Chapter 24
The Role of New Educational Technology in Teaching and Learning: A Constructivist Perspective on Digital Learning

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Abstract Constructivism as a perspective on teaching draws upon research into the nature of learning to inform pedagogy. From a constructivist viewpoint educational technologies are potential tools for enacting curriculum through particular pedagogic approaches. New technologies therefore add to the teacher's toolbox offering alternative ways to bring about learning within an established strategy. Digital technologies offer considerable new possibilities for the teacher, but should always be used as part of principled pedagogy rather than seen as ends in their own right. This chapter considers key features of constructivist thinking about learning, and offers some illustrative examples of situations where digital technologies have particular potential to support school teachers adopting a constructivist perspective to inform their classroom work.

Keywords Constructivism • Constructionism • Learning theory • Optimally guided instruction • Dialogic teaching • Educational technology • Teaching and learning • Constructivist perspective • Digital learning • Pedagogy • Constructivist teaching • Educational technologies • Tools • Curriculum • Pedagogical approaches • New technologies • Facilitating learning • Digital technologies • Teachers • Principled pedagogical approach • Principles of constructivist thinking • School • Teachers

Introduction

The availability of new digital technologies that can be applied in educational contexts is certainly to be welcomed. Such technologies are increasingly offering tools of immense potential to support classroom teaching and learning. For such tools to be widely adopted in a sustained way, and for them to be effective in supporting school learning, it is important that new technology is seen as offering useful

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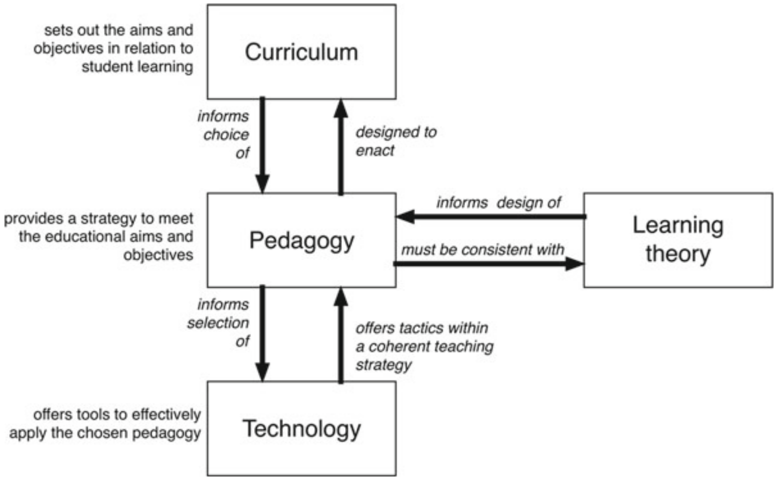

Fig. 24.1 The role of educational technology in the planning of teaching

solutions in response to genuine educational needs. The logic here should be in the direction of C→P→T (curriculum→pedagogy→technology), in the sense that teaching starts from curriculum in terms of the aims of the educational process, which are responded to through pedagogy—informed by theories of learning—and then drawing upon the most appropriate technologies (see Fig. 24.1).

New digital technologies can provide excellent tools to realise effective pedagogy that is enacted to meet desired educational goals—but it is important that teachers do not get seduced by the power or novelty of the technology or use it for its own sake. That will be obvious to most teachers, but the investment in new technology, the enthusiasm many students show for digital tools and media, and the temptation to be seen to be up-to-date and following educational trends, can all act as seductive drivers.

Teachers, like most learners, are unlikely to fully master new technologies immediately (Aldunate & Nussbaum, 2013), and will need to develop their pedagogic skills by testing out the use of new techniques in different contexts (e.g. in relation to different curricular aims and different groups of learners). This has been true whenever new technology has become available, whether that be roller chalk boards, overhead projectors, in-house reprographic facilities, cassette players, or wipe-off white boards. However, traditionally such advances in technology have been infrequent, allowing time for teachers to become familiar with the characteristics and affordances of the technology. Since the advent of relatively cheap and mobile computing devices which act as general-purpose programmable machines (which can be connected together through the Internet, so offering potentially infinite possibilities) the rate at which new digital tools have become available has been much greater. A new teacher today is faced with a constant flux of information about new tools ('apps', etc.) that could be adopted in the classroom whereas previous generations of teachers typically went years between major new technologies being available to facilitate teaching and learning.

