Effective Teaching and Learning: Perspectives, Strategies and Implementation
Nova
Due: November 30th 2017

This is the author's manuscript version

The version of record is:

Taber, K. S. (2018). Scaffolding learning: principles for effective teaching and the design of classroom resources. In M. Abend (Ed.), Effective Teaching and Learning: Perspectives, strategies and implementation (pp. 1-43). New York: Nova Science Publishers.

Scaffolding learning: principles for effective teaching and the design of classroom resources

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Abstract

Within educational discourse the idea that teachers should 'scaffold' student learning is extremely widespread, yet it is often less clear what this means in the classroom beyond the teacher structuring learning activities and offering students support. Many teachers associate the term with the educational thinking of Vygotsky, but are often less clear what would comprise an effective teaching scaffold. This chapter reviews use of the term scaffolding in teaching, and explains the purpose of scaffolding in the context of Vygotsky's developmental theory. The chapter draws upon Vygotsky's spatial metaphor for how learning activities could be positioned in relation to the learner's current and potential levels of development. This activity 'space' is divided into three zones: scaffolding has potential to support learning that can facilitate student development, but only when the learning activity is located in the central zone (the ZPD) and is mediated through scaffolding. The chapter offers an analysis of the function of scaffolds, their role in classroom differentiation, and the logic of 'fading' (reducing scaffolding as learning proceeds). This suggests principles that teachers need to take into account in order to effectively employ scaffolding as a strategy in their teaching. Scaffolding can be based on direct mediation through dialogue between a learner and a teacher, but in classroom teaching there are severe constraints on how much one-to-one interaction each individual learner can access. Teachers wishing to scaffold learning therefore have to design learning activities and support materials that will place students in their ZPD. To illustrate this process, two distinct types of scaffolding tools are characterised in relation to different stages in the scaffolding of learning new conceptual schemes and frameworks.

Introduction

This chapter explores the notion of scaffolding, a term which refers to a key strategy for effective teaching. The notion of scaffolding derives from a particular perspective on development and learning based on the work of Lev Vygotsky (1934/1986, 1978), and makes most sense within that context. The core ideas of this perspective are set out as the basis from which the notion of scaffolding was recognised as a teaching strategy. Scaffolding is linked to the idea of the 'zone of proximal development' (ZPD): another term often heard in educational discourse, but less often operationalised within educational practice with any sense of precision. To use scaffolding authentically, and so in a way likely to substantially support learning, teachers need to understand and apply the logic of the underlying theory. The present chapter seeks to support that shift from acknowledging the principle to appreciating how to apply it in real teaching episodes.

Some starting points

In the context of this chapter, teaching is seen as activity intended to lead to learning (usually in others), such as the actions of a teacher that are intended to bring about learning in his or her students. Learning is considered to be a change in the behavioural repertoire, that is a change in the potential for behaviour (Taber, 2009b). After learning, some new behaviour becomes possible that was not possible before. Often in formal education that behaviour is verbal - something represented in speech or writing as an answer to a question. Behaviour reflecting learning could however be diverse: to improvise a fugue on piano, to recite a soliloquy from a classic theatrical play, to list the capital cities of African counties, to solve quadratic equations, to bind correctly in a rugby scrum, to identify the metallic components of salts from flame colours…

Learning is here defined as *a potential* (for behaviour) because learning that occurs will only actually produce behavioural evidence of that learning if that behaviour is subsequently elicited or otherwise motivated. A student could learn the dates of office of British Prime Ministers for an examination, but the actual questions asked may give no reason to demonstrate this learning. Quite possibly, this hypothetical student might well then go through the rest of her life with no reason to demonstrate this knowledge. In this hypothetical case, learning has taken place but this would never be apparent to an observer. At a physiological level, learning has led to actual material change. Scientists conjecture that some small changes in brain structures have occurred at the synaptic level to modify the connectively of neurons, but these are changes which cannot currently be directly observed and in any case could not presently be meaningfully interpreted even if they could be tracked. So although itv is believed that learning correlates with changes in a physical substrate within the brain, knowing this is currently of little direct application in research and practice in education (Taber, 2013a).

If teaching is considered to be activity intended to lead to learning then *effective* teaching should be judged in terms of activity that facilitates the intended learning. This is noteworthy because, as most teachers recognise, professional efforts to support learning are often not entirely successful. Some students in a typical class will commonly fail to demonstrate skills, to master techniques, or to understand canonical concepts that have 'been taught' to them.

Judging whether teaching is effective is actually quite difficult, as the person evaluating needs to not only be able to recognise the teacher acting intentionally in relation to some specific desired learning (i.e., the teaching), but then also to know when learning has occurred. We have to know there is a *change* in the behavioural repertoire: both that the student is capable of some behaviour now, and also that they were not capable of this behaviour before the teaching. That, in turn, requires not only opportunities to demonstrate the behaviour, but also that the student is motivated to do so (before and after the learning) and is not obstructed (for example, by ill-health, hunger, fear, fatigue, etc., cf.Maslow, 1943) or distracted from doing so.

There are further complications: even if we could know for certain that the student could not do X (whatever X might be - say improvise a fugue on the piano, or demonstrate an understanding of the theory of relativity) before teaching, and then could do X afterwards, that does not prove the teaching was the cause (or the sole cause) of the change. People develop in some regards as they mature without teaching, and they sometimes teach themselves, or learn from informal sources (perhaps the student watched a documentary on this topic the previous night) or may have private tuition to supplement formal classes. Moreover, our pre-test itself acts as an invitation to produce behaviour that may then initiate learning. A person undertaking a pre-test may well go on to reflect on questions they could not readily answer or activities they could not engage in, and give consideration to how they might have responded differently. Even if there is no deliberate reflection, this does not exclude preconscious cognition triggered by the pre-test experience (such that even asking a person if they have given any thought to the pre-test questions is not helpful in excluding the pre-test from having triggered processes that produce new learning). So unequivocally demonstrating learning, let alone effective teaching, is challenging. Often in research we have to settle for evidence for claims of learning that remain subject to many caveats (Taber, 2013a).

The present chapter, however, discusses general principles. Whilst the term 'scaffolding' is common in educational discourse, and in many national contexts teachers are encouraged to undertake scaffolding, the term is sometimes used very loosely, and without strong linkage to the theoretical grounds it was constructed on. In practice, 'scaffolding' is sometimes seen as simply synonymous with structuring learning or supporting learners. Whilst structuring and supporting are key elements of scaffolding, a more principled account is needed to inform teachers of how to use the approach as the finely tuned technique it is intended to be, rather than a blunt general tactic.

This chapter explains why scaffolding is considered to be a key strategy for effective teaching, and discusses the challenge of applying the principle within classroom teaching. The discussion here is quite general in nature, but another chapter in this edited collection offers some exemplification drawn from a particular context (an area of physics learning). That chapter (Taber & Brock, this volume) reports a study demonstrating the difficulty of designing teaching materials sufficiently 'fine-tuned' to contribute to scaffolding in teaching. The specifics of the materials used in that study will be of special interest to science teachers. Of wider interest, the study offers an example of the kind of thinking that needs to underpin attempts to provide learning support that can genuinely be considered scaffolding, and highlights how difficult it may be to judge the precise level of support needed to match students' readiness to be supported in this way.

Theoretical background to the notion of scaffolding: Vygotsky's notion of development and the role of cultural tools

Although scaffolding is not a term that Vygotsky himself used in his writing, it is usually understood as deriving from his perspective on development, learning, and education (Taber, Forthcoming). Vygotsky is considered to have been a psychologist, although he had wide interests. One of his areas of professional concern was the education of students with various disabilities and this seems to have been a strong influence on his thinking about teaching. Vygotsky considered that when a learner had a specific limitation that impeded learning through the usual modality, then the teacher or education system could (and should) find ways to compensate by providing alternative means to facilitate the learning. If a student was visually impaired then an alternative to visual presentation of learning material could be found. There is a responsibility on the educator to help find a potential route to achieving learning outcomes.

Vygotsky was working in the Soviet Union in the period after the Russian revolutions, and his way of thinking was strongly influenced by some aspects of Marxism, and in particular the role of dialectic in development. (Ironically, Vygotsky's work later became banned under Stalinism for being politically suspect and failing to sufficiently follow the party line.) Vygotsky saw a parallel between different scales of development, considering that the biological evolution of mankind, the cultural development of a society, and the education of children, to be related or analogous processes (Taber, Forthcoming). In each case dialectic was at work: the status quo would be challenged, and, through a process of engaging with such challenges, there would be a development to a higher level.

