UNDERSTANDING LEARNING: LESSONS FOR LEARNING, TEACHING AND RESEARCH

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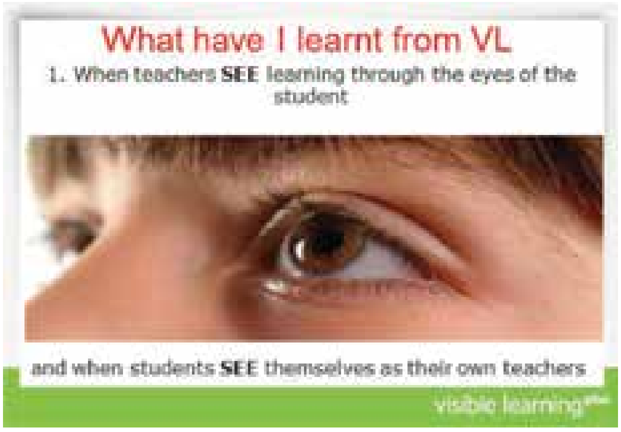
ABSTRACT

This presentation starts with the five major messages from Visible Learning, outlines a notion of 'learning', then develops seven fundamental principles of learning: learning involves time, energy, deliberate teaching, and effort; the structure and relations of learning; there are major limitations of the mind; the student as social animal; confidence as a multiplier; the need for maintenance and feedback; and identifying the major learning strategies. The new Science of Learning Research Centre is promoted as an opportunity for developing a 'heat map' of learning, for assessing, developing and enhancing learning – and for creating a powerful new narrative relating brain research to learning and teaching.

Over the past decades I have been trying to ascertain the major influences on student achievement. The three Visible Learning books have elaborated my findings – *Visible learning: A synthesis of over 800 meta-analyses in education* (Hattie, 2009), *Visible learning for teachers* (Hattie, 2012) and *International guide to student achievement* (Hattie & Anderman, 2013) – and the major theme in these books can be summed up by requesting teachers and school leaders to have the mindset 'Know thy impact'. This leads to closer attention on the impact of the adults on the learning of students, demands they seek evidence of student responses to their interventions, and begs the moral purpose question about the nature of worthwhile domains of understanding that the impact is meant to enhance. The claim can be expressed as shown in Figure 1.

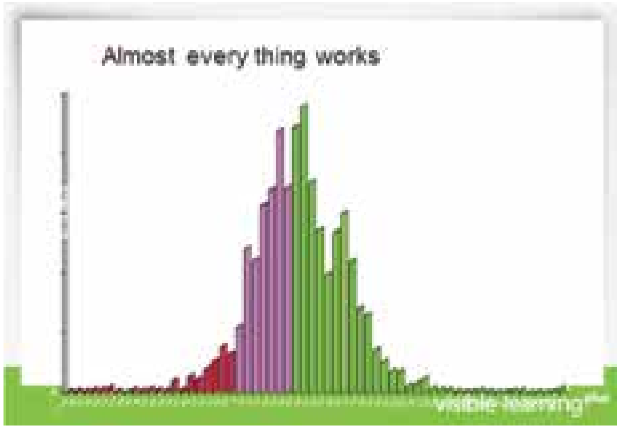
These are the 'Big Five' findings that follow from 'Know thy Impact':

- *All interventions are likely to work:* the question thus should be what is the magnitude of any intervention? Any intervention higher than the average effect ($d = 0.40$) is worth implementing.
- *The power of moving from what students know now towards success criteria:* the more students are aware, as



Source: Visible Learning Plus

Figure 1 Know thy impact



Source: Visible Learning Plus

Figure 2 All interventions are likely to work

they start a series of lessons, what success is expected to look like, then the more engaged they are in the challenge (provided it is a challenge as they may already know what it means to be successful, or the challenge may be too easy or too hard), and they more they are likely to enhance their achievements.

- *Errors are the essence of learning and they are to be welcomed as opportunities:* we go to lessons because we 'do not know' and thus errors, mistakes and not knowing are the key to all subsequent learning. Errors should be seen as opportunities to learn but to admit error requires high levels of trust (between student and teacher, and between student and student).
- *Feedback to teachers about their impact:* the most powerful person in most classrooms who relates to enhanced achievement is the teacher – the more teachers are open and seek feedback about their impact (relating to how many students they affect, which aspects of the lessons are being learnt, struggled with, and so on, where to go next).
- *The need for passion about, and to promote the language of learning*: it requires a passion to see the impact of one's teaching to maintain the energies, the mission and the attentions to student learning. It also requires a narrative about effort, learning, high expectations and avoiding a language of labels, ability and low expectations.

WHAT IS LEARNING?

The common feature in the above is a focus on 'learning' – although our current Australian community has an obsession about 'achievement', 'standards' and 'ability'. The latter lead to policies that favour those with higher achievement, those above the standards and those with much ability. This obsession is more negative about those with lower achievement, those not above the standards, and those with lower ability. This has led to claims about schools or students from low socioeconomic areas not being successful, and schools or students in leafy suburbs being successful, and this has muddied the waters about the nature of success in schools. As has been documented elsewhere (Griffin, 2013), Australia is falling backwards in the world comparisons and most of this 'backwards' movement is a function of the top 20–30 per cent of students not gaining as much as they did 10–20 years ago. Partly, this is because of the attention to the lower achievers, lower socioeconomic areas and the claims that they are 'not above the standards' and thus we have avoided a focus on the learning of the top 20–30 per cent. Indeed, there is much evidence that Australian teachers are more effective with the below-average students in terms of adding value to their prior achievement and enhancing their learning, and not so effective with those students above the average (Griffin, 2013). There is much power in getting the narrative correct.