There is then a risk of new technology being used in those ways which are, or can readily become, familiar to teachers, rather than in the most optimal ways (Mishra & Koehler, 2006). Teacher education and properly supported development in the use of technological tools are therefore essential. Moreover, teachers may resist innovations, such as unfamiliar new technology (Avidov-Ungar & Eshet-Alkalai, 2011). Teachers often tend to minimise the disruption to familiar and well-established classroom routines by assimilating the new into existing schemes and ways of working (Hennessy, Ruthven, & Brindley, 2005) in ways that may undermine the particular strengths of the novelty—with the danger of later inappropriately deducing that the innovation does not actually offer much, if any, advantage over previous approaches.

Teachers working in school systems tend to be assigned excessive workloads compared with most other professionals. A lawyer or a business consultant who was meeting with a group of clients would expect to be able to schedule considerable preparation time for that meeting. By contrast, most school teachers work with large and often diverse groups (often including some learners who would rather be elsewhere), and are expected to deal with a number of such groups during the school week—and to fit planning along with assessment, administration, professional development, liaison with various other professionals and parents, and sundry other professional duties, around a teaching timetable that often gives minimal breaks between their classes. Therefore, however well motivated and intentioned class teachers may be, the system in which they work necessitates that they prioritise their planning time—e.g. on topics not taught before, or on groups where there is an identified problem—giving them limited time for preparing many of their classes. The C → P → T logic (first revisit the aims of the course, and so the class objectives within more global concerns; consider the most suitable pedagogy to meet these objectives; then select the best tools to support that pedagogy) easily becomes short-circuited. Inevitably, much updating of teaching schemes is more superficial, and it is tempting for teachers to simply bring in new technologies as direct substitutes for what has gone before. Sometimes that may work well—but clearly a more principled approach is preferred.

So school systems are set up in such a way that some inertia is inevitable, and whilst schools as institutions generally welcome the new, there can be a tendency to adjust initiatives to fit custom and practice rather than to revisit that practice at a fundamental level (Hennessy et al., 2005). This is seen in the curriculum in some subjects where despite content being originally selected as instrumental to fit particular educational aims, it tends over time to come to be seen as somehow inherently essential to learning a subject. So in the sciences for example a particular industrial chemical process that was once seen as an authentic and socially relevant example of the application of chemistry, and that has been taught and assessed for many years, may be retained long after it ceases to be relevant to current industrial practice. Whether observing and evaluating teaching as an outsider, or reflecting on a lesson as a classroom practitioner, it is always important to start from a consideration of the particular educational aims the lesson is supposed to meet, to mitigate what might be termed 'practice creep'—the tendency to focus on, and over time modify and evaluate, a teaching activity in its own terms without regard to its original educational purpose.

Moreover, a teaching activity reflects the enactment of a particular pedagogic approach which should have been (originally) selected to respond to the educational purposes of the lesson. Pedagogy can be considered as the science or craft of teaching, and there is considerable research and scholarship on effective teaching and learning (Laurillard, 2012; Moore, 2000; Muijs & Reynolds, 2001). In particular, this chapter considers an area of educational theory sometimes referred to as constructivism which has been widely adopted as a basis for thinking about student learning (Novak, 1993). There is a range of often critical debates around the nature of constructivism, and what might be termed constructivist teaching (Phillips, 2000; Tobias & Duffy, 2009). This is unfortunate as the core of constructivist thought that is generally adopted in educational contexts derives from a strong theoretical and evidential base. These complications will be briefly addressed to clarify how constructivist learning theory is understood in this chapter.

What Is Constructivism?

