Chapter 1

Paradigmatic challenges for educational technology

> "All social movements involve conflicts which are reflected intellectually in controversies. It would not be a sign of health if such an important social interest as education were not also an arena of struggles, practical and theoretical."
> John Dewey [Dew59:pv]

The aim of this chapter is to highlight that, despite the hype, there are some difficulties with the application of educational technology (ET). I shall concentrate on the need for ET to offer more of the *experimental*, *flexible* and *meaningful* characteristics of everyday learning in the world. Current ET struggles to address this issue because of a 'paradigm conflict' between learning with computers and learning in an everyday sense. The 'conceptual challenges', as opposed to implementation or political challenges, concern the need to bridge the gap between computing activity and learning as a sense-making activity. To overcome these challenges, *eight significant characteristics of learning* are introduced that ET should aspire to support. The remainder of the thesis explores an approach to computing, Empirical Modelling (EM), that aims to support these characteristics.

1.1 Educational technology and paradigmatic conflicts

1.1.1 What is educational technology?

Educational technology (ET), e-learning, Information and Communication Technology (ICT), and Computer Aided Learning (CAL) are all terms that refer to a very wide range of computer-related technologies that support teaching or learning. They include the use of multimedia CD-ROMs, web-based teaching materials, discussion boards, collaborative software, e-mail, blogs, wikis, chat software, computer aided assessment software, educational animation, simulations, games, learning management software, intelligent tutoring systems, integrated learning systems, mobile learning, to name just a few. A description of educational technologies by the Joint Information Systems Committee identifies a wide range of activities in which computers may be of assistance, from blended learning where traditional learning is combined with technology, to learning that is completely delivered through a computer [JISC04]. Some potential benefits of ET are identified as [JISC04]:

- learning material and support can be accessed from anywhere (assuming appropriate technology is available);
- learning material and support can be accessed at any time;
- feedback from learning can be instantaneous;
- collaborative tools allow learning to extend beyond the current physical location (using the Internet for example);
- learning material and support can extend the potential of traditional learning environments;
- learning material and support using technology can be fun.

While it is clear that ET can have a positive effect on learning, the benefits highlighted above paint a picture of technology as providing better delivery and communication mechanisms (with the exception of the benefit of technology being fun).

1.1.2 The reality of educational technology in the educational system

Technology is seen by many as a way of improving education. Figures within the British government have indicated that technology will drive improvements in learning and education. Jim Knight, Minister of State for Schools, in his 2007 BETT Conference speech [Kni07] declared that: "Technology will be a vital part of our drive to securing higher standards and better schools for all." The Gilbert Report [Gil07], presented to the Secretary of State as a vision for learning in 2020, states clearly that "technology influences what, how and why children learn". In a survey on the progress of education in Britain [GdC05], Green, de Waal & Cackett point out that expenditure on education has risen by 5% each year since 2000, with increasingly more of each budget being spent on technology. According to advice presented to the government, ET is supposed to enable us to learn what we want, when we want [Gil07]—and the government is equally enthusiastic with one senior member ambitiously declaring that education with technology has the potential to be "the great liberating force in providing opportunity to all" [BEC07].

Although there is widespread acceptance that technology *can* bring benefits to education, there is some concern whether current technology *is* of actual benefit. In the UK, the common criticism that ET is ineffective due to lack of government funding comes at a time when expenditure on education is increasing and overall expenditure is above the European average [GdC05]. Albirini, in a paper on the crisis in educational technology [Alb07], highlights the growing scepticism surrounding the value of ET: "Despite huge expenditure, wide experimentation and research, and discursive enthusiasm, educational technology has failed to show substantial benefits to the field". Following this, he adds that "efforts to explain and subsequently resolve the crisis of educational technology have centered mainly on the material obstacles to the implementation of educational technology in schools", such as lack of funds, inadequate planning, shortage of computing expertise, insufficient teacher support, and a fear of security and misuse. Albirini, however, is more concerned that "the real causes of the crisis extend beyond these concrete problems to more theoretical issues related to the *'identity' of educational technology*, its *theoretical assumptions*, and its *paradigmatic conflict with education*" (my italics) [Alb07].

1.1.3 Explaining the crisis

Education technology has been promoted as having the potential to transform education, with the same revolutionary and reformist attitude with which the information age transformed the industrial age [Alb07]. Albirini explains that the drivers behind the information age were stand-alone tools that automated the human element to some extent, putting the focus on the computer not the person to do the job. While this has been successful in industry, education has not been able to accommodate this approach and holds on to a more structured dependable industrial system controlled by a human element [Alb07]. Thus, Albirini argues, the 'identity' of technology is questioned in education as it has not yet shown the revolutionary or reformist role with which it is associated. The second issue that Albirini considers is the disparity between the assumptions of ET and those of education [Alb07]. Educational technology aims to remove the structure of the classroom, decentralise access to tuition, increase access to material, and enhance student collaboration and exploration [Alb07]. The conflict arises because education is founded upon a top-down hierarchical structure from the educational authority right down to the classroom, linearly organised activities, the presentation of prescribed material, and teacher-to-student interaction [Alb07]. Albirini views the mismatch between these assumptions as a major obstacle to the integration of ET in classrooms.