Anatomically modern humans have fundamentally changed the conditions of their lives over thousands of years through the iterative development of culture. This is possible because of the existence of cultural tools that support the learning and development of new generations. In particular symbolic tools - language and the like - enable the young to enter modern society without having to personally repeat the processes by which myriad earlier generations incrementally built that culture. Tools are extremely important to effective learning, and Vygotsky pointed out just how important words in particular were as tools (Vygotsky, 1934/1986), but in modern societies verbal language is supplemented by an array of other symbol systems shared by the community at large, or by particular cultural groups (to represent electrical circuits; to represent positions in chess games, etc). Such symbolic tools are ubiquitous: in everyday life they regulate behaviour in traffic, help us identify toilets, or find the checkout till in a large department store; they indicate the value of monetary tokens; reflect tribe or sub-culture membership; summarise forecasts of the next days's weather; and so forth.

As well as the widely-shared natural languages spoken in societies, there are adjunct specialised lexicons in trades, professions, hobbies, and academic fields. There are several layers of language used to programme computers. There are conventions for representing complex musical scores specifying key and time signatures, as well as the pitch and duration of actual notes. For those who have the specialised knowledge, there are meanings or implications represented in the allegories adopted in classical painting, as well as in architecture, in music, in typography, and in the formations adopted by football managers. An established academic field such as chemistry has developed its own system of symbolic representation (chemical formulae, structural formulae, electronic configurations…), much of which in that particular case has a property of being 'usefully ambiguous' in allowing discourse that shifts between discussion of the technical descriptions of chemical phenomena at the everyday (macroscopic) level and the theoretical explanatory accounts relating to the submicroscopic scale of molecules and ions and electrons and the like (Taber, 2013b). Every well-developed area of human activity has evolved its own set of specific symbolic tools to support thinking and communication.

However, the young are not born with those tools, so they first have to be introduced to them by whose who already wield them, which over time enables them to make these tools their own. Vygotsky considered that this meant that the learner has to first engage in activity with more proficient tool users, sharing in the activity, but reliant on the inter-personal nature of the activity, until in time they can 'internalise' the tool, and so will be able to engage it without support. Languages such as Spanish and English evolved to communicate with others, and Vygotsky considered that the process of internalising such a language not only allows competence in interpersonal communication but also provides an important set of tools for the internal talk that supports the development of higher level thinking processes (Vygotsky, 1978). Once we have mastered a language we can talk things through, and construct logical arguments, even without having someone else to talk to or argue with. We internally simulate significant others to talk things over with (imagining what they might advise us in a particular situation) or we simply talk to ourselves - initially out loud, but then - usually - silently.

The zones of actual, proximal, and distal, development

One of Vygotsky's most influential ideas was what is usually translated as the zone of proximal development, ZPD, or sometimes as the zone of next development. The ZPD[1] is much referred to, although sometimes in a quite vague way. The 'zone' is not an actual physical space but an activity space - a 'space' relating to behaviours or competencies (or potential problems). Vygotsky introduced the idea in the context of assessment, and in particular diagnostic assessment. Vygotsky pointed out that children were normally assessed by being set a task for which they would get no external support. We might think of the term sometimes used in schools: 'exam conditions'. This mode of assessment targets what the student can succeed at unaided.

Vygotsky considered that such assessments had limited value in informing teaching - they can show what a student has mastered (their zone of actual development, ZAD) but offer the teacher limited guidance on how to proceed in facilitating further development of thinking or skills. Vygotsky argued that two students who demonstrated similar performance on such an assessment - two students with similar ZAD in terms of the skills or knowledge being tested - might have very different potentials for moving on in their learning (very different ZPD). Instead Vygotsky suggested assessing the learner as they worked with an adult or more advanced peer to assess what they could achieve with support - what lay within their ZPD. Vygotsky argued that knowing about the ZPD gave much more useful information to the teacher in planning teaching.

In many educational contexts there has been a shift from expecting school learners to work alone on problems in class to paired and group working, or at least allowing pupils to seek advice from their peers when needed. There is an extensive and well-established area of scholarship around cooperative learning (Johnson & Johnson, 2009; Slavin, 1980). Yet it is still common to suspend these classroom norms and move back to lone working in silence when there is a test. That is appropriate perhaps in terminal examinations, but even then only if we need a summative assessment of what a student can achieve unaided.

The continued use of these kind of tests within education in many contexts seems ingrained. We might point to three trends which suggest that assessing purely within the ZAD is seldom optimal:

- It is now commonly recognised that in the adult workplace very few people work on tasks totally alone without access to support. Rather teamwork is valued (Raybould & Sheedy, 2005), and modern digital technologies offer easy access to various forms of support even when someone is physically alone;
- There has been a strong trend in some educational contexts to persuade teachers to shift the focus of classroom assessment, from summative assessment ('assessment of learning') to formative assessment ('assessment for learning') (Black & Wiliam, 1998);
- Given the notion of life-long learning, there is (or should be) no point in a person's educational career which represents the terminal stage of their learning and development (Broadfoot, 1998); so formative assessment is always likely to be more useful than summative assessment.

Despite these considerations, Vygotsky's argument that assessment is most useful in the ZPD has had limited impact on high stakes testing in many national contexts, where formal examinations are commonly administered to individuals, working in silence, and usually in closed-book conditions (i.e., with no access to reference works or the internet etc.). The *idea of the ZPD* has been much more influential in thinking about how teaching and learning activities are set up, at least in the sense of the widespread use of the concepts of the ZPD and scaffolding in discourse around teaching. That is, the ideas are widely referenced, if perhaps less well technically embedded in practice. As explored below, enactment requires careful tuning of teaching,

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1 In this manuscript the abbreviations ZPD, ZAD, ZDD are used to refer to both the singulars (zone of…) and the plurals (zones of…) as appropriate. That is, "…students' ZPD…" should be read as "…students' zones of proximal development…"

and offering support and structure to learners does not necessarily qualify as scaffolding learning in the ZPD.

The spatial metaphor divides the activity (or achievement) space into three zones (see figure 1). One zone consists of the skills and competencies that a learner has already acquired (the ZAD). Tasks that are set in the ZAD are able to be successfully completed (assuming the learner can be motivated to engage with these tasks) at a high standard - with few errors and high accuracy. In some workplaces this may often be what is wanted. The key tasks assigned to a worker should be within their competence so that they will be successful. We usually want the surgeon operating on our loved one, the solicitor arranging our house purchase, the driver of our bus, the bank teller handling our savings deposit, and the lifeguard on duty during our children's swimming lessons at the municipal swimming pool, to all be competent enough to successfully complete the tasks associated with their work. We normally want the qualified worker to practice within the ZAD (even if we acknowledge that there should *also* be opportunities for professional development).