The term constructivism is widely used across a range of different activities including philosophy, psychology, education, art, and research methods. The different uses are linked, but are not identical. This means that constructivism is sometimes associated with arguments about whether there is a reality beyond that constructed by the human mind, and whether objectivity is possible in research studies. These are important debates, but can be put aside when considering how constructivism is generally understood as an educational theory. There is no reason why a teacher cannot consider themselves as an educational constructionist despite their position—or lack of one—on such philosophical questions. Constructivism as an educational theory concerns what has been found out about the way learning occurs in human minds, and so is important in informing how teaching is organised. Digital technologies have been considered to fit well with a constructivist stance on teaching (Petko, 2012). This chapter briefly outlines some key features of constructivist thinking, how this can inform pedagogy, and some examples of how digital technologies can support constructivist pedagogy (see Fig. 24.2).

What Is Constructivist Teaching?

Just as there are complications over the different uses of the term ‘constructivism’, the notion of ‘constructivist teaching’ has been variously represented—sometimes leading to unfortunate associations (Bowers, 2007; Cromer, 1997; Kirschner, Sweller, & Clark, 2006). The understanding used here is simply that constructivist teaching is teaching informed by a research-grounded constructivist model of learning. Some scholars have attempted to variously characterise constructivist teaching as teaching by enquiry (which it certainly can be), ‘progressive’ teaching (but often when the

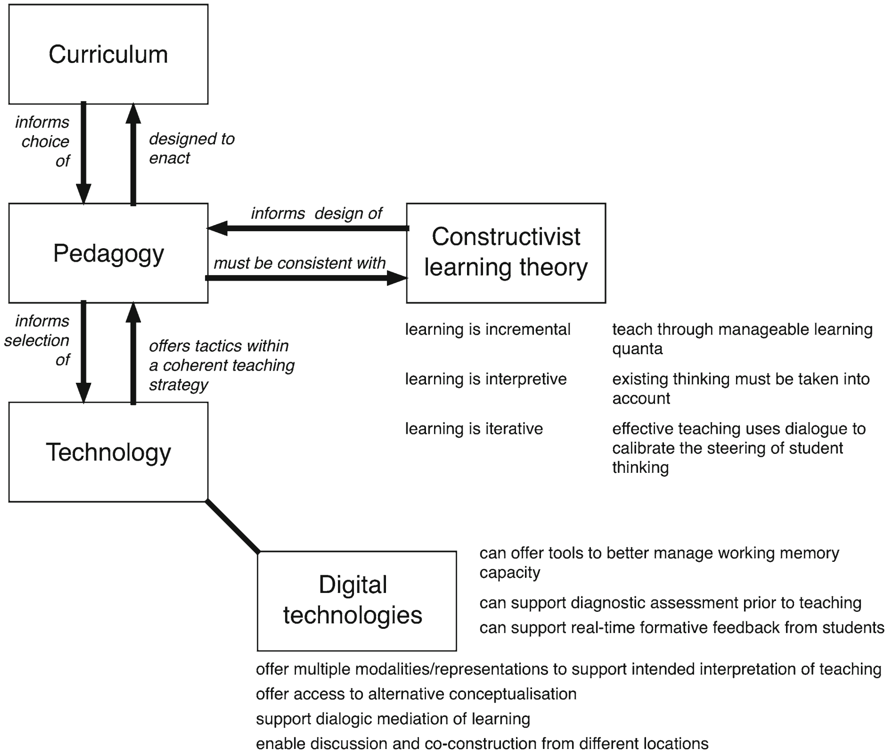

Fig. 24.2 Digital technologies offer affordances to support constructivist approaches to teaching

term is used in a derogative sense), discovery learning (which in an important sense it is, although not in the way critics often use this term), learner-centred (which it is in one sense, but again not always in the way suggested)—and minimally guided learning (which it certainly is *not*). An especially influential analysis has suggested that in effect constructivist teaching is synonymous with such labels as progressive or child-centred learning, and has chastised this type of teaching as having minimal direction from the teacher (Kirschner et al., 2006). However, this does not reflect the more common understanding of the application of 'constructivism' in education.