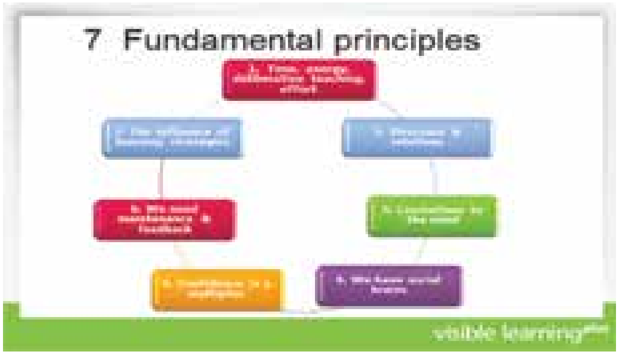
A major argument in this discussion is that there should be more attention to the narrative of 'learning', as it is via developing 'learning' for all students that there will be subsequent effects on 'achievement'. While there are many definitions of 'learning', the one that is the basis for this presentation is that learning is the process of developing sufficient surface knowledge to then move to deep or conceptual understanding. There are many influences in the Visible Learning work that indicate the importance of this notion of learning (see Table 1).

Table 1 Influences that indicate the importance of the notion of learning as moving from surface to deep knowledge

Rank	Influence	Effect size
1	Student expectations	1.44
7	Classroom discussion/listening to learning	0.82
10	Feedback	0.75
11	Reciprocal learning – questioning, clarifying, summarising, predicting	0.74
12	Teacher–student relationships	0.72
13	Spaced v. mass practice	0.71
14	Metacognitive strategies	0.69
21	Self-verbalisation and self-questioning	0.64
22	Study skills	0.63
23	Teaching strategies	0.62
24	Problem-solving teaching	0.61
27	Concept mapping	0.60
32	Worked examples	0.57
48	Goals	0.50
54	Concentration/persistence/engagement	0.48

Source: Visible Learning Plus

SEVEN FUNDAMENTAL PRINCIPLES



Source: Visible Learning Plus

Figure 3 Seven fundamental principles

PRINCIPLE 1: LEARNING INVOLVES TIME, ENERGY, DELIBERATE TEACHING AND EFFORT

Substantial investments of time, energy, deliberate teaching and personal effort are required to develop mastery in all knowledge domains. Intelligence, ability and talent are not enough. Consider a study by Clark and Linn (2003) in which the same science eighth-grade curriculum was taught in four different ways: either as a full 12-week semester topic, or in streamlined (cut-down) form in either nine-week, six-week or three-week versions. The same four topics were covered, but the amount of time devoted to the four units of work was dramatically reduced. Assessments took the form of both multiple-choice and written tests. The results were startling. The reduced time allocations barely made any impact on the multiple-choice tests. But students who had to cover the content in reduced time were unable to pass the written tests that assessed the depth of understanding. For instance, students who covered the content in three weeks scored around 25 per cent on the written sections, despite scoring 90 per cent on the multiple-choice test. Students who had studied the full version scored 90 per cent on multiple choice and 67 per cent on written sections.

It is not time, but particular uses of time and timing. And this relates specifically to investments in learning. The greatest predictor is engaged time and academic learning time, particularly for low-achieving students. But simply spending more time on an activity does not necessarily lead to skill improvement unless there is a deliberate effort to improve student performance, such as specific teaching to the skill, making the success criteria explicit or feedback to reduce the gap between where the student is and the success criteria. It is deliberate practice.

Note, as an aside, the number of intended instruction hours in primary and high schools across 34 countries (see Figure 4) – and the correlation with PISA: reading is 0.20, maths 0.32 and science 0.35. Longer is not necessarily better.

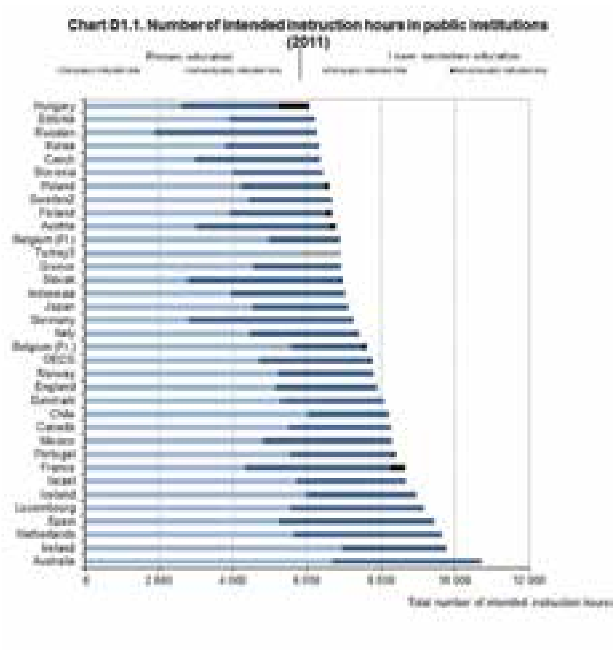


Figure 4 Number of intended instruction hours in public institutions

The key idea behind deliberate practice is that the time devoted to training tasks needs to be such that a person can identify and achieve mindfully and sequentially. Instead of being haphazard or recreational, this form of practice is highly structured. Typically, practice schedules are achieved under supervision of a teacher or coach. Performers are presented with tasks that are initially outside current performance levels but that can be mastered within hours by focusing on critical aspects and refining technique though repetition and feedback. In essence, there is always an intended cognitive or psychomotor skill targeted and this is assessed though objective means. Immediate short-term goals and adaptive corrective feedback become major components inherent in this process.