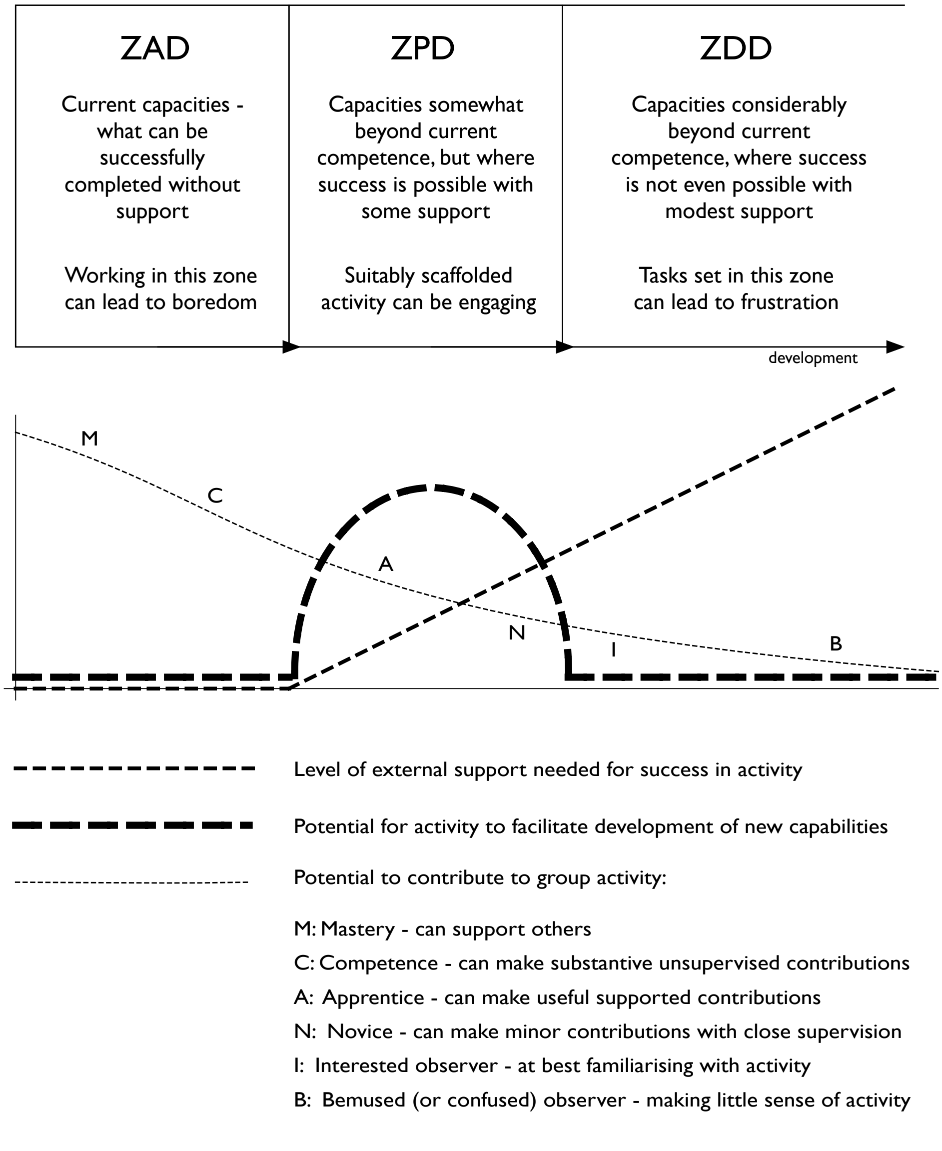

Figure 1: Schematic representation of the zone of proximal development (ZPD)

However, within education the aim is to help learners to progress, and the work they do is not undertaken for its own sake (only of value when there is proficiency, as is the case with much paid work) but rather is meant to be educative: to help facilitate learning and development. The real work of a learner is learning and not the material produced as a by-product during the process (i.e., the notes and assignments that students commonly refer to as their 'work'). Carrying out tasks with competence offers limited scope for development. There may be some gains in accuracy and efficiency (working faster), or a widening of the range of application of previous learning, but a person does not usually develop new skills or substantially novel conceptual schemes simply by repeatedly applying existing ones. If education is about developing learners further (as it should be) then working in the ZAD is insufficient. We do not usually want the learner to simply practise within the ZAD.

Outside the ZAD are two further zones that represent competencies not yet attained (see figure 1). Some of these competencies can be considered close to the ZAD (i.e., proximal, within the ZPD). Others are further from existing competence: in a zone of distal development (ZDD) - some 'distance' from the current level of development. When Vygotsky's ideas are applied in teaching, the distinction between the ZPD and the ZDD is not considered to be arbitrary. Activities are considered to fall within the ZPD when a learner who is unable to successfully complete them unaided, is however able to succeed in them with a level of structured support that allows the learner to incrementally master the activity. An activity in the ZDD is (in terms of the spatial metaphor of zones) however 'too far away from' the current level of development to allow the learner to benefit from being supported in the task. The degree of support needed for success on a task that falls within the ZDD is so great that the learner's engagement in the shared activity would be peripheral and not educative. Vygotsky suggested that the extent of the ZPD - the 'distance' from current development where a learner could effectively learn with support and so extend their development - would vary from person to person. Similarly, in relation to a particular individual, their ZPD might be broader in some areas that others: perhaps a particular learner can only be effectively supported in learning geometry within a narrow ZPD, but their ZPD is more extensive when it is considered in terms of creative writing or spin bowling or perhaps even calculus. These points seem to inherently follow from Vygotsky's line of thought, and should warn us against taking the spatial metaphor too literally: a person's ZPD needs to be seen as occurring in a phase space [2] where the 'distance' from the ZAD to the ZDD will vary in different dimensions. The ZPD has a manifold geometry in a multi-dimensional phase space.

Figure 1 offers one representation of the spatial metaphor of the three 'zones', bearing in mind the proviso that the horizontal dimension should be seen to represent a one dimensional projection of a manifold ZPD. Another disadvantage of this kind of representation is that it might suggest the zones are fixed and have absolute borders. With development, the ZAD and the ZPD actually grow (represented by the arrows on the line labelled 'development' in figure 1) as new competencies are mastered, or become closer to current competencies respectively. In some ways visualising the zones as more like nested bubbles (rather than boxes) of capabilities and potential capabilities might give a better feel for the concepts. However, figure 1

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2 Normal graph paper reflects a two dimensional 'space' where each unique position is identified by two coordinates, and the distance between two points can be measured, or calculated (using Pythagoras's theorem) from the pair of coordinates. The axes of the graph paper act as conventional reference framework allowing points to be given coordinate values. The three dimensional space we experience requires three coordinates (and a reference framework) to locate a point. Distances can be calculated by similar method to that used in two dimensions, but the three dimensions cannot be readily and directly represented on a flat surface to allow direct measurement of distances between points. A modern model of the universe uses the notion of space-time where time is a fourth dimension, and four coordinates (and a reference framework) are needed to locate any particular point in space-time. Again two dimensional representations either ignore two dimensions or project them in way that distorts the 'actual' space. The idea of a phase space is that the principle of multiple dimensions and reference axes can be applied to systems other than simply spatial dimensions - such as is done with space-time. In physics the idea is often used in relation to the possible values of position and momentum a system may exhibit. In a class of students who took examinations in mathematics, science, history, geography, music, literature, and ethics, it would be possible to conceive a seven dimensional 'space' where every possible combination of test scores could represented. It would only be possible to directly represent two dimensional slices of this phase space on a flat surface - e.g., plotting scores in mathematics against score in music.

uses boxes as these can readily be juxtaposed against some schematic graphical representations. These (purely qualitative) schematics give an indication of how the zones relate to individual capabilities, to potential to contribute productively to group activity, and to the extent to which activity within a zone can support further development.

Consider two examples. A parent may humour a child who wants to engage in some activity well beyond their current capabilities by sitting with the child and carrying out the activity in such a way that there is a successful outcome because the adult has completed the task. The child may be engaged in the activity, but does not have sufficient understanding of the task to direct activity in a productive way, and would not benefit from the experience in terms of being able to successfully engage in the activity in future. In effect the child is playing, and this may be a useful and enjoyable activity in its own terms, and could lay important groundwork for future learning (Bruner, 1983) but there is no structured learning occurring that can actually allow the child to succeed in the task themselves in the immediate future. For instance, imagine the child sitting in the passenger seat of a car and working a toy steering wheel in a haphazard manner, as her mother next to her actually drives the car.

This may be contrasted with a genuine apprenticeship. The new apprentice lacks the skills needed to carry out a trade and initially observes and helps with routine and low-demand aspects of the master's activity [3] - what has been called legitimate peripheral participation (Lave & Wenger, 1991). The master structures the apprentice's activity, building up their responsibly and input, until the apprentice is ready to demonstrate the competence to work unaided. Traditionally in craft contexts the (now ex)apprentice demonstrates their new competencies by producing their own journeyman pieces unaided. These show potential clients that they are qualified to accept commissions on which they will work without direction and support.

The child playing at driving is aping an activity within their ZDD. The apprentice is working within their ZPD, and their learning can be scaffolded by the master providing the right level of support at different stages of the apprenticeship - until by the end of the process all such support has been 'faded' and the learner is no longer an apprentice but a fully fledged craftsman. At this point the core activities of the craft are no longer within the ZPD, as the ZAD has grown to encompass the new competencies. Perhaps the journeyman will continue to develop her skills by setting herself more challenging tasks in her (now expanded ZPD) and working towards recognition as a master of the craft. The traditional notion of apprenticeship is today also understood in terms of such considerations as identity and belonging as well as simply acquiring skills (Chan, 2013), but still reflects the 'journey' of moving from being unable to practice, through supported practice, to independent practice, that is inherent in scaffolding of learning.