In the way the term constructivist teaching is used here, the term refers to teaching which is actively and carefully planned, which requires the active involvement of the teacher, and which is designed to be *optimally* guided (Taber, 2011). This implies that constructivist teaching does not inherently involve offering students high or low levels of guidance for particular tasks, but rather selects the level of guidance according to the particular task and learners. This is a key point as it relates to a key feature of good teaching, which is that it provides experiences for learners that are educative in the sense of neither being so routine as to lack challenge, nor being so demanding as to make substantive progress unlikely for the student. Such judgements relate to not only the task itself, but also its match to the learner's current state of knowledge and skill, and the level of support provided—either directly by the teacher, or through planned access to learning resources (for example, use of the Internet), or through the organisation of the class in such terms as student grouping (Taber, 2015).

It follows from this that in order to provide a sufficient level of challenge to make learning activities genuinely educative, a teacher may sometimes deliberately limit the support they provide during the activity, which might therefore seem to an observer as minimally guided teaching (but only because of the planned match of learning objectives, student, task demand, and resource). It is equally the case, however, that at other times, in order to provide a sufficient level of support to make learning activities genuinely educative (again in terms of the match between demands, students, and support in relation to particular objectives), the same ('constructivist') classroom would look very different, and would be seen to be very teacher led, with students receiving a good deal of direct guidance.

Constructivist Learning Theory

There is no single constructivist learning theory, but the basic principle of educational constructivism (sometimes called pedagogic constructivism or psychological constructivism) is that complex conceptual knowledge cannot be transferred wholesale between minds, but rather that conceptual learning is a process of constructing or building up knowledge. This sometimes leads to accusations of a relativist view of knowledge, that is, the view that all knowledge is subjective, and relative to a particular cultural or even personal viewpoint (Matthews, 2002; Scerri, 2003). However, as suggested above, constructivist teaching does not rely on any such philosophical stance about knowledge. The pedagogic constructivist perspective is simply responding to what has been learnt about the nature of human learning (Taber, 2013). It is not a prescription that everyone *should* be encouraged to develop their own unique take on the world, but rather a recognition that to some extent this is what inevitably tends to happen (Glasersfeld, 1989). Nonetheless, as discussed below (and see Fig. 24.3), there is also a recognition of the important role of social interaction that tends to channel people to think in similar ways.

Research on human conceptual learning suggests that it is interpretive, incremental, and iterative (Taber, 2014). Learning is interpretive in the sense that learners do not always understand the teacher as intended (as indeed is the case more widely in human interaction). The learner has to make sense of what they are shown and told, and can only do so in terms of existing experience, knowledge, and understanding—what might be termed the available interpretative resources. When what they are told does not seem to link to any existing interpretive resources, they make limited sense of it, and long-term retention becomes less likely, and can only be rote rather than meaningful (Ausubel, 2000). In practice, it is usually more a matter of the degree to which the learner can link teaching to existing resources rather than simply learning being purely rote *or* meaningful.

Learning is incremental in the sense that human cognition has a kind of system 'bottleneck' in the faculty known as working memory. Human working memory has

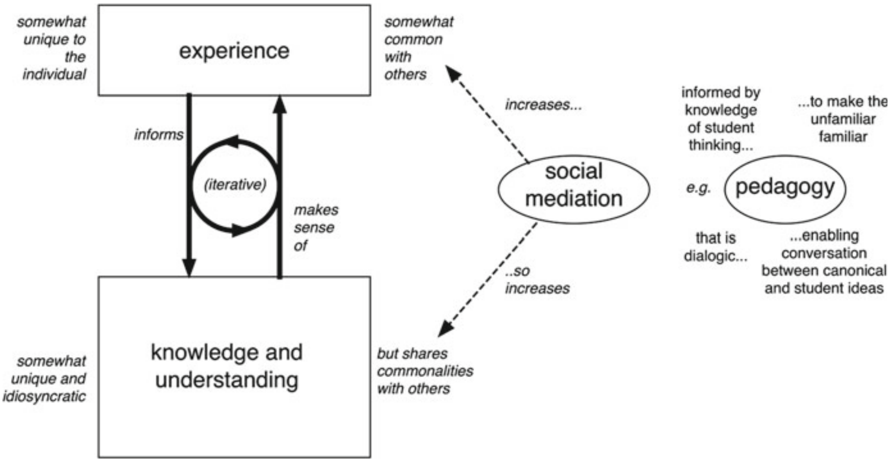

Fig. 24.3 The extent to which an individual's conceptual constructs match canonical knowledge is influenced by social mediation that allows the learner to be aware of, explore, and compare alternative conceptualisations