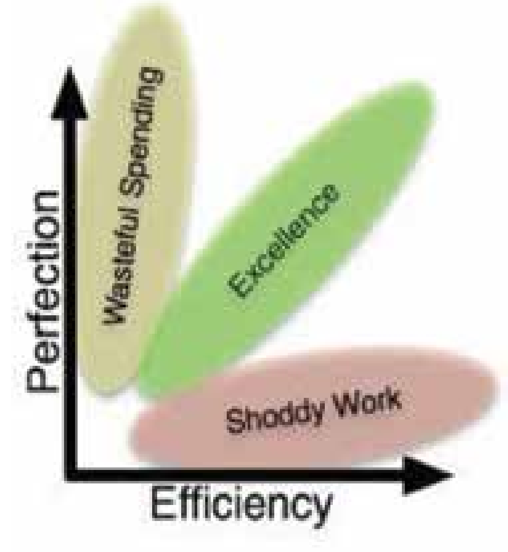


Figure 5 Perfection v. efficiency

Where is the concept of efficiency in schooling? Imagine two high school teachers teaching the same concepts to groups of similar students. If one teacher manages to have all students learn these concepts in half the time of the other teacher – where is the reward? The problem is that this teacher still has the same time and now has to find something to do with the students in the other half of the time. Often they cannot go too fast and then impinge on the next level of the curriculum as they can disturb the next teacher's expectations and timetabling about what is supposed to happen. At best they can provide enrichment – and such spreading sideways has low effect-sizes on assisting students to learn new challenges. When I look at many accountability systems, it is rare to find anyone grappling with introducing efficiency as a desirable attribute of systems (but see Colorado's model).

When we ask teachers what they mean by 'challenge', they often refer to the nature of the material: this text is challenging but this one is not; this problem is challenging but this one is not. But some students do not then engage with the challenge of the text and thus do not see it similarly! When you ask students, they say challenge is 'when their head hurts'. So here is a problem. It requires much effort and it is tiring to overindulge in learning.

Since the beginnings of psychology there have been explanations of how we think at least two levels. William James (1890/2007) distinguished between associative and deep thinking; others have distinguished systems, one that is classical and operant conditioning and a second system that is the more conscious aspects of our thinking mind. System 1 is fast and responds with immediacy; System 2 entails using time to 'stop, look, listen, and focus' (Stanovich, 1999). More recently Daniel Kahneman (2011) wrote about the two systems he distinguished as 'thinking slow' and 'thinking fast'. Slow thinking is System 2, which requires deep, challenging and sometimes 'hurting' thinking. Fast thinking is System 1, which rapidly calls on knowledge to be used in thinking slow. The more we make learning automatic (like learning the times tables) the easier is it for us to devote our cognitive resources to System 2 deeper tasks (such as using the times tables to problem solve).

For those who struggle at school there is a double whammy – they do not have as much 'fast' automatic System 1 knowledge, thus when asked to do System 2 (slow thinking) they have to not only recall and understand the times tables then have to apply it to the problems. The more able students only need to devote their thinking resources to System 2, slow thinking.

Too often we then label these students with lower System 1 thinking as struggling, not able, and so on, and the vicious cycle continues The art of teaching is to ensure that the task is appropriate – for example, give the struggling students the System 1 knowledge so they can devote the cognitive resources to tackle the System 2 problem and thus make them more equal to the brighter students who have better System 1 capacities.

So the message for Principle 1 is extensive engagement in relevant practice activities at an appropriate and challenging level, enabling successive refinement, with room to make and correct errors, and lots of feedback. It is time devoted to conscious monitoring, time that requires concentration and persistent such that there is stretching to take on new challenges until these challenges becomes automatic. It is introducing efficiency into the lexicon of teachers and learning. Further, it is being aware of what cognitive resources we need to bring to a task to 'make our head hurt', knowing that we can only do this thinking slow for short durations, that it is built on high access to thinking fast (more automatic) knowing and structuring tasks to allow not only for the thinking capabilities of the student but also in being specific in the success criteria as to what is required.

PRINCIPLE 2: STRUCTURE AND RELATIONS

Luria (1976) was one the pioneers of relating the brain structures and functions to human learning. He developed a tripartite model of learning including simultaneous thinking, successive thinking, and planning and executive functioning (see Naglieri, Das & Goldstein, 2013).

Successive processing involves information that is linearly organised and integrated into a chain-like profession (parsing from the particulars to the whole) and simultaneous processing involves seeing the whole and then parsing into the particulars. Planning, executive control, develops later (he argued about age 9–12 years, which compares to Piaget's move from operational to formal operational thinking) and is responsible for regulation, conscious impulse control, self-monitoring, planning and executive regulation. For example, many whole language advocates base their claims on simultaneous thinking (if the students see the whole, they can then appreciate the details), whereas phonics proponents base their claims on successive thinking (if the students understand the specific parts, they can then form whole words or texts). Of course, it is not that simple, but we do note the effect-size from the whole language is 0.06 and phonics is 0.54. I also note a good model that shows that is not that simple (see Figure 6).