Cognitive limits to learning - why cultural transmission is not straightforward

We can understand the need for scaffolding in terms of some key aspects of how learning occurs. If we consider an area of skills, such as a toddler learning to walk, or someone learning to ride a bicycle, it is usual for progress to involve much falling down on the task and the associated bruises to pride if not the actual body. Success is achieved eventually due to the ability of the body to learn as a system through feedback. This is largely a process that occurs outside the remit of consciousness. Motor signals from the brain lead to outcomes that are monitored to modify future motor signals. In time the toddler can put together a sequence of movements that increasingly leads to a horizontal (walking) rather than just a vertical (falling) direction of travel, and the novice cyclist is able to balance and steer with greater finesse. Part of what is going on is the selection and scaling of movements (which muscles to contract, how much, how quickly), but there is also a process of building up 'chunks' of actions. Individual motor instructions are compiled into

[3] It should be pointed out that the use of the traditional term master, one who produces masterpieces, is not meant here to imply the gender of the expert.

sequences - sensorimotor schemata, that might be characterised as 'pre-concepts' (Piaget, 1970/1972, p. 26) - that can be triggered automatically as a whole sequence.

A person can walk up a set of stairs through the initiation of a complex sequence of movements which are largely compiled into a single set of instructions. In a new building where the height, number, and texture, of stairs may be unfamiliar, attention has to be paid - to provide feedback to customise the general script for this particular circumstance. In a very familiar home we may be comfortable using the stairs in near complete darkness (even if that may not be entirely wise) as we need very little feedback to carry out the much practised set of actions. As this type of learning is largely based on preconscious processes building up tacit (implicit) knowledge embodied within a particular body (a person of particular height, weight etc.) it may not be easy for the skilled person to reflect on what they have achieved to guide others. Yet this is precisely what sports coaches, for example, try to do (Jones, Edwards, & Viotto Filho, 2016).

The implicit nature of the knowledge base behind much expertise can also be seen as the motivation for neuro-linguistic programming (NLP) - an approach to helping novices develop towards expert level of skills by analysing signs of how the experts are internally representing their expertise. Some commentators consider this approach to be fundamentally flawed, and lacking any strong evidential basis, even though it has proved commercially profitable for those selling the idea (Roderique−Davies, 2009). One author who undertook an analysis of studies on the effectiveness of NLP shifted to rather less scholarly language in concluding "my analysis leads undeniably to the statement that NLP represents pseudoscientific rubbish, which should be mothballed forever" (Witkowski, 2010, p. 64). Given that even the internal representation of a person's *explicit* knowledge (what they know that they know, and can so attempt to share) is not always readily communicated to others (Taber, 2013a), how much more challenging is a project to transfer expertise that the expert herself cannot directly interrogate. Sensorimotor learning, then, is largely implicit and involves (i) refining actions through feedback, and then (ii) compiling them into sequences that become part of the repertoire of actions available to the learner. The learner has learnt to coordinate and synchronise many gross and more subtle motor actions, but consciously works with the compiled sequences at a more executive level in order to walk, run, leap, toss, catch, etc.

Similarly, with conceptual learning, there is a process of construction of knowledge from component parts (Taber, 2011). In parallel to learning involving sensorimotor skills, it may only be after acquiring, coordinating, and compiling, components into a coherent scheme (a schema or a conceptual framework) that anything of obvious value has been learned. As one example, the theory of natural selection (proposed by Darwin and Wallace, but later synthesised with ideas from genetics and statistics) is incredibly powerful once understood: having application throughout the life sciences. Yet acquiring the theory relies on the understanding of a range of distinct concepts and principles, and how they may be related into a coherent conceptual scheme (Taber, 2009b). As with learning to walk or cycle, having part of a conceptual scheme internalised may be of limited value to the learner. Just as 'nearly walking' or 'nearly cycling' may still mean falling, so having an understanding of most aspects of a theory may not be sufficient for sensible application (of the kind that gets pass-level credit in academic examinations for example, and certainly for making original contributions to a field).

A difference between the two types of learning may relate to the kind of feedback that is inherently available to support the process. The toddler's brain seems able to use feedback of failure to construct a successful scheme of activity: the goal (moving about on two feet) is sufficiently clear for sensory and proprioception feedback to be interpreted to judge (with some trial and error) when modifications are bringing the goal closer. Much academic learning is not of this kind - the kind of feedback processes that have led to current understandings of the causes of the agricultural revolution, the nature of space-time, or other theoretical and conceptual material, operate over long periods of time within extended scholarly communities - learners do not get direct feedback on their learning of such matters from the natural environment (and so rely on feedback form the *cultural* environment in which they learn).

Vygotsky would point to the dialectic of scholars challenging each other's ideas, and developing defences against such challenges, leading in time to a new synthesis - which can later be challenged further. Theorists following Vygotsky would describe this process as being an activity system (Engeström, Miettinen, & Punamäki, 1999) comprising a networked community engaged in a particular common activity, acknowledging particular shared rules or conventions, and structured through a particular division of labour, as well as adopting particular tools and systems of mediation. In science there is a basic dialectic between theory and empirical data: scientists imagine possible schemes and explanations for phenomena, which motivate further data collection (perhaps through additional field observations, or the designing of experiments), which either challenge the theory, or suggest possibilities for refinement or further testing (of the range of application etc.)

The challenge to transferring this process to school learning occurs at two levels. The current state of knowledge in a field evolved over decades of scholarly discussion among people who could commit many years to their specialist work. Even if learners are capable of the same level of thinking, any sensible notion of education must accelerate the historical process. Moreover, children are not always capable of the same level of thinking. There is clearly a process of cognitive development that takes a neonate to a level of maturity that enables them to engage in the abstract levels of thinking required to master the ideas of music composition, sports strategy, narrative structure, food-webs, or whatever (Piaget, 1970/1972). According to Vygotsky this process of cognitive development itself depends upon acquiring the symbolic tools available in the society (Vygotsky, 1978), and, moreover, that the kind of mature abstract thought we associate with adult thinking is dependent upon particular socialisation processes - such as formal education (Luria, 1976). Without support along the way (from family, media, school, etc), no learner is likely to grapple their way to understand thermodynamics or Marxist notions of history. That support needs to come from those already initiated into these cultural products and able to use the tools that culture has developed - such as language.

This is important as the human brain supports learning in a way which is incremental, interpretative, and so iterative (Taber, 2014). The working memory capacity of humans is extremely limited (Baddeley, 2003), and so we tend to only be able to mentipulate very limited amounts of unfamiliar material. Indeed we only make sense of substantive amounts of unfamiliar material by using what we already 'know' (i.e. think, believe, understand) as interpretative resources - with the risk that in this process of making sense we readily distort material by misinterpretation. Left to its own devices, then, the learner's mind iterates new interpretations in terms of sense made by previous iterations - such that personal ways of understanding can soon diverge between people. This need not happen if there is an external agent judging whether a learners' meaning is shifting towards target knowledge and providing feedback (analogous to the role of information that the toddler uses tacitly when learning to walk). Much of formal education is about offering this kind of guidance towards culturally accredited goals.

That this model of how learning occurs is not fanciful can be seen by considering what happens when different 'learners' are encultured within different societal groups which have different notions of what counts as currently accredited cultural knowledge. Scientists inducted within different research traditions (paradigms, or disciplinary matrices, or research programmes) diverge on their constructions of descriptions and explanations of nature (Kuhn, 1996; Lakatos, 1970); different religious groups in the same country diverge on matters of faith; opposing political groups diverge on the ideology applied to judge what is desirable, how to achieve it, and what to make of the current state of civic affairs. In these, and other parallel cases, a novice/inductee will be guided to largely adopt the thinking of the particular group they join. In each case the iterative process means that new material is interpreted in a particular way and so becomes a coherent part of a particular kind of constructed edifice, supported by interactions with others in the group. Although genuine dialogue between a socialist and a conservative has the potential to offer a dialectic that can support their jointly constructing new understandings, it is more commonplace for their different fundamental ideological commitments to shape how they interpret and understand the arguments and claims of the other *within* their existing belief systems. Human cognition has evolved to have a very strong confirmation bias (Nickerson, 1998). Genuine dialogue, where interlocutors from different traditions or perspectives make real efforts to understand and consider the positions of others, is of course possible (Popper, 1994), but it can be difficult intellectual work. This is highly relevant to schooling, as facilitating substantive conceptual change often involves just such work (Scott, 1998).

Tools to overcome cognitive limitations

There are many commonplace tools used to overcome the limitations of human cognition (which likely was usually a pretty effective system in the environment where modern humans evolved, even if it may not seem ideal for modern technologically enhanced environments that are so rich in symbolic information). Teachers have long known that repetition can be employed as device to support learning. Telling a student once that humans have 23 pairs of chromosomes (assuming, reflecting the previous section, that suitable prior knowledge is in place to allow the learner to make sense of the significance of '23 pairs of chromosomes') may not lead to retention of the fact. Getting the students to chant the statement ten times at the start and end of lessons is likely to be much more effective, even if pedagogically rather primitive, and perhaps not the best use of teaching time.

