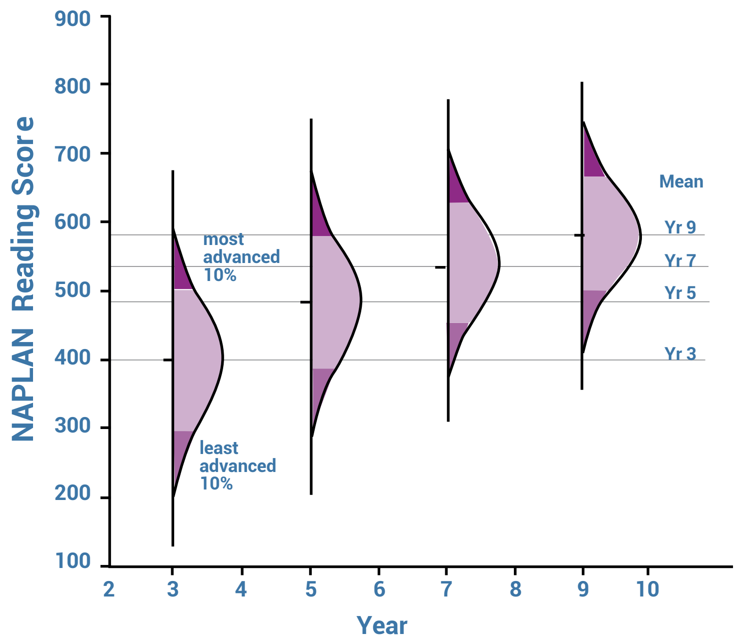

Figure 8 Distributions of student attainment in reading (source: NAPLAN)

Siemon et al have studied variability in students' levels of attainment in mathematics.[33] With the assistance of modern measurement theory, they constructed a sequence of eight 'developmental levels' of mathematics attainment from 'relatively naïve beginnings' (Level 1) to 'more sophisticated understandings and capacities' (Level 8). These levels are shown on the left of Figure 9. At each level, the mathematics skills typical of students at that level were described and illustrated, with the researchers noting the possibility of developing teaching and learning materials appropriate to students at each level.

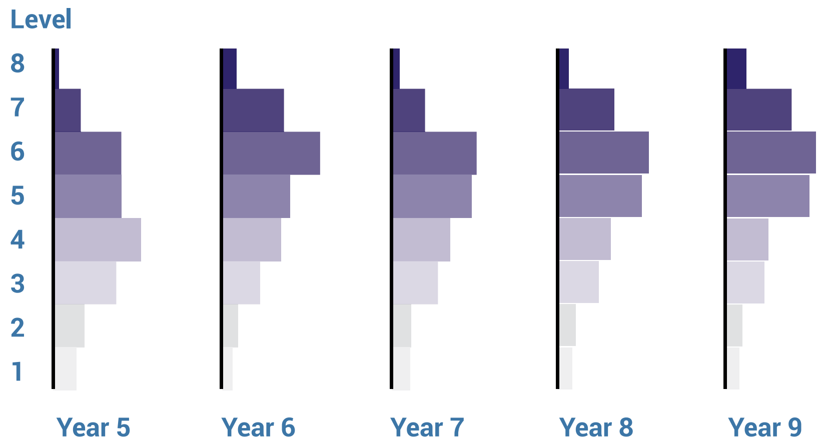

Figure 9 Distributions of student attainment in mathematics (Based on Siemon et al., p. 13)

Figure 9 shows the proportions of students assessed at each level for about 1300 Australian students in each of Years 5 to 9. A striking feature is the spread of students across the eight levels in each year group. The researchers noted that, because Level 1 corresponds in the current curriculum to about Year 2, and Level 8 corresponds to about Year 9, 'the spread within each year level represents a range in students' mathematics achievement equivalent to seven years of schooling'. This example illustrates the importance of recognising that students are at very different points in their long-term progress and of constructing frames of reference for establishing individuals' current levels of attainment, regardless of their age or year group.

33 D Siemon, A Barkatsas & R Seah (eds), Researching and using progressions (trajectories) in mathematics education, Brill, The Netherlands, 2019, p. 13 (figure 1.1).

An essential step in constructing such a frame of reference is to describe and illustrate the nature of long-term development in an area of learning. In most learning areas it is likely to be appropriate to describe and illustrate progress by first describing and illustrating progress in particular aspects of the area. For example, attainment levels in mathematics might be developed by first describing development in particular aspects of mathematics including, but not limited to, algebraic reasoning, geometric reasoning and statistical reasoning.