a very limited capacity in terms of the number of—what are termed—'chunks' of information it can handle. There is much filtering of sensory information (at a pre-conscious level, besides whether a learner is deliberately paying attention or not) before it reaches the level of the system where it becomes consciously available and can be processed in working memory. What counts as a chunk of information is however subjective, as it is linked to the interpretive processes referred to above. Material that is already familiar and well established in long-term memory can be handled as substantive chunks, and therefore the degree to which a teacher's speech or some instructional text (such as on a website) or the instructions for a learning task makes demands upon a learner's working memory depends upon the extent to which it can be understood in terms of prior learning. Two learners with similar cognitive capacities may cope with teaching very differently depending upon the extent to which they can interpret new information in relation to existing understanding. Effective learning has to be presented to learners in (what they find to be) manageable learning quanta.

The Importance of Learning the Tool Before Learning with the Tool

Digital learning tools can be either a burden or a valuable support in regard to the limitations of students' working memories. Any unfamiliar technology or tool (digital or otherwise) or process potentially compromises learning by burdening working memory. For this reason it is not sensible to introduce new technologies and tools (such as an unfamiliar application) in a lesson where students will already be challenged by the demands of meeting new content they are expected to master. Rather, learning to use a digital tool is a substantive task in its own right, and only when the tools are familiar can they become an effective means of supporting other learning. Certainly learning the tool should involve applying it in some authentic context, but the chosen context should be just that (a context) and not something that it is important for the students to learn about whilst familiarising themselves with the tool. So, for example, the context might be a relevant and interesting example, which is not specified as essential in the curriculum, or perhaps a topic that has already been studied where the activity can be seen as review of prior learning.

However learning to use and becoming familiar with such tools may be a sensible investment of class time if once mastered the tool can then support learners in overcoming the restrictions of working memory. This is a well-established principle—in the sense that something as prosaic as pencil and paper can be used as a tool to overcome working memory limitations in carrying out an elaborate calculation that has too many steps to be 'held in the head'. Digital tools often consider affordances in this sense. For example, data loggers in school science labs may partially automate the routine aspects of the collection of laboratory data (as is often the case in professional laboratories) allowing students to focus more on the concepts and patterns the practical work is meant to illustrate. It has been found that school lab work which is designed to support conceptual learning is often carried out with minimal engagement with the target ideas, partially because the need to focus on the manipulative work leaves limited capacity for the intended mentipulative activity (Abrahams, 2011). Digital technology can support learners in making lab work minds-on as well as hands-on. Sometimes (depending on the educational purpose of the particular lab activity), simulations may be more effective than actual laboratory work.

The same basic principle applies in many other areas of school learning. In a language lesson, translation between languages may be the focus of an activity where the teacher may be expecting the student's working memory to be occupied with handling a translation. But in a history class, for example, a student might find some apparently relevant text in a foreign language. Possibly the student could use a dictionary to attempt a translation, at least where they had some familiarly with the language concerned. This would require the application of their cognitive resources to the translation and would be time consuming. A student who had learnt to use a tool like Google translate could likely achieve as good or better a translation much quicker whilst leaving most of their capacity for thinking about the meaning of the text in relation to the historical issue they were studying. This is an example of a powerful tool that can be mastered very quickly—indeed the most important part of learning to use the tool is learning to appreciate that any translation between languages is potentially imprecise and needs to be treated with caution (e.g. an interesting exercise is to translate a phrase successively between several different languages and then back to the original language).