A skilled teacher is likely to instead use a 'drip feed' approach, taking opportunities to reinforce such information at every opportunity where useful links can be made ('So you will recognise the word chromosome here, can anyone recall what chromosomes are and why they are useful?…they are often described as occurring in pairs: can anyone recall what the significance of them being paired is?… how many pairs do we find in the human genome?…etc.) Here the teacher uses what Vygotsky recognised as key tools (words) to convey ideas, reinforce learning, and support the development of desired links between concepts (cf. Ausubel, 2000). Rather than simply trying to reinforce by repetition, the drip-feed approach revisits the information in relevant contexts to support the integration of the learning into coherent schemes that broaden understanding (Taber, 2015), forming logically consistent conceptual frameworks, and potentially allowing wider transfer of learning across contexts (Lobato, 2006). That is, where simple chanting of what is meant to be learned is a ZAD activity, the frequent use of structured questioning to highlight and probe opportunities to link to prior learning can engage a learner in activity in the ZPD.

Vygotsky may have proposed the ZPD, but arguably Plato demonstrated the principle in his use of Socratic dialogue. In his Meno, Plato (380 BCE) gives an account of how, by responding to Socrates' carefully sequenced questions, an uneducated slave boy is able to demonstrate knowledge of a geometric idea he had previously never been exposed to. This phenomenon was posed as a dilemma - sometimes known as the learning paradox (see figure 2). Either a person already knowns something, in which case demonstrating knowledge does not need to be explained as nothing new has been learned; or they do not, in which case they cannot demonstrate the knowledge as it is not available to them. If you already know something, you cannot be said to later learn it. If you do not know something, you are not in a position to seek it and will not be able to recognise it, so cannot come to know it. According to Plato's thinking, the way out of this dilemma is belief in the reincarnation of a person's eternal soul into new bodies, allowing the person to access knowledge from before the most recent rebirth. On such an account, Socrates helped the slave boy realise that he knew something that he had forgotten he knew, because he had not previously accessed the knowledge in his current life.

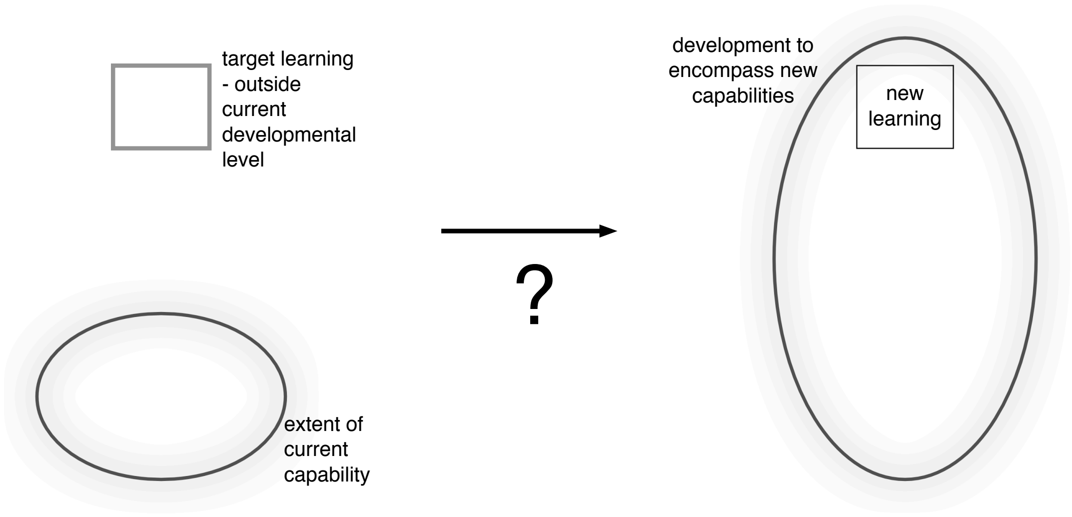

Figure 2: The learning paradox - how can a learner master something genuinely novel?

Vygotsky's theory, however, would suggest the slave was operating in the ZPD supported by the structure offered by Socrates's ('Socratic') questioning, and so was able to learn a *new* scheme mediated through language and other symbol systems (in this case, a geometric construction in the form of a diagram). From a constructivist perspective, the slave had the necessary prerequisite knowledge, and the required cognitive skills, to develop the new conceptual scheme. However, he had no reason to seek the new knowledge, and would likely not have readily spotted how his existing knowledge could be organised in a new way. Socrates both motivated the slave to think about geometry (as he was expected to be polite and respectful, and so to humour his master's guest) and structured his thinking along a particular path to facilitate the construction of new knowledge. From this perspective, the slave discovered new knowledge, with a level of guidance provided by someone more knowledgable in the topic (Taber, 2011).

Tools to support learning

A simple kind of tool a person might use is a notepad. Most people would struggle to remember a long list of items when shopping - but writing the items on a list, which can be referred to item by item, acts as tool to allow more successful action than would likely be possible without the tool. Similarly, someone who needed to find the total floor space of their house (if replacing all the floor coverings perhaps) might be able to measure each room, calculate the area of the floor, and add that to a running total kept in mind (rehearsed in the phonological loop of working memory, that is by constantly repeating the number to themselves between updates, perhaps). However, having a notepad allows the recording of each measurement, and each calculated area, and readily checking all stages of the calculation, and avoiding potentially costly mistakes that might arise by relying on undertaking the sequence of products and sums and keeping track of the running total using only internal (mental) representation. For many of us, 'doing it in our head' would also likely mean starting again after any interruption or distraction.

The instructions with flatpack furniture do similar work as symbolic tools. Faced with all the parts and fittings, most consumers would have little idea of how to put together (for example) their new chest of drawers. A sequence of diagrams showing parts, orientations, and necessary actions, allow the careful consumer to build the furniture. All of the requisite actions are within the capability of the person (within their ZAD), but not the knowledge of how to sequence those actions to move from a pile of parts to a finished item of furniture.

In an explicit educational context, a particular kind of symbolic tool that can support learning would be the advance organiser (or 'organizer'). This idea was developed by Ausubel, as part of his theory of meaningful learning, and was described as "a pedagogic device that helps…by bridging the gap between what the learner already knows and what he [or she] needs to know if he [or she] is to learn new material most actively and expeditiously" (Ausubel, 2000, p.11). Ausubel had highlighted how meaningful learning required the material to be learnt to be potentially relatable to a learner's existing conceptual resources, and for the learner themselves to recognise the new material as linking to this prior learning. Advance organisers have been characterised as

> "always relative to the particular learner and subject matter…(1) [A s]hort set of verbal or visual information, (2) Presented prior to learning a larger body of to-be-learned information, (3) Containing no specific content from the to-be-learned information, (4) Providing a means of generating the logical relationships among the elements in the to-be-learned information, (5) Influencing the learner's encoding process. The manner in which an organizer influences encoding may serve either of two functions: to provide a new general organization as an assimilative context that would not have normally been present, or to activate a general organization from the learner's existing knowledge that would not have normally been used to assimilate the new material" (Mayer, 1979, p. 382).

The role of an advance organiser is to facilitate linkage between existing relevant prior learning and new learning, relating to Ausubel's notion that meaningful learning not only requires taught material to be *potentially* relatable to a learner's existing conceptions, but also for the learner to *actually* relate the new learning to existing conceptual structure. One of the common ways in which teaching can fail to lead to the intended learning is when the student does not make the links the teacher anticipates with prior learning and experience (Taber, 2001).

Providing vicarious support through scaffolding

The notion of scaffolding was popularised by Wood and Bruner and their colleagues (Wood, Bruner, & Ross, 1976) as a metaphor (Maybin, Mercer, & Stierer, 1992) that was useful to explain the implications of Vygotsky's work for pedagogy. Initially the idea was described in the context of a child interacting with an adult, such as a parent, but given Vygotsky's own description of the ZPD, a more advanced peer may take the role of the adult. Indeed it has been suggested that under certain conditions having a gifted learner work with a less advanced learner may both scaffold the less advanced learner, allowing them to progress when working on something in their ZPD, whilst simultaneously ensuring a student who has already mastered the work is engaged in their own ZPD by being asked to work with material at the higher level needed to effectively explain it to another (Taber & Riga, 2016). As many teachers have recognised, the level of mastery of material required for effective teaching is greater than generally required to demonstrate competence in most formal assessments (Taber, 2009a).