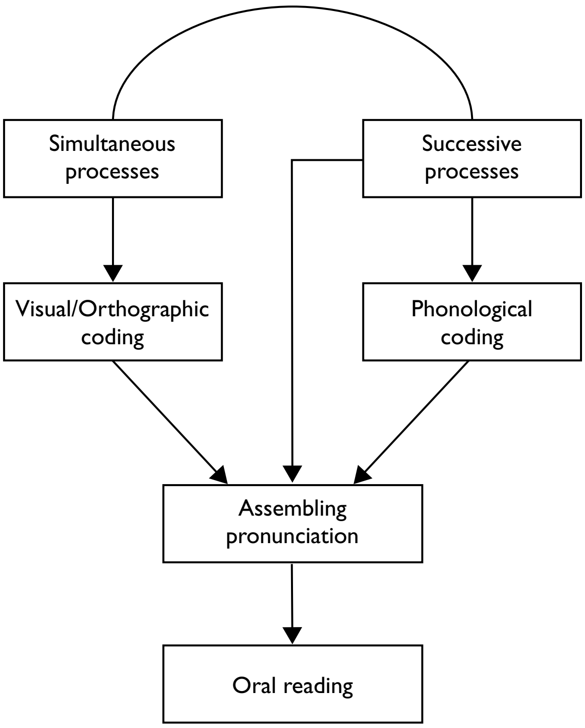


Figure 6 Reading is not simple

There is a strong claim that our brains start more in the simultaneous mode as dominant – we see a work and make inferences and interpretations – often through play and early experiences with parents, siblings and peers. Then along comes school, and in particular reading, which primarily relies on skills in successive thinking. As Scribner and Cole (1900) noted, reading then serves two functions: it not only teaches students how to think successfully, it is also a useful skill to then be able to read so we can learn many other subjects. But so often teachers see it only in terms of the latter and fail to realise they are teaching a specific set of learning skills – how to think serially. For many students who have not picked up this skill prior to coming to school this is a double whammy – they struggle to learn to think serially and now have difficulties in reading that prevent them then 'reading to learn' other subjects.

In many ways the computer interfaces of today demand more simultaneous thinking and many of the successive thinking skills we have are not as relevant to this interface. Maybe this is why some teachers struggle to incorporate technology into their teaching – they are over-engaged with and over-value developing successive thinking. Perhaps in the beginning there was simultaneous thinking, along came the printing press such that societies then valued successive thinking, and with technology we are reverting to value simultaneous thinking – and the world of schools has not kept up. Of course, it would be wonderful if we had both, although for me (Hattie), I know that I am so much better at successive than simultaneous and have learned to cope with simultaneous stimuli by working out how to successively process – but this is much 'slow' thinking.

Now, let us place these notions of 'fast' and 'slow' and Luria's thinking into one model (see Figure 7). The SOLO model was developed by John Biggs and Kevin Collis (1982) and has four levels: one idea, many ideas, relate ideas and extend ideas. The first two relate to surface knowing and the latter two to deep knowing. We have used this model in developing test items, scoring rubrics, classroom observation, developing teaching lessons, analysing progress and for understanding learning. The model highlights the importance of knowing something (the first two steps) before thinking about it. Too many innovations in education value the deep and forget it is based on the surface.

Source: Visual Learning Plus

Figure 7 The SOLO model

One of the hardest things to accomplish in learning is transfer of understanding. This is because deep understanding is so embedded in the knowing of much surface information. This is why many programs like enquiry-based teaching (0.31) and problem-based learning (0.16) have low effects, as they are too often introduced outside the context of knowing many ideas, or introduced as some kind of generic skills development that can then be applied across content domains. (Note, for example, problem-based learning is much more successful in the fourth and later years of medical school but not in the first year of courses).

Certainly one of the features of high-impact passionate teachers is their proficiency to move students from surface to deep knowledge. In a study of National Board Certified (NBC) teachers, compared to similarly experienced but non-NBC teachers, we found that the greatest difference related to the SOLO taxonomy (Smith, Baker, Hattie & Bond, 2008). We collected artefacts of student work, and developed scripts of the lesson plans and had these independently coded as to evidence of surface or deep knowledge. In the classes of the expert teachers, 75 per cent of the artefacts were at the deep level and 25 per cent at the surface, whereas in the experienced teachers' classes, 25 per cent of the artefacts were at the surface level and 75 per cent at the deep level. Expert teachers know how to move students from surface to deep much more effectively than non-experts.

PRINCIPLE 3: LIMITATIONS OF THE MIND

Source: Visual Learning Plus

Figure 8 Limitations of the mind

Dan Willingham (2009) has advanced the thesis that the human brain does not naturally want to think about matters we normally deal with in schools. This is because school thinking requires much effort, the realisation of much brain resources and allocation of personal energies, high levels of confidence (particularly in the face of making errors and the face issues of 'not knowing'), high levels of uncertainty and many unknowns, and thinking uses up many resources. To resist an invitation to think is not necessarily an indication of laziness. It could reflect a decision to be economical, cautious or even prudent with our personal resources. It is much easier to conserve energy and avoid initiating actions when outcomes are uncertain. If you have had many opportunities to not realise learning when asked to expend the energy it helps confirm the belief that it is not a good use of thinking (e.g. thinking slowly) next time so it is easier to resist and not engage. Indeed many of us are quite risk averse, so why should children also not be so?