Supporting Teachers in Formative Assessment and Remedial Instruction

Learning is necessarily iterative as a result of being both interpretive and incremental. In some curriculum areas there is a good deal of research suggesting learners come to class not only often deficient in expected pre-requisite learning, but also often holding alternative conceptions of curriculum material (Duit, 2009). That is, learners may have their own ideas about how things are which are inconsistent with what is to be taught in the curriculum. If teachers do not spot this, then learners will often misinterpret teaching in terms of their existing alternative understandings, and so build up different meanings to those intended by the teacher.

Again this suggests ways in which digital technologies can best support learning. The iterative nature of learning complicates the work of the class teacher tasked with leading students towards canonical understandings of target knowledge. As learning is a process of knowledge construction, the teacher's lesson plan is based upon a model of the learners' current state of knowledge. If the teacher knowingly adopts a constructivist perspective for their work, then this will be an explicit model: otherwise it is a tacit model (where the teacher's planning makes implicit assumptions about students' prior knowledge and readiness for progression). The teacher is anticipating how the learner will interpret and make sense of teaching, based on their knowledge of the students' current levels of knowledge and understanding. No one has a comprehensive understanding of another's conceptualisations—so such a model is inevitably partial and not entirely accurate (Taber, 2013). Effective teaching is therefore an interactive process where the teacher is constantly seeking feedback on how learners are making sense of teaching, and adapting ongoing teaching accordingly—acting as a kind of 'learning doctor': diagnosing, hypothesising, and testing student thinking (Taber, 2014). This is recognised in the emphasis in recent years on the importance of formative modes of assessment—so-called assessment for learning, rather than just assessment of learning (Black & Wiliam, 2003).

The high level of interaction characteristic of the school teacher's work explains, in part at least, why notions of teaching machines that seemed promising in the mid-twentieth century have not led to the replacement of teachers—even with the advent and almost ubiquity of the modern personal computer. Yet this level of teacher-student interactivity is an ideal that it is very difficult to maintain in the classroom. Commonly, teachers use a wide range of questions as an integral feature of their classroom presentations of subject matter (Edwards & Mercer, 1987)—questions intended to check on attention, background knowledge, whether students are making the expected links with previous learning, whether students are appreciating references to everyday examples, whether they understand the analogies and metaphors being used, whether they might be inappropriately applying unhelpful common alternative conceptions to make sense of teaching, and so forth. Teachers ask these questions to inform decisions about the next pedagogic move: whether it would be best to proceed with the next phase of the lesson plan, give further examples, recap earlier work, etc.

This decision-making draws upon a diverse knowledge base: the teacher's knowledge of the subject matter, of subject pedagogy (pedagogic content knowledge), of the students in the class, and of the moment (cues about students' current state of attention, etc.). For an experienced teacher this draws upon accumulated learning from iterations of formal study and classroom experience. (The constructivist model of learning applies as much teachers as any other learners.) It seems very likely that the highly networked nature of the human brain facilitates 'online' classroom decision-making based upon a diverse and imperfect knowledge base (an area where human cognition is more suitable than machines applying linear logic and formal algorithms).

In practice the teacher usually carries out this process by questioning a small number of students. The teacher may make the choice of which student(s) to question using her knowledge of the class, or by a system that ensures that everyone has a chance of being asked, but relies on one or a few children being proxies for the class. In this context classroom response systems can be very helpful (Fies & Marshall, 2006). Where appropriate the teacher asks a multiple-choice question (either about student confidence in their understanding, or to test that understanding) and all students can respond discretely by pressing a button or touching an icon. Such a survey of the class falls short of interacting in detail with each child, but can ensure that the teacher has a much better overview of the levels of understanding at that point in the lesson.

Although computer-based learning systems lack the level of interactivity of a detailed conversation with a teacher, they can be used to complement the teacher in areas such as diagnostic assessment and remedial support. Research into student understanding and common learning difficulties in topics informs the development of diagnostic tests to use before teaching a topic (Treagust, 1988), and digital versions of these tests can support the busy teacher with ready collation and analysis of the data. Similarly, computer-based teaching materials developed for student use outside the formal classroom, can be used for remedial work, or where a student cannot attend a class. Drawing upon subject-based pedagogic expertise, these materials can offer some level of interactivity (Taber, 2010), based on subject experts' knowledge of the most likely errors and sticking points in a topic. The sophistication of such systems is increasing such that they offer increasingly individualised feedback to learners (Narciss, 2013).