The term 'scaffolding' has become widely used, but often in quite vague ways for forms of support that do not necessarily meet the criteria for scaffolding (Pea, 2004; Puntambekar & Hubscher, 2005). Scaffolding implies more that just structuring a learning activity, or offering support. For something to count as scaffolding it has to relate to a task prescribed in relation to a specific learning goal that a learner is not yet able to succeed in unaided, where the scaffolding has been designed specifically to bridge the task demand in the light of the learners' current level, and where it actually allows the learner to be more successful than would have been possible otherwise (Maybin et al., 1992). It has also been argued that true scaffolding must lead in time to the learner developing the capability to succeed in the task unaided, and so must be 'faded' so that the learner gradually takes on full responsibility for the activity (Pea, 2004; Puntambekar & Hubscher, 2005).

We can understanding fading as a process that an autodidact (i.e., one with sophisticated enough metacognitive awareness to effectively manage their own learning) would naturally employ. This can be appreciated in relation to one of the examples drawn upon earlier. Consider a thought experiment of a consumer who successfully built a 'flat-pack' chest of drawers by carefully following the diagrammatic instructions provided to build the furniture, and then decided to order and build an identical second unit; then a third; then a fourth,…

Initially the task requires careful attention to each diagram in the sequence, including identifying parts (e.g., which pieces of wood), fixtures (e.g., which screws or dowels), and the necessary orientations of the parts (e.g., which way around do parts go, and which of the pre-drilled holes do the screws need to go through?) Over time the process of building a unit would become quicker, with less chance of misinterpreting the instructions. Indeed the need to refer to the instructions at all would decrease. (Even on the first item, building several identical drawers would likely be achieved with less time interrogating the diagram for successive drawers). If our hypothetical handy-person had the space and enthusiasm to keep buying further kits and building identical units, they would in time get to the point where they could unpack the components and build the chest without any reference to the instructions, having internalised the whole process - a process that might have seemed overwhelming when initially looking over the instructions for the first build.

In effect the instructions act as a form of scaffold, a support that allows someone (who designed the construction) with the knowledge of how the build proceeds to vicariously enable someone else (a consumer) who has not internalised that knowledge to none-the-less achieve something that is only possible with the knowledge. If the handy-person building multiple units has confidence to refer to the instructions less and less, and eventually not at all, we see the process of fading a scaffold, where the scaffold is incrementally withdrawn as the learner no longer needs it. Now the knowledge represented in the instructions sheet has become internalised by the learner. This is a key process described by Vygotsky - the learner first engages in activity with others more knowledgeable / experienced /skilled on the social or interpersonal plane, and through sharing in that activity gradually internalises the knowledge/skills to the mental or intrapersonal plane where they allow successful individual activity.

In this example, symbolic tools - a set of diagrammatic instructions - allows the more knowledgable and the novice to engage in a form of shared activity despite not being in the same place, nor engaging in the activity at the same time. Indeed the person creating the instructions may have since retired, become senile, or even died. A person with some prerequisite skills within their ZAD (using a screwdriver, identifying components from a diagram, following stepwise instructions, orientating components into compound configurations, etc.), but without the capacity to construct furniture from the kit of parts, develops the ability to put together a unit in an hour or so. Constructing the chest of drawers has been shifted from a ZPD activity requiring scaffolding to a ZAD activity through one dimension of the ZAD developing as a result of the learning experience. Our modern technologies (including printing and communications and distribution systems) allow the interpersonal plane to be extended beyond synchronous, face-to-face engagement.

What this kind of asynchronous activity does not allow is for feedback from the person in the 'teacher' role. The kind of scaffolding discussed by Bruner and his colleagues allowed the 'teacher' to observe errors and guide accordingly. The do-it-yourself consumer only gets feedback in terms of whether the build appears to be proceeding as the instructions suggests should be the case. We might suggest (only partly tongue-in-cheek) that flat-pack furniture should carry a warning that it should only be constructed by consumers with sufficient metacognitive nous to monitor their own learning and frequently check their progress towards the intended final outcome of the activity.

In this everyday example, the 'learner' (assuming they do have the metacognitive awareness to monitor their activity) automatically refers to the support structure less and less, but in formal educational contexts it may require the teacher to actively and progressively withdraw the scaffold as they judge a learner can manage with less support. Learners may lack confidence to shift away from the support themselves (or in some modern education systems may be habitually used to, and so expect, learning activities supported by recipe-type instructions) and may even misconstrue the purpose of a learning activity as being to produce accurate 'work' when it should actually be seen as a means to extend capacity which may well involve some productive errors as part of deep engagement in the activity.

One challenge for teachers who are experts in their subject is to see the (very familiar) subject matter to be taught 'at the learner's resolution' (Taber, 2002). What seems simple and straightforward to the teacher may initially look complex and overwhelming to the learner. What seems obvious to the teacher may have only become so with extended familiarity over time. The scaffold allows the learner to work at their own resolution, focusing on manageable sub-tasks at any time, and being guided through how to sequence and relate these. As the task begins to be internalised, 'chunking' (i.e. building composite mental representations as entities that can be mentipulated as single units) occurs, and the 'grain size' of the task shifts. What had seemed like a great many trees (to borrow a common aphorism) becomes perceived as a few clumps of woodland interspersed with a few clearings, and then ultimately simply as the (now comfortably familiar) forest. The learner is 'seeing' (or at least visualising) the task at a different resolution than before. Eventually the whole task is sufficiently internalised for the necessary know-how to be accessed from composite representations in long-term memory and processed in working memory (with its limited number of 'slots') without referring to external representations (Taber, 2013a).

Designing scaffolding tools

Pea (2004) has given labels to two distinct kinds of scaffolding functions discussed by Wood and Bruner and their colleagues. He refers to (i) channeling and focusing, and to (ii) modelling, as having distinct functions. He describes these as:

> "1. Channeling and focusing: Reducing the degrees of freedom for the task at hand by providing constraints that increase the likelihood of the learner's effective action [channeling]; recruiting and focusing attention of the learner by marking relevant task features (in what is otherwise a complex stimulus field), with the result of maintaining directedness of the learner's activity toward task achievement [focusing].
>
> 2. Modeling: Modeling more advanced solutions to the task." (Pea, 2004, p. 432)

The present author (Taber, 2002, pp. 72-74) suggested two types of tool useful to teachers to support scaffolding in learning, alongside such activities as DARTS (directed activities related to text). DARTS take various forms, such as providing a technical diagram with incomplete labels, and an associated text that could be interrogated to complete the labelling of the diagram. DARTS were intended to provide more 'active' learning tasks that could be used to review topics or support new learning as an alternative to the kind of basic note-making which can become little more than copying information from the teacher's notes or a book. I suggested that sometimes well considered DARTS could amount to scaffolding tools, but only if they were used within learning activities that met specific criteria. These criteria for scaffolds are

> 1. They must ask the learner to undertake an activity/task which is beyond their present ability if unsupported;
> 2. They must provide a framework of support within which the learner can be successful by relying on the structured support;
> 3. They must provide reduced support as the learner becomes familiar with the area, and is able to cope with increased demands; [...and]
> 4. They must result in the learner being able to undertake (unsupported) the activity/task which was previously beyond them. (Taber, 2002, p. 74)

Two specific types of scaffolding tool were proposed to address two aspects of the challenge of learning - that:

> (i) "even when students have available the necessary prerequisite knowledge for new learning they may not always be aware of which ideas are relevant [and] the limited

> register for processing information [i.e., working memory]…makes it difficult for students to juggle the information so that they can use it effectively as the basis for developing new learning"
>
> (ii) "the logical structure needed to develop the new ideas may exceed the processing capabilities of the student. Although each step in an explanation may itself be manageable, the overall structure may 'swamp' the student and seem much too complicated" (Taber, 2002, p. 73).

To address these two set of challenges it was suggested the teacher could offer two types of scaffolding tools, PLANKs and POLES - which, extending the scaffolding metaphor, took "the roles of providing 'horizontal' and 'vertical' support" (p.73) respectively. Firstly,

> "[teachers] can identify the necessary prerequisite knowledge, and not only be sure that students have covered the material, but that these ideas are marked out as relevant at the start of the new teaching episode. It may also be possible to organise the ideas for the students, into a form which will best facilitate the new learning…PLANKs are PLAtforms for New Knowledge. Scaffolding PLANKs are presentations of ideas that are already available to students, but arranged in a form which aids the student in reorganising their knowledge to build up new ideas" (Taber, 2002, pp. 73-74).