Plus there is mental availability – there are issues of ease of access to surface knowledge to then manipulate, relate and extend; there are constraints of working memory as how much we can hold in memory and work with at the one time; there are knowledge gaps that are revealed when thinking that need attention before relating (we may expend energy to close knowledge gaps but give up if they are knowledge chasms); it is easier to rely on memory than thinking (and our memory for ideas may be limited in some domains); and most of us have beliefs about knowledge (indeed I survive very well with beliefs about how cars move and know next to nothing).

John Sweller (2008) has been most instrumental in outlining the limitations of our cognitive load, and showing ways to optimise learning within our load limitations. He noted that there is intrinsic cognitive load that is fixed by the nature of the task; extraneous cognitive load imposed by the learning conditions and instructional context; and the personal cognitive load, which is the limitations of how much can be processed by a particular individual. Obviously balancing these loads is the critical aim of instruction. For example, one way to assist students to solve a maths problem is to reduce the load by giving them the answer so then they concentrate on the process. Providing students with worked examples is a powerful method (note the effect size of 0.57 by providing a group with a worked example compared to another group learning the same material without a worked example). Similarly the 'flipped classroom' invites students to overview the vocabulary and main ideas before then immersing oneself in learning these ideas and the relations between them. Having pictures and words, having prompts and questions very adjacent, avoids using cognitive resources to flip between ideas; getting rid of redundant material stops expending energy of what matters less (clarity outweighs elaboration); hearing other students thinking about the material as well as the teacher greatly enhances learning (we are indeed social learning animals); and having multiple opportunities to learn the material (particularly over time) are all other ways to reduce cognitive load – such that the student can think slow about what really matters in the learning.

PRINCIPLE 4: WE ARE SOCIAL ANIMALS IN REACTING TO OTHERS, LEARNING FROM OTHERS

We learn from social examples: watching, doing, deliberative instruction and feedback from other people. Similarly, much *information assimilated through personal discovery can be shallow, insecure and incomplete*. Consider the following five teaching principles that seem intrinsic to human evaluation and species survival (Csibra & Gergely, 2006):

- the cooperativity principle: there will be adults around who will transmit relevant knowledge even at some cost to themselves
- the principle of ostension: an adult signals to the child that an act is shown for the child's benefit and not the benefit of the adult teacher
- the principle of relevance: both child and adult teacher recognise the goal-directed nature of the learning situation, that the knowledge communicated is novel, and would not be figured out by the child unaided
- the omniscience principle: mature members of the community store knowledge in themselves that they can manifest anytime even when they are not in any need to use the knowledge themselves
- the public knowledge principle: the knowledge transmitted is public, shared and universal. The classic example here is language. Vocalisations and words used by one adult individual are not unique to that individual.

We spend much time mimicking and watching others; indeed we are very much social chameleons. Graeme Nuthall (2007) has written extensively of the power of social relations in the classroom and how students learn a tremendous amount by mimicking other students, by watching and listening to how they interpret what teachers say and do, and his book was appropriately entitled *The hidden lives of learners*, due to how much is actually hidden from the teacher who stands up front, dictates the lesson flow, talks the majority of the day, and then reflects on the 20 per cent (maximum) that the students see and hear. It is why I have entitled my work 'visible learning' to highlight the importance of making the learning visible. It is probably why mirror neurons have so much to say about how we learn.

Mirror neuron theory suggests that whenever humans interact within the same physical space, the brain of the individual who is observing will neurologically 'mirror' the person they are watching. A good deal of research into this effect then followed to the point where a general conclusion appears possible: *the same cortical circuits that are implicated in executing an action respond also when observing someone else executing that action*. Although research with human beings cannot be carried out with the same level of precision possible with animal subjects, many studies using magnetic imaging techniques show critical areas of the brain are highly active when people watch and interpret other human beings. The watching seems particularly important in reinforcing prior learning, or from listening to teachers and reading material.

PRINCIPLE 5: CONFIDENCE IS A MULTIPLIER

We need a certain amount of confidence that we can learn a task before we are prepared to exert mental energies in to learning, and to facing the risk that we may fail. This is why in Visible Learning there is so much emphasis on success criteria, as they can indicate to the student what success looks like and the student (often with help) can estimate how far away from success he or she is, the amount of energy needed to attain success, and to be more focused on attending to the tasks that lead to the success. So often classrooms ask students to 'engage' and such a low-level success criteria is often endless (when they have succeeded in 'engaging' they are asked to do more 'engaging'). Instead we need to invoke the 'Goldilocks' principle: the success criteria cannot be too easy and not too hard. Similarly some of the teaching tasks are to inspire confidence, to provide the safety nets, and to help in calibration and efficacy of learning judgements – and certainly social interactions with others are crucial in the developing these competencies.