Day et al have developed descriptions of how algebraic reasoning develops across the middle years of school, although they note that algebraic reasoning also needs to be cultivated in the primary years.[34] The researchers refer to these descriptions of development as a 'learning progression' incorporating three big ideas: Equivalence, Pattern and Function, and Generalisation. Their algebraic reasoning progression is designed to 'identify where students are in their learning journey and where they need to go next' and 'to design teaching advice to help teachers provide appropriate activities and challenges to support student learning'.

> One of the biggest problems confronting the teaching and learning of algebra is that while the end points or goals of algebraic reasoning may be clear to teachers and textbook writers, not enough is known about how important and sophisticated concepts, such as the three big ideas [Equivalence; Pattern & Function; Generalisation], develop and how they can be supported throughout the primary and junior secondary years. Within the same classroom, some students may have achieved a relatively deep understanding of key algebraic ideas while other students may be operating at a much more basic level. Expressed another way, teachers need to know how to gather reliable evidence to show the level at which students are operating, and what specific teaching is most likely to move everyone's thinking forward.[35]

Day and her colleagues commenced their research with a review of the research literature to identify a small number of 'big ideas' of algebra. The three big ideas they identified provided the core of their approach to algebraic reasoning. The literature review also revealed that very few attempts to describe the nature of progress in algebra made use of core ideas of this kind.

On the basis of their review of the research literature, the researchers drafted a 'hypothetical learning progression' consisting of eight levels, with the three big ideas represented at each level. Although the focus of the progression was on algebraic reasoning, it was considered important also to identify algebraic content in the progression 'as students, at different levels, need content about which to reason'.

This initial learning progression constructed from the research review provided a basis for developing tasks to explore students' levels of algebraic reasoning. A total of 25 tasks and 75 subtasks were developed, each with its own scoring rubric (usually a 3-point scale) for teacher use in judging the quality of student reasoning. A purpose of the rubrics was to 'show teachers what they need to look for, and how to foster the kinds of classroom discourse and feedback that will move students' reasoning forward'. The tasks were trialled on students in Years 7 to 10, revised and then administered to more than 1500 students across Australia.

The statistical analysis of the resulting data was used to construct a map showing the difficulties of all subtasks as reflected in students' success rates. Although the three big ideas informed task development, because they proved so 'intertwined' in practice, a single map was developed to include all subtasks. This map was used to inform the final learning progression, with the eight levels now being 'based on the evidence of what the students at these levels could actually do'.

The analysis of the data showed that students found algebraic reasoning more challenging than the hypothetical learning progression anticipated. The researchers speculated that algebraic thinking and reasoning are underemphasised in the school curriculum and that 'many students, and possibly some teachers, perceive the focus to be almost exclusively on symbol transformation and manipulation'.

34 L Day, M Horne & M Stephens, 'Reframing mathematical futures II: developing students' algebraic reasoning in the middle years', in D Siemon, T Barkatsas & R Seah (eds), Researching and Using Progressions (Trajectories) in Mathematics Education, Brill, The Netherlands, 2019, pp. 126–156.

35 Day et al., 'Reframing Mathematical Futures II', p. 126.

Generalised descriptions of the eight levels of algebraic reasoning were then developed (see Figure 10) and the levels were elaborated for teachers with illustrative learning activities and assessment tasks. Teaching advice also was developed for each level to support teachers to consolidate learning from earlier levels of the progression and to introduce the next level of algebraic reasoning.

Following the study, these researchers made their algebraic reasoning progression, reasoning tasks and scoring rubrics available to all teachers, noting that they 'provide teachers with a window on student thinking about algebra and enable them to know more about their students' understandings, which should enable them to better target their teaching'. They also noted that learning progressions of this kind have implications for curriculum design which 'should be based on what students can actually do and how they usually progress'. And they developed a series of six professional learning modules to support teachers in their development of algebraic reasoning.

Finally, recognising that students in any classroom are likely to be at different levels of attainment, and that teachers need to cater for this diversity, the researchers provided examples of learning activities that could simultaneously be used with students working at a range of levels. These activities can be thought of as low-floor, high-ceiling activities, with each activity being accessible to less advanced students, but also challenging and extending more advanced students.

Implications of variability in student attainment

The observed variability in students' levels of attainment (as illustrated in Figures 8 and 9) tends to be under-recognised in educational policies and practices based on year-level learning expectations. In their research with focus groups of teachers, Joel Rose and Chris Rush of New York's New Classrooms identified an acute tension between 'an underlying policy context rooted in grade-level expectations' and 'an instructional program that is best for each student'. Many teachers in their focus groups described feeling caught between the system's expectation that they would focus only on year-level content and their beliefs about what individual students needed and were ready to learn next. One teacher commented, 'the curriculum we were given says the kids should already know everything up to their grade, and they don't. I was even told a couple of times when I first started that I was teaching below-grade work, and I should be doing on-grade work. But the students weren't ready for that yet.'