Then,

> "secondly, the teacher can provide some form of partially constructed outline for the new knowledge, and make this available to the students as a guide for the new learning… POLES are Provided Outlines LEnding Support [or Provided Outlines Lending Epistemological Support]. Scaffolding POLES are provided by the teacher, and give a framework (outline) for exploring and succeeding in a concept area, that allows the learner to come to know about the topic. They lend support, because they are only to be relied upon whilst the learner is developing understanding and confidence in a topic" (Taber, 2002, pp. 73-74).

A number of examples from teaching chemistry were offered of how learning activities could be designed as scaffolding PLANKS or POLES. In particular, in the case of learning the concept of hydrogen bonding, two activities were suggested, one "to get students thinking about relevant ideas (bonds as attractions, electronegativity, bond polarity etc.), and to organise these [previously learnt] ideas into a suitable logical framework for learning about a new idea" and one to "explicitly lead students to construct this new knowledge [of the nature of hydrogen bonding]" (p.76). It was acknowledged that the former activity, the PLANK, might be considered to be the kind of activity Ausubel suggested as an advance organiser.

Scaffolded learning supports development

Figure 3 offers a scheme to show how such scaffolding can support substantive new learning that can facilitate development (by providing a pathway to address the so called learning paradox represented in figure 2). The first stage consists of the teacher identifying some target learning which falls outside of the capabilities of a student given their current capabilities. The target learning must fall within that learner's ZPD. The teacher begins by alerting the student to the prerequisite knowledge or skills that are needed to undertake the new learning (these foundations for the new leaning must already exist within the ZAD), and helping the learner not only bring these to mind, but to organise them in the most productive way to support new learning. A 'PLANK' is then put in place to support activity extending from the ZPD towards the target knowledge (step 2).

A suitable structured, mediated activity is designed to build up the 'steps' towards the target knowledge (steps 3-5). Sufficient familiarity with this new structure through interpersonal (social) activity will allow the learner to begin to internalise the structure, developing his or her unaided capabilities, and reducing the distance between what is comfortable, familiar and mastered, and the target knowledge (step 6). The learner is led to engagement in the target activity itself (step 7) and is able to operate with less external structuring (step 8). Eventually the target knowledge becomes internalised such that the scaffold is no longer needed at all (step 10) and so in time the learner is able to engage with the new learning without mediation at all (step 11). The new learning becomes more robust, and now falls within an extended range of capabilities (step 12).

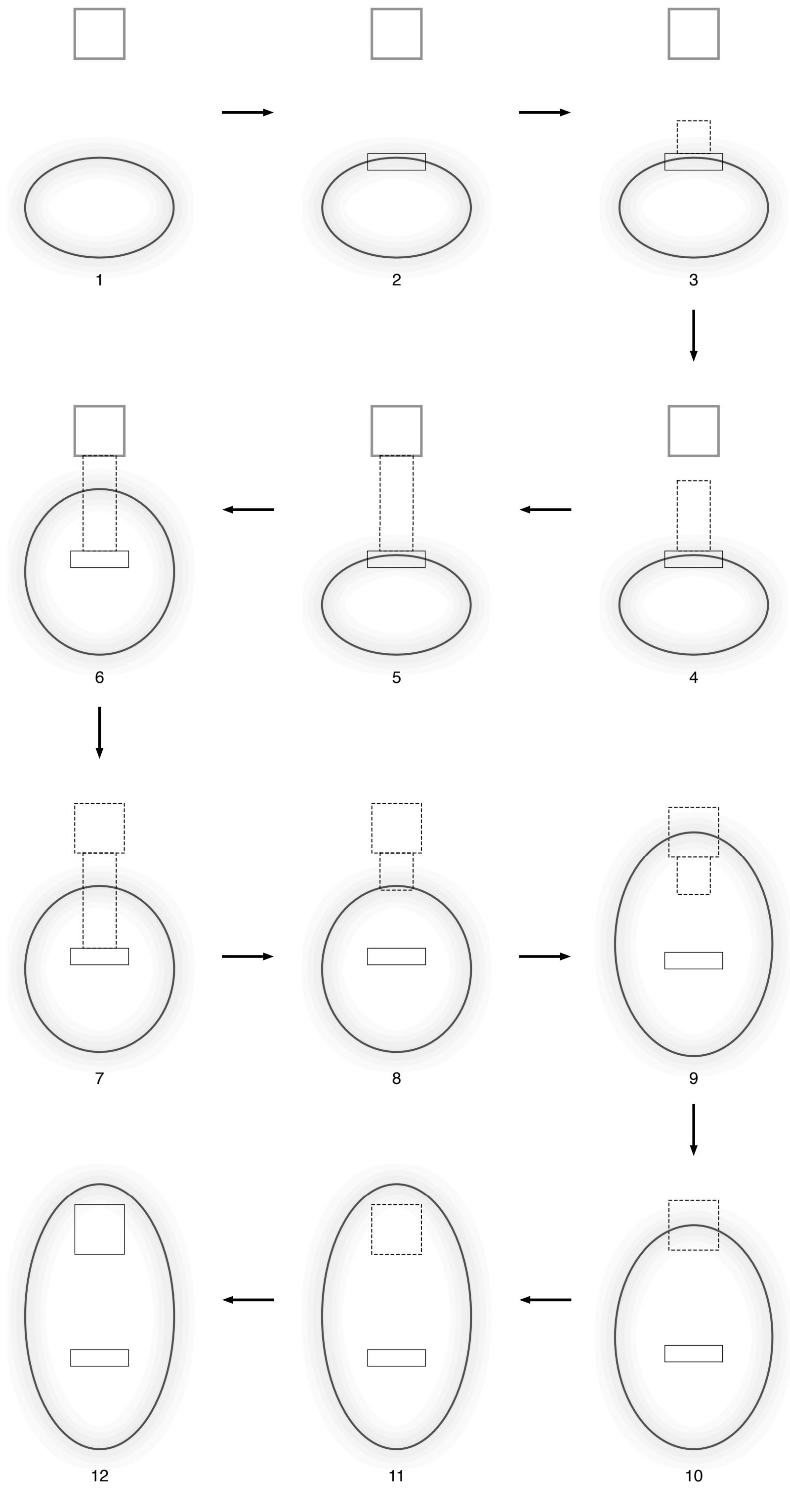

Figure 3: A highly schematic representation of how scaffolding structures activity that can be internalised to produce new learning.

In terms of the three zones, figure 4 summarises the overall effect of scaffolding in allowing mediated activity within the ZPD, which leads to new learning that leads development (expansion of the ZAD to encompass the new learning, and a resulting growth of the ZPD itself). As the ZPD reflects the 'space' where new types of learning become possible with suitable mediation, any growth in the ZAD (what has been mastered) is likely to be accompanied by a growth in the ZPD as well: some activities which would have previously been unproductive even with mediation are now located within an expanded ZPD. This is only possible however, if the mediation offered by an activity is able to act as genuine scaffolding (as in figure 3), which necessitates well-designed teaching, using carefully thought-out tools.

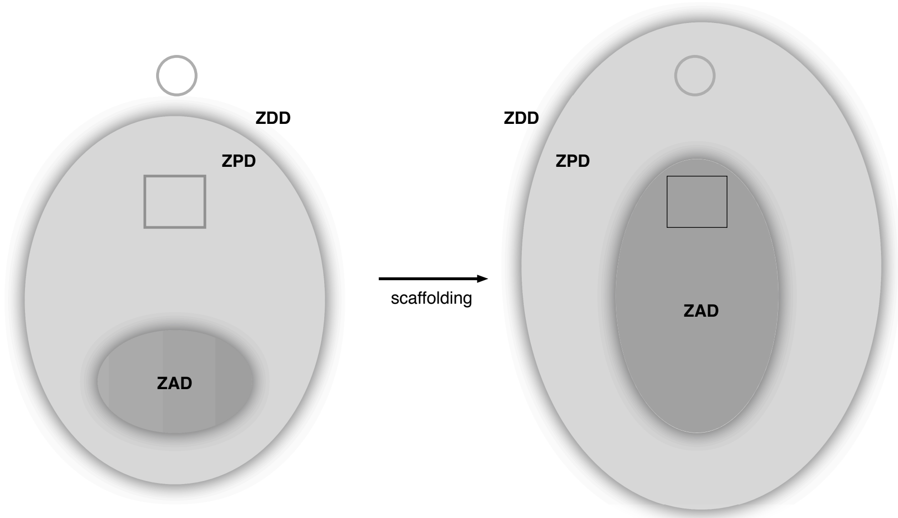

Figure 4: (Scaffolded) learning leads development that in turn makes more advanced learning possible.