Figure 9 Confidence is a multiplier

PRINCIPLE 6: WE NEED MAINTENANCE AND FEEDBACK

We require high levels of maintenance in learning and thus the ability of teachers to diagnose where the student is relative to the criteria of success is critical. This is where notions such as assessment *for* learning, of assessment *for* teachers, student assessment capabilities are all invoked – the aim of using assessment to help understand where in the progression the student is such that appropriate interventions can take place. This leads to many critical learning notions:

- the importance of multiple opportunities to learn: most of us need three to four different opportunities to learn before we actually learn and remember knowledge

- this is why we need the proverbial 10 000 hours to become experts, as it requires high levels of deliberate practice, over learning, attending to the many potentially valuable relations (and students spend about 15 000 hours in school from ages 5 to 16, so we do have this time)
- maintenance is optimised with spaced versus massed practice ($d = 0.71$).

This emphasis on maintenance implies a worthwhile model for teaching not based on the typical models of constructivism, enquiry learning, direct instruction, eclecticism and so on but on the notion that teachers are to DIE for – diagnosis, intervention and evaluation. The optimal model is when teachers have high-level skills in diagnosing where on the learning progression a student is, having multiple interventions in their tool kit then to optimise the best teaching relative to that diagnosis, and constantly evaluating their (the teacher's) impact on the learning and where needed to alter their behaviour, their interventions and their materials to optimise student learning.

We have for too long seen the maintenance of learning embedded in the student and, of course, this is where we want it – but it so often does not start there: it starts with deliberate teaching. This is why we have spent so much time developing assessment tools for teachers to help them know their impact (e.g. e-asTTle: Hattie, Brown & Keegan, 2005), why we want teachers to assist students to become assessment savvy to help in their own diagnosis, response to intervention and evaluation of learning, and why we see the 'teacher as evaluator of their impact' as central to the Visible Learning messages.

A key aspect of maintenance is feedback, as it is what happens *after* instruction. The meta-analyses relating to feedback show very high values ($d = 0.75$) but it is also among the most variable of effects. We have endeavoured to develop a model of feedback based on three critical feedback questions that work at three different levels, as shown in Figure 10 (Hattie & Timperley, 2007).

Source: Visual Learning Laboratories

Figure 10 The three-level feedback model

This is a topic for a whole session, so let me just provide some highlights here.

- The three levels shown in Figure 10 correspond to the SOLO taxonomy: *task* is akin to surface, *process* to the jump from surface to deep and *self-regulation* is indeed deep learning. Thus the nature of feedback that is most powerful differs as the student moves from surface to deep.
- When we ask teachers what feedback means they typically focus on 'Where am I going' and 'How am I going'. They emphasise the 'past', typically providing feedback in terms of comments, clarifications, criticism, confirmation, content development and corrections. But when you ask students, they are emphatic – it is what helps them know 'Where to next?' and in our analyses of feedback (written and verbal) that is less frequent in classrooms (other than procedure directions to complete this, do that).
- There is a crucial distinction between feedback given (there is often a lot given by teachers in a day) to feedback received (typically can be measured in seconds per student). Much feedback given (especially to whole classes) is rarely received. Thus the need to focus on how students understand the feedback given, what they interpret from this feedback, and what they then use to progress.

- Among the most powerful notions is that when the feedback to the teacher is maximised about their impact on students, this has the greatest beneficial effects for the student, as it is then teachers are adaptive in their interventions, have a more effective sense of the magnitude of the influence they are having, and the prevalence of their impact is shown to them in terms of how many students are 'learning'.
- One of the most powerful ways for teachers to 'hear' their impact is via classroom dialogue (d = 0.82). This is more rare than many expect (for example, over three months in the Gates MET study (Joe, Tocci & Holtzman, 2012), about 60 per cent of maths classrooms in the USA did not have a single classroom discussion), they are not easy to set up to maximise return (I have PhD students working on the efficiency of setting up dialogue), and there seems so much reinforcement value in students hearing other students thinking aloud ('Come on down mirror neurons'!).
- We need to be more attentive to observing students learning in classrooms and less attentive to how teachers teach. Watch the students not the teacher; watch the impact of the teacher on students not the teaching methods of the teacher.

PRINCIPLE 7: LEARNING STRATEGIES

There has been a long history of searching for the best learning strategies that students can learn to benefit their learning. In this last section, these are outlined and a direction offered to better understand the optimal learning strategies, understand the moderators or conditions under which various learning strategies are best invoked, and to emphasis the notion that these strategies can be taught. At the moment, about 5 per cent of classroom time is spent teaching skills and strategies and this seems minimal if learning to learn is so powerful. There is also a tendency by students (indeed by all us) to overuse the few strategies that seemed to have worked for us in the past – and often this leads to reinforcing non-optimal strategies. Sometimes we need to be taught to unlearn some strategies and replace them – and this is a worthwhile aim of schooling.

The first message is that generic learning strategies can be used for surface-level knowledge but, to attain deeper knowing, it needs to be underrated within the content domain. Consider, for example, the SOLO taxonomy: strategies such a mnemonics, rote learning and memorisation can be undertaken with learning an idea or ideas but have much less impact for relating and extending ideas. Hattie, Biggs and Purdie (1996) completed a meta-analysis of 279 effects from 51 studies on the effects of learning strategies and found that lower level strategies have a reasonably high effect on surface learning but much lower effects on deeper learning. When the thing to be learned is near (immediate recall, soon after learning, reproductive) strategies out of context have a higher effect than when it is far (long-term recall, transformational) when it needs to be accomplished within the subject domain.