Rose and Rush concluded that attempts to portray year-level curriculum standards as 'rigorous' mistakenly assume all students in the same year of school have reached the same point in their learning. Educational policies based on year-level teaching may even be hindering some students' progress: 'Policies push teachers to focus on grade-level material to the exclusion of individual growth, which may be causing some of the most disadvantaged students to fall even further behind. The policies may also be preventing advanced learners from progressing to skills beyond their assigned grade level, even when they have the ability to do so.'

> The [year-level] standards alone do not provide guidance to teachers on where to focus instruction. They signal to a seventh-grade teacher, for example, that all seventh-grade students should be taught seventh-grade content—whether they happen to be performing two years behind grade level or two years ahead...
> In K–12 education, while the gaze of policy makers is focused on how students are performing relative to grade-level assessments, learning gaps continue to accumulate below the surface, making longer-term success harder to achieve...
> We must candidly acknowledge the trade-offs and costs a policy orientation focused on grade-level expectations creates. For far too many students, these costs are substantial given their unfinished learning from prior years...
> If policymakers want to create the space for schools to better meet the unique needs of their individual students, they must create new policy frameworks that enable and encourage these practices.[36]

[36] J Rose & C Rush, *The Iceberg Problem: how assessment and accountability policies cause learning gaps in math to persist below the surface....and what to do about it*, New Classrooms, New York, 2019.

Level	
8	Is able to combine a facility with symbolic representation and an understanding of algebraic concepts to represent and explain mathematical situations. Explanations are sophisticated using logical thought and the language of reasoning. Can use multiple representations in a coordinated manner to solve, analyse, convince and conclude. Can visualise the form and structure of a function, at least graphically, from a real context. Is able to work in a context-free environment using symbolic language and treat algebraic expressions (e.g. 3X+2) as single entities. Can generalise more complex situations. Is able to establish and describe equivalence involving the four operations explaining relationships in symbolic terms. Can use abstract symbols to solve problems in context with multiple steps.
7	Is able to use and interpret algebraic conventions for representing generality and relationships between variables. Beginning to use sound logical reasoning with appropriate reasoning language (e.g. if… then, must) evident. There is more coordination of multiplicative thinking and the associated language to notice algebraic structure. Can recognise and use the relationships between multiple entities and connections between and within different representations. Able to establish and describe equivalence explaining relationships using the distributive property and the inverses of addition and multiplication. Can generalise quite complex situations and in more direct situations beginning to use simplest form.
6	Can use and interpret basic algebraic conventions to represent situations involving a variable quantity. Beginning to explain using logical language and to use if… then reasoning. Uses symbolic language but the need for simplification is still being developed. Able to generalise simple arithmetic relationships with justification, including multiplicative relationships, but is often still context bound. Can show why several expressions are equivalent, typically employing numerical (non-symbolic) justifications.
5	Able to use multiplicative reasoning in simple situations. Can reason with more complex additive situations involving larger numbers and subtraction but usually by examples. Has moved from algebraic expressions to using equations. Can derive a strategy that maintains equivalence, but cannot yet generalise. Able to use symbols to express rules. Can follow, compare and explain rules for linking successive terms in a sequence. Beginning to generalise using words or using some symbolic generalisations in simple situations. Recognises and represents simple functional representations. Can justify an argument using mathematical text. Beginning to generalise but connects closely to building on in context.
4	Beginning to work multiplicatively and simultaneously coordinate variables, although still uses specific examples to convince. Able to reason and generalise in simple situations. Can recognise and interpret relevance of range from table and/or graphs and to recognise functional relationships. When faced with more complex algebraic situations is unable to use the full range of explanation or handle all of the information simultaneously. Beginning to transition to abstraction by inserting a number for a pronumeral.
3	Beginning to use symbolic expression and elementary reasoning. While still using arithmetic approaches there is evidence of relational reasoning with the numbers and providing some explanation. Beginning to recognise simple multiplicative relationships but without explanation. There is some evidence of coordination of two ideas but explanation is limited. Algebraic expressions are used rather than equations. Beginning to recognise equivalent relationships. Can explain simple generalisations by telling stories, manipulating materials and very simple use of symbolic language.
2	Beginning to recognise patterns and relationships and conjecture about this. Able to identify numbers that vary and numbers that stay the same. Engages with the context, but arithmetic reasoning typically based on calculations is still being used. Recognises some multiples and some relationships like 6 more/6 less, while not necessarily recognising equivalence. Can work with simple scales and transfer from a table of values to a graph.
1	Can continue simple patterns, but likely to build them additively. Reasoning is confined to specific incidences and numerical examples of simple physical situations. Arithmetic thinking is used. Abstraction and generalisation not evident at this stage.