Designing effective tools of this type is challenging. It requires co-ordination of:

a) knowledge of the particular skills, concepts, etc to be taught;
b) knowledge of the background disciplinary structure to identify the prerequisite learning that must be in place, and which needs to be activated during the learning of the new material;
c) knowledge of learning processes - such as how limitations of working memory will constrain the scale and scope of new learning within manageable steps ('learning quanta');
d) elements of pedagogic knowledge - such as how students commonly understand (and perhaps misconstrue) the identified prior learning, and the common learning difficulties experienced with the new target learning;
e) knowledge of the particular learners (in effect, aspects of their ZPD) to pitch the level of the support materials and the optimal amount of structure to provide (to offer challenge, but not excessive challenge). This reflects Vygotsky's point that assessments that are informative to teachers (formative assessment) should be assessments of the learner's ZPD.

Some readers may recognise that (unsurprisingly) some of the themes specified here are similar to the considerations that have been identified as important when designing learning progressions to inform curriculum development in topics (Alonzo & Gotwals, 2012).

The challenge of this kind of work is exemplified in another chapter in this collection (Taber & Brock, this volume) which describes a small-scale study to test the potential of a simple scaffolds designed to help learners (expected to already hold the prerequisite concepts) construct an understanding of the nature of orbital motion - a conceptual area where learning difficulties are commonly reported. The study reports an attempt to test the potential of a simple scaffolding POLE task, undertaken after a preparatory PLANK task, to support the developing understanding of the physical principles used to explain why orbiting bodies can have (relativity) fixed orbits. In that study it was found that pitching the scaffolding tools at the right level is challenging, but that a simple scaffold can support learners to show progression in their thinking.

Relating the role of scaffolding in classroom teaching to direct instruction, constructivism, and differentiation

This chapter has discussed the nature of scaffolding, a pedagogic principle developed from Vygotsky's developmental theory, and, in particular, his notion of the ZPD. References to the scaffolding of learning are common in many educational contexts, although it has been suggested here that supporting learners and structuring learning activities do not comprise scaffolding unless certain conditions are met. The support provided must allow students to be productively engaged in a task where learning is being mediated though the level of support provided, even though that task presents too high a level of challenge for those students to make progress without support.

The notion of scaffolding is more problematic in school classrooms than in its original setting of a child engaged in one-to-one activity with an adult, where the adult 'teacher' receives constant feedback and can adjust the level of support provided as seems indicated. Extending the application, or 'range of convenience' (Kelly, 1963), of the scaffolding construct to classroom teaching involves additional challenges. A teacher is usually working with several dozen different individuals, all with their unique starting points and strengths and weaknesses as learners. The arguments of proponents of direct instruction (Kirschner, Sweller, & Clark, 2006), who claim whole class teaching with teacher exposition is superior to learning through discovery approaches, can be understood in part in terms of the lack of feasibility of a teacher simultaneously directly monitoring and adjusting support for each student within a diverse class of learners - each with their uniquely 'shaped', multidimensional ZPD.

Yet if we most value the kind of learning which facilitates the development of new skills and conceptual schemes (as surely we should), then direct instruction (where a teacher engages in whole class teaching to present the material to be learnt) faces precisely this same challenge of working in the disparate ZPD of students within any class. When what is being learnt is 'more of the same' - additional facts fitting within existing conceptual frameworks, additional exemplifications of previously learnt principles, and the like - direct instruction, when skilfully practised, may well be somewhat effective, at least when the teacher is engaging and motivates student attention. In Piagetian terms, here learning is largely assimilation of new material within existing schemes, and requires minimal accommodation (Piaget, 1970/1972). In the Vygotskian perspective discussed in this chapter, such learning is pitched within the ZAD, and direct instruction is likely to be effective for those students who hold the necessary prior learning (which is often only some of the students in any particular class). A knowledgeable teacher who has mastered the material, can effectively highlight prerequisite knowledge, and then present new material within that context, and suggest how new examples, variants, or applications, fit within previously developed conceptual schemes.

However, Vygostky was not primarily concerned with this kind of more-of-the-same learning, but rather learning that linked to development of new skills, new schemes, and new capacities. Here Vygotsky thought that learning led development: that is development was facilitated by relevant learning. This clearly invites the learning paradox referred to above. If the development (for example, of new higher level cognitive abilities) strictly depends upon learning that requires those very abilities, then it might seem that such development could not occur. Further development, it might seem, relies on learning which is not open to the learner at their earlier stage of development.

Vygotsky offers a way out of this paradox, because this kind of learning occurs in the ZPD, and requires social mediation, so the learner can initially experience successful engagement with support that will later allow (once internalisation has fully occurred) successful engagement that then no longer requires support. In this situation, learning is a discovery, and the learner has to make that discovery, and make it their own. This is the basic principle of constructivism in education (Glasersfeld, 1989) - even when a teacher directly shows us something, we still have to make the discovery ourselves. The teacher can set up all the conditions for the discovery, but it still relies upon the learner being attentive to the intended stimulus, actively engaging in making sense of it, and interpreting it in a way consistent with the teacher's intentions. As much literature in science education clearly shows (Taber, 2014) - students commonly make quite different discoveries (or none at all) from the ones the teacher intended, even when the teacher thinks the teaching was direct, clear, precise, and unambiguous.

Rarely can a novice learner make these discoveries unaided - so usually unguided discovery learning is very ineffective: the directed instruction lobby are right about that (as educational constructivists have long recognised, e.g., Driver, 1983). However, constructivist teaching is not about open-ended discovery, but optimally guided instruction (Taber, 2011). The learner has to make the discovery, and the teacher is charged with setting up the conditions and channelling the process. In a context of individual tuition, a kind of direct instruction based on Socratic type questioning might do the job very well, and skilled teachers commonly attempt to extend this process for use in whole class teaching (during those segments of teaching that might be considered 'directed instruction').

Yet clearly if scaffolding of new conceptual frameworks requires a careful match between learner starting points and the support offered, then direct instruction of classes through this approach is 'hit and miss' - at best uneven, with the presentation only being pitched well for some students. Unless one is teaching a class of clones maintained in a common environment, Socratic questioning operating in the ZPD of some in the class will be pitched within the ZAD (offering nothing new) or ZDD (offering nothing meaningful) for others.

The kind of scaffolding tools discussed in this chapter, PLANKs and POLES, suffer from the same kind of difficulties. Any particular teaching material that is optimally designed for some learners with be too challenging, and or lack sufficient challenge, for some of their classmates (see, for example, Taber & Brock, this volume). This is an important point, as effective differentiation of teaching is perhaps the most problematic issue shared by school and college teachers at all levels, whatever they are asked to teach, and wherever they may be teaching.

Scaffolding tools used in teaching then do not *of themselves* solve the problem of differentiation. However, they may be part of a powerful differentiation strategy for two reasons. Firstly well designed scaffolding tools can be tweaked in several ways. The same material can be offered to some students and not offers. The materials can be provided, and then removed, for different learners in a class at different times. Once first developed and tested, individual materials can have 'versions' with different amounts of support: some students need more hints, some need more channelling (more constraints of the degrees of freedom in a task), some need more explicit steps set out in an overall process than others. When materials are developed on digital platforms, some level of 'intelligent' response to student input can be used to route a learner through a path customised to offer them particular support at different stages.

The other aspect is of course that such materials are not intended to replace the teacher, but to complement the teacher: being used as a teaching tactic within an overall pedagogic strategy. As well as making decisions about which materials to provide, to which students and when, the teacher also makes decisions about student grouping, and how to best use her own time during learning activities. Different students, or different groups of students, will benefit from different amounts and types of direct help. That is the crux of the challenge of differentiation, and the reason that in practice student-centred mixed ability teaching (and all class teaching is mixed ability teaching to some extent) may often seem less effective than whole-class teaching. For at least in 'direct instruction' all of the class may to interact with the teacher for much of the time, even if this interaction is pitched at some compromise level that some students will not fully follow and others will find tediously obvious.

Conclusion

Well-designed scaffolding materials, with customisation for different groups of students in a class, used by a teacher who is managing both access to these tools, and access to her direct input, can provide learning activities that are differentially supported so that it is more likely that all of the learners are working in their ZPD, and so guided in making the kinds of learning discoveries that facilitate their development. Developing effective, customised, scaffolding tools is challenging (again, see Taber & Brock, this volume), but this is surely a challenge teachers have to face. It might be argued that whole class teaching which aims for anything less does not seek to be genuinely educative, and so wastes a great deal of the time and effort of a great many learners.

Acknowledgement: This chapter benefitted from valuable conversations with, and comments by, Dr Richard Brock.

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