The effectiveness, particularly for learning deeper understanding, may be more subject-specific. De Boer, Donker-Bergstra, Daniel, Kostons and Korpershoek (2013) used 95 interventions from 55 studies and found that the influences of strategies are higher in writing (1.25), science (0.730), maths (0.66) and lowest in reading comprehension (0.36). The most effective combination of strategy instructions included a combination of 'general metacognitive knowledge', the metacognitive strategy 'planning and prediction' and the motivational strategy 'task value' or valuing the task to enhance student performance the most effectively. Thus:

> *teaching students skills such as determining when, why and how to use learning strategies, how to plan a learning task, and explaining the relevance and importance of a task (so that they see the importance of what they are doing) are therefore important aspects of self-regulated learning interventions. (De Boer et al., 2013, p. 59)*

Valuing the task was the single greatest effect and this entailed not only the degree to which the task is considered as relevant, important and worthwhile – the development of a positive style of attribution, which enhances the student's self-efficacy – but also being aware of what success in the task looks like and why it is powerful for further learning (including the student's belief in his or her ability to successfully complete the task). In maths, elaboration, or connections to new material was more effective and this emphasises knowing student's prior or current understanding and then connecting the student to 'where to next'. The bottom line, however, is that it is a combination of strategies (d = 1.32), not a single one-at-a-time strategy. There is also a criticalness about students knowing what success looks like before undertaking the task and giving feedback that relates to 'where to next' that is the key to then gaining the value out of learning strategies.

Dunlosky, Rawson, Marsh, Nathan and Willingham (2013) completed probably the most comprehensive review of 10 strategies.

- practice testing: self-testing or taking practice tests over to-be-learned material
- distributed practice: implementing a schedule of practice that spreads out study activities over time
- elaborative interrogation: generating an explanation for why an explicitly stated fact or concept is true
- self-explanation: explaining how new information is related to known information, or explaining steps taken during problem solving
- interleaved practice: implementing a schedule of practice that mixes different kinds of problems, or a study schedule that mixes different kinds of material, within a single study session
- summarisation: writing summaries (of various lengths) of to-be-learned texts
- highlighting/underlining: marking potentially important portions of to-be-learned materials while reading
- keyword mnemonic: using keywords and mental imagery to associate verbal materials
- imagery for text: attempting to form mental images of text materials while reading or listening

Table 2 How generalised were the effects?

Materials	Learning conditions	Student characteristics	Criterion tasks
Vocabulary	Amount of practice	Age	Cued recall
Translations	Open v. closed book practice	Prior domain knowledge	Free recall
Lecture content	Reading v. listening	Working memory capacity	Recognition
Science definitions	Incidental v. intentional learning	Verbal ability	Problem solving
Narrative tests	Direct instruction	Interests	Argument development
Expository tests	Discovery learning	Fluid intelligence	Essay writing
Mathematical concepts	Rereading lags	Motivation	Creation of portfolios
Maps	Kind of practice tests	Prior achievement	Achievement tests
Diagrams	Group v. individual learning	Self-efficacy	Classroom quizzes

Source: Visual Learning Plus

- rereading: restudying text material again after an initial reading.

They found two strategies that had highest effects – practice testing and distributed practice (spaced v. massed); three with moderate effects – elaborative interrogation, self-explanation, interleaved practice; and the others low effects. They also found no major moderators to these conclusions (see Table 2).

Finally, Lavery (2008) completed a meta-analysis and found highest effects for organising and transforming, self-consequences, self-instruction/verbalisation and self-evaluation (see Table 3).

The bottom line is that low-level strategies more effective for near or surface-level learning, but strategies must be taught in the context of the subject to attain deep-level knowledge; and the effectiveness of strategies for depth is likely to vary across subjects. Strategies or study programs that are taught out of context (like Feuerstein and Arrowsmith) may led to gains for surface knowing (and this is indeed most worthwhile) but are unlikely to have as much effect in leading to deeper understanding. So, we need to know when to play 'em and know when to hold 'em.

These studies also reinforce the power of six big ideas:

- developing student assessment capabilities, being involved in planning and prediction (for example, knowing success criteria), and seeing the value of the task
- allowing students to 'hear themselves think' (self-verbalisation, self-explanation, self-consequences, self-instruction, self-evaluation) – that is, participating in becoming self-teachers

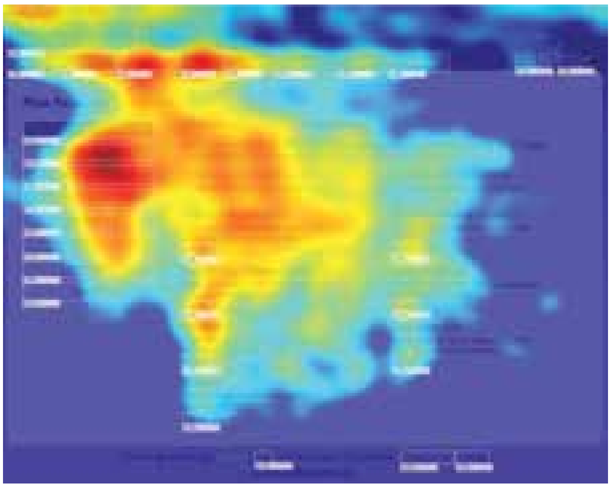
Table 3 Learning strategies sorted by effect size