Encouraging the Student to Be Active in Their Learning

Constructivist instruction is sometimes linked with learner-centred approaches to teaching. This association can be understood in part in terms of how constructivist learning theory acknowledges the inevitable individual differences in how learners understand teaching and build up their own knowledge (given their unique set of interpretive resources, based on their prior knowledge and experience). However, this should not be taken to suggest that constructivist teaching cannot be full class teaching—it rather means that the constructivist teacher does not teach as if all students will respond to teaching in the same way.

Another association is with notions of active learning. Again, however, it is not that a constructivist perspective suggests that learning 'should' be active, but rather that learning *is* by its nature an active knowledge construction process. The activity referred to is cognitive, and some kinds of learning commonly occur without conscious deliberate attention—although that is not the case for the learning of academic concepts. Constructivist theory suggests that students need to be actively processing during learning of conceptual material, but this does not necessarily require a student to be moving about or making noise, as students can be mentally active whilst sitting quietly listening to the teacher. (Of course the length of time students will be cognitively engaged in learning in such a mode varies with factors such as age, motivation, topic, and teaching style!)

What this sense of active learning does mean is that metacognition (Whitebread & Pino-Pasternak, 2010) can be very important in learning as students who examine and deliberate on their own learning are likely to actively process material in what are termed 'deeper' ways (Rhem, 1995). Digital tools that support learner metacognition can be very useful here. One example would be applications that allow students to prepare and modify (and track changes in) concept maps—although, as with all digital tools, it is important that the usability of the tool is such that student working memory capacity is not burdened by using the tool itself (Weinerth, Koenig, Brunner, & Martin, 2014).

This perspective also provides some support for the 'flipped classroom' model of instruction (Seery, 2015). The argument here is that traditionally much class time is spent with the teacher presenting, and students noting down, information that could be just as easily acquired from texts, to give learning that is then reinforced and checked through exercises carried out in private study when teacher support is not available. Whether or not this assumption is widely true in many school classrooms today (e.g. Mortimer & Scott, 2003), it seems to be sound in relation to many university lectures.

The flipped classroom movement argues that it is more effective to get students to do the reading before class, and spend class time on activities, such as working through examples, when there is peer and teacher support available. Although the principle has long been argued in terms of students making their own notes from books before class, increasingly digital technologies are allowing teachers to provide resources (such as videos) for pre-class work that goes beyond simple texts. In this context, the Khan Academy—an independent not-for-profit organisation in the USA—has made available a wide range of videos on many topics that students around the world can access through the Internet. There has been some criticism that sometimes these types of videos do not make the most of the affordances of technology—being little more than taped lecture segments—but even this offers some multi-modality (Jewitt, Kress, Ogborn, & Tsatsarelis, 2001) that is not available in a traditional printed text.

Social Aspects of Knowledge Construction

Although this theoretical perspective on learning (sometimes labelled 'personal' constructivism) focuses on the nature of individual cognition and considers learning as a process of *personal* construction of knowledge, its corollary is that learning of canonical knowledge (as in school) is very much a social process. Individuals are able to construct new ways of thinking about the world for themselves, and sometimes these ways of thinking are genuinely original (i.e., 'big C creativity'—and some culturally new perspective, model, theory, tool, school of thought, narrative genre, or whatever, is created). However all such learning is constrained by the available 'data' and interpretive resources.

Some of the interpretive tools people use to make sense of the world are based on implicit (that is, not open to deliberation) 'primitive' knowledge elements that form through the brain's ability to spot patterns and apply them as the basis for developing expectations about future experience (Smith, diSessa, & Roschelle, 1993). These knowledge elements are primitive in the sense that they operate early in the process of making sense of sensory information, and so are used in the stages of perception least accessible to consciousness. Such processes are considered to be fundamental to all conceptual learning, but a solitary person who relied completely on this mechanism to construct models of the world would by themselves reconstruct very few of the established cultural inventions of humanity.