Figure 10 Levels of algebraic reasoning[37]

37 Day et al., 'Reframing Mathematical Futures II', p. 142.

Learning environments

A fifth body of research has explored the role of learning environments in successful learning. These studies have highlighted the importance of inclusive, supportive environments in which all learners' backgrounds, strengths and starting points are recognised and welcomed, strong relationships are built, and collaborative learning (including project-based and problem-based learning) is encouraged.

Meaningful engagement and successful learning are strongly influenced by learners' attitudes and expectations. Research clearly demonstrates the importance of learning environments that are welcoming and that provide learners with a sense of belonging and personal meaning, as well as a sense of autonomy and control over their learning. Learning is maximised in environments in which learners believe they are capable of learning successfully, receive supportive and helpful feedback to make decisions about their learning, and are able to monitor and reflect on the progress they are making.

Teachers play a vital role in creating such environments. Research has illuminated how they do this. To be most effective, the environments teachers create and the learning opportunities they provide build connections with learners' backgrounds, starting points and individual learning needs. Teachers promote healthy, productive relationships within the learning environment and motivate learning by stimulating interest and curiosity. They provide appropriate balances of direction, guidance and autonomy. They build learners' confidence in their ability to learn and encourage an ongoing focus on learning and mastery rather than performance. And they provide feedback that guides next steps in learning and assists learners to appreciate and monitor their progress.

Many studies have investigated learning environments as social contexts in which learners and their teachers continually interact. These studies have included research into the role and importance of interpersonal relationships in learning success and the role that culture plays in the learning process. Learners bring a wide variety of background knowledge and starting points to their learning, including varied cultural and linguistic backgrounds. For some learners, mismatches between cultural background and the culture of the learning environment can make the learning environment unfamiliar and unwelcoming, making it more difficult for learners to engage productively in learning. These mismatches can include differences in understandings about rules, behaviours and appropriate uses of language. This research is revealing that cultural considerations are key determinants of learning success and critical factors in all learning.

A number of research studies have considered the role of collaborative/cooperative learning environments and have demonstrated how the quality of collaboration among learners and between learners and teachers influences learning outcomes. Learning often is promoted by focused, cohesive learning communities in which learners work together to support each other's learning. This research has included studies in which learners collaborate on a problem or project that members of a team undertake jointly. Some studies have explored collaboration of this kind in online environments. In 'collaborative learning', there is a need for learners to work together to set goals, make decisions about roles and responsibilities, share tasks, communicate, and address issues as they arise. Some studies have examined the benefits of cooperative learning of this kind in cross-disciplinary problem-solving contexts. Benefits appear to include greater social acceptance of group members, increased task orientation and improved self-esteem.

> For some students the culture and practices of school are not markedly different from those they experience outside of school, while for others going to school is a cross-cultural experience that can bring challenges.[38]

[38] National Academies of Sciences, Engineering, and Medicine, *How people learn II*, p. 136..

Metacognition

A sixth body of research has explored the importance of metacognition to learning. This research includes studies of learners' conceptions of, and knowledge about, learning itself; awareness of personal strengths and weaknesses in relation to the demands of tasks and challenges; and 'self-regulation' skills in planning, monitoring, revising and reflecting on learning progress.

Researchers define metacognition as awareness and understanding of one's own thinking and learning processes. This includes a learner's knowledge about themselves – their current levels of attainment, strengths, weaknesses and ways of learning. Learners with higher levels of metacognition have greater control over their learning. They are better able to monitor comprehension of what they are learning, recognise when they do not understand or when there are gaps in their knowledge or skills, identify the need for additional information and proactively seek that information, and recognise inconsistencies between new information and what they already know. Metacognitive skills also enable learners to recognise and reflect on what has worked and not worked in their learning, what does not make sense, and what needs further investigation. In short, higher levels of metacognition provide higher levels of self-awareness and self-monitoring.

Research shows that learners are more likely to learn successfully if they have an understanding of where they are in their learning (their current levels of knowledge, skill and understanding), if they are able to plan ahead and direct their learning to achieve challenging but realistic learning goals, and if they are able to monitor progress in achieving those goals. Metacognition also involves the ability to reflect on and evaluate the success of efforts to improve. Evidence suggests that some of these behaviours are more difficult for younger children, but that learners can be assisted over time to build skills in self-regulation.

Research findings in areas including physics, writing and mathematics indicate that metacognitive strategies are best developed in the context of individual subjects rather than as generic skills taught separately. Attempts to develop metacognitive skills in isolation from subject matter generally have resulted in failure to transfer to specific learning contexts. A general conclusion from research is that the teaching of metacognitive strategies should be a priority in all school subjects.

> A 'metacognitive' approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.[39]

[39] eds Bransford et al., How People Learn, p. 18.