Strategy	Example	Effect size
Organising and transforming	Making an outline before writing a paper	0.85
Self-consequences	Putting off pleasurable events until work is completed	0.70
Self-instruction	Self-verbalising the steps to complete a given task	0.62
Self-evaluation	Checking work before handing in to a teacher	0.62
Help seeking	Using a study partner	0.60
Keeping records	Recording of information related to study tasks	0.59
Rehearsing and memorising	Writing a mathematics formula down until it is remembered	0.57
Goal setting/planning	Making lists to accomplish during studying	0.49
Reviewing records	Reviewing class textbook before going to lecture	0.49
Self-monitoring	Observing and tracking one's own performance and outcomes	0.45
Task strategies	Creating mnemonics to remember facts	0.45
Imagery	Creating or recalling vivid mental images to assist learning	0.44
Time management	Scheduling daily study and homework time	0.44
Environmental restructuring	Efforts to select or arrange the physical setting to make learning easier	0.22

Source: Lavery (2005)

- participating in deliberative practice (not just rote learning and lots of practice) that is distributed or spaced
- being given and seeking feedback particular related to then valuing the task and seeing the benefits and effects of learning the ideas
- teaching relations between ideas – organising and transforming (seeing the higher level connections)
- knowing many power strategies and then knowing when, why and how to use them –knowing what to do when you do not know what to do.

CONCLUSIONS



There is much to do, and one of the wonderful opportunities is the establishment of the Science of Learning Research Centre between the University of Melbourne, ACER and the University of Queensland. We have a healthy agenda and it is exciting that the agenda of this conference is to be that of many of our academic lives for the next four years. The three themes of the Centre are developing learning, understanding learning and assessing learning. Let me conclude with two of my wishes for the centre.

First, I would like to see a prioritisation of attention to the most critical learning strategies and not a shotgun approach at any that just seem interesting or easy to measure. Then would it not be wonderful to develop a 'heat map' of learning in a classroom such that teachers can better understand where learning is occurring, as opposed to coasting, distraction, or confusion?

This means we need better measurement of learning. I would argue we have excellent, indeed an over-saturation of, measurement of achievement and adding more seems wasteful. But we have few measures of learning, and certainly few measures of learning not based on self-report scales. To develop scenarios, to develop vignettes, to develop real-time simulations where a student's learning strategies can be understood, to know then how able a student is to retrieve, apply and learn from various strategies, how the student switches between strategies, and how to optimise the use of the strategies would be powerful. Then we may be better prepared to *teach* students learning strategies and how and when to use them; this may lead to changing the current narrative from why students cannot learn and hence prescribing drugs (for example, Ritalin), labelling (for example, autism, Asperger's), and actually change students' learning strategies to maximise learning and create opportunities for them to become their own teachers. Therein is one aim.

Second, we cannot promise to find the brain correlates of learning within the next four years. I think we know a lot about the brain and learning, but know so little about how to use such information in a classroom. We are spoilt with silly claims about the brain and the neuro-trash and absurd claims are aplenty (see della Chiesa, Cristoph & Hinton, 2009; Lilienfeld, Lynn, Ruscio & Beyerstein, 2010). Consider four examples:

- It could be the case that the music training during childhood facilitates certain aspects of cognitive development in non-musical areas (the jury is still out). *But* this knowledge is *not helped* by overblown fallacious claims that listening to Mozart's sonatas stimulates dormant neurones and so promotes a student's intelligence and ability to study.

- Individuals are dramatically different in how they respond to information, how they recognise patterns, and in the knowledge and strategies they bring into a learning situation. *But* this knowledge is *not helped* by overblown claims that learners come with distinctive styles of learning that affect how they actually do learn.
- Young people are accustomed to using modern technologies and highly powered software to produce impressive PowerPoint displays. *But* this knowledge is *not helped* by overblown claims they form a new variant species called digital natives.
- It is the case that learning necessarily involves neurological correlates. *But* this knowledge is *not helped* by overblown claims that school learning has to follow brain-based learning principles. (Brain-based learning is as meaningful as leg-based walking or stomach-based digestion.)

In each instance, the validity of the genuine knowledge claim is countermanded by advocates who go too far. How do we know what is valid and what is overblown? That is what science will do for us: it brings constraint into the business of claiming knowledge. Science demands that claims reflect a validly generated database of evidence. And this is how it has to work for education. Reality is harsh: many 'soft options' thrive, have their moment in the sun and whither on the vine.

Thus the second aim for the science of learning over the next four years is to create a better narrative about the implications of brain research for learning: one based on the dynamics and flow of information and learning and not structural claims (right brain, left brain, the brain is a muscle, and so on); one that allows all of use to converse in a language that makes a difference to our teaching and learning. It is an exciting few years ahead.

Throughout this discussion the words 'brain' and 'neuroscience' have barely been mentioned. This is not because these are unimportant, to the contrary. It is because the current dialogue is overblown in too many false claims and a major mission of the Science of Learning Research Centre is to identify, research and understand effective teaching and learning practices in the light of current knowledge about basic learning processes and factors that influence successful human learning.

All the parts of this presentation are expanded in our forthcoming book: *Visible learning and the science of how we learn*.

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