Rather, socialisation processes, such as are institutionalised in formal schooling, and in particular the use of language and other symbolic tools—as discussed by Vygotsky (1934/1986)—allow learners to build complex explicit (i.e. open to conscious deliberation) conceptual schemes upon their primitive knowledge elements (Taber, 2013; Vygotsky, 1934/1994). The conceptual understandings learners build are dependent upon their interpretations of the ideas presented to them by others—such as their teachers (see Fig. 24.3). This is what allows there to be cultural reproduction, so each generation does not need to reinvent the wheel (or, say, the computer mouse). However, non-canonical ideas which learners meet (in the family or wider society, in their reading or television viewing, or on dubious Internet sites) are also available to be drawn upon as well as the canonical ones (Blackmore, 2000). So for example in a community with high levels of racial prejudice, or where illness is believed to be due to evil spirits or hexing, formal teaching will not be working within an existing conceptual vacuum. Moreover, the ready availability of various forms of social media can accelerate the spread of technically incorrect ideas as effectively as canonical ones.

Teaching and Learning as Dialogic Activity

Increasingly scholars have recognised the role of dialogue in teaching for clarifying, sharing, and comparing ideas and understandings. Dialogic teaching involves the exploration of multiple viewpoints in the classroom (Boyd & Markarian, 2011).

It could be suggested that in subjects where the curriculum requires the learning of specified authorised conceptualisations this would be less effective for teachers, and more confusing for learners, than simply focusing on the canonical ideas to be taught (Claxton, 1986). However, the constructivist perspective suggests that there are always likely to be multiple understandings of curriculum topics and teaching among a class, and addressing this requires making explicit, and exploring, these different understandings. Teachers need to make elicit learners' ideas, and then incorporate consideration of them in the classroom presentation (Duit, Treagust, & Widodo, 2008). Pair and group discussion work may be used to elicit or explore ideas given the usual limitation of only one teacher seeking to engage a large group of learners in dialogue.

Digital technology offers a range of tools to facilitate the processes of making explicit and exploring different learners' views: chat rooms, fora, wikis, student blogs, and so forth. The adoption of virtual learning environments allows the dialogic work of the classroom to be spread through time and space, as student home study tasks need no longer be seen as intended as solitary activities but can become interactive even when students are not easily able to meet physically outside the timetabled class.

A perspective closely related to construct*iv*ism is construct*ion*ism. Constructionism concerns people learning in the context of a learning culture that has a focus on constructing some form of artifact. This can be a physical object, but digital tools can provide virtual environments within which learners can work together to build new objects (Parmaxi & Zaphiris, 2014). Again, the increasing ubiquity of home computers and mobile devices connected through the Internet offers the potential for joint construction work to take place outside the classroom without students needing to be in the same physical space to work together (Watson, Murin, Vashaw, Gemin, & Rapp, 2011). School-age children today are often quite used to the idea of being virtually together and engaged in shared activities when physically apart, and with modern digital technology there is no reason why the social, dialogic, aspect of knowledge construction within a group has to come to an end when students leave the school premises for the day.

Conclusion

Technology offers tools that must be carefully chosen to fit particular purposes. Educational planning needs to begin with a consideration of our purposes, and then consider the strategy (i.e. pedagogy) to be adopted accordingly. Constructivist ideas are based upon work exploring the nature of learning, and how it can best be supported by teaching. Conceptual learning will be incremental, interpretive, and iterative in nature (Taber, 2014) regardless of the subject matter or the educational technology available to support teaching. Effective pedagogy therefore requires structuring what is to be taught through manageable learning quanta, finding ways to relate unfamiliar material to what is familiar to learners (and so depends upon knowledge of the students' prior ideas and understanding), and a dialogic approach that (a) allows students to explore and compare ideas and (b) gives the teacher ongoing feedback on the students' thinking to guide real-time decision-making about the next pedagogic move in the classroom. Digital technologies offer considerable affordances for supporting such pedagogic approaches, and increase the potential for school teachers to work as constructivist teachers.

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