Findings by Goodson and Mangan [GM95] suggest that the demands of computer use on existing learning environments (e.g. schools) lead to a 'culture clash' between the computer and many areas of the curriculum. They reason that, due to the pedagogical and organisational changes that computer use dictates, some subjects in the curriculum are unlikely to be compatible with the use of computers. Selwyn [Sel99] discusses the attitudes of 16-19 year old students to computers in the classroom, and his findings show that attitudes vary mainly according to subject areas as well as student access to computers. These findings suggest that ET, and its designers, should be more sensitive to not only the paradigm of learning, but also the differences in culture across a wide range of learning situations and environments.

Albirini says that in the end we have to choose whether we shall stick with our industrial system for education, or if instead we should develop a new paradigm for education that is more aligned to technology and the information age [Alb07]. From Shaffer & Kaput's point of view, a new paradigm is already developing [SK99]. In their evolutionary perspective on technology and mathematics education, they argue that a new cognitive culture, which they term 'virtual culture', is developing based on the use technology for the externalisation of symbolic processing [SK99]. Shaffer & Kaput view 'virtual culture' as a fifth stage that follows on from Merlin Donald's acclaimed analysis of human culture into four distinct cognitive development stages over a period of at least three million years [SK99]. Donald's fourth stage is identified as 'theoretic culture' or culture based on external representations such as written symbols [Don91]. The development of the cognitive ability to use external representations made it possible for humans to keep records, as well as reflect on the interrelationships among recorded ideas, and Donald suggests that modern scientific culture developed from the existence of external notations for thinking [Don91:p320]. Shaffer & Kaput's fifth stage differs from the fourth stage in that human beings have developed the cognitive ability to use external *processing* (as a consequence of technological developments) [SK99]. The simple example given is that of a spell-checker which performs a processing task that would have previously been performed by a person [SK99]. At the present time, we are only at the very beginning of 'virtual culture', given that 'theoretical culture' goes back around 30,000 years [SK99]. Shaffer & Kaput explore the possible changes in mathematics education that may result if this new virtual culture develops [SK99], and if they are correct then we are, as Albirini says [Alb07], on the verge of a new paradigm for education.

The prospects of a new paradigm for education are further emphasised by Riley [Ril07], a researcher in the history of education and pedagogic innovation. Riley explains the use of ET as fitting into three idealised classes: functional substitution, functional delegation, and functional innovation [Ril07]. Functional substitution is associated with the typical use of multimedia, where previous mediums of transmission are replaced by technology for (e.g.) more realistic graphics. Functional delegation is associated with the use of word processors, spreadsheets, and other generic software that can simplify the concerns of the teacher or student as tasks are delegated to the computer. Both of these uses of ET have been relatively well-explored. The third classification of use is functional innovation, which has so far been associated primarily with computer modelling. Models can serve as "a way of thinking, a means of expression, and a subject of investigation" [Ril07]. The functional innovation use of ET is what Riley views as having the potential to significantly change education because it involves for the first time putting 'heads and computers together' [Ril07]. Riley suggests that the full character of functional innovation has yet to be realised and if it does evolve into the new paradigm for education then the change may be measured in generations rather than decades.

1.1.4 Unravelling the paradigm conflict

The above discussion highlights one aspect to the paradigm conflict that there is a mismatch between the rich potential for enhanced learning afforded by new technology and the constraints of old-style educational practice. However, the focus of this thesis is at a more practical or technical level. My interest—and the link with EM—is in how ET can be developed to overcome the conflict and mismatch, or to support a new paradigm for education. Such changes or developments, as noticed by Riley, occur on a macro-level over long periods of time, whereas on a micro-level of interactions among students, change in ET can have an immediate effect [Ril07]. Therefore, the task is to consider the paradigm conflict at a primitive level, in particular at the level of characteristics of learning that ET can aim to achieve, which may eventually lead to new practices and a new paradigm for education.

In some respects Albirini's explanation of the paradigm conflict [Alb07] is too loose to be able to offer any suggestions for improving ET. However the theoretical issues he highlights are echoed in Jonassen's concerns towards educational technologists in his book entitled *Modeling with Technology* [Jon06]. Jonassen states more clearly that a major problem with ET is that educational technologists have assumed that if you create lessons that use technology and show them to students then they will learn [Jon06:pxiii]. Under these theoretical assumptions the purpose of the technology is to communicate ideas to learners, thus replacing the role of the teacher. As a technologist (or computer scientist), the primary challenge is to make the communication as efficient and effective as possible, as can be seen from the benefits that JISC proclaim [JISC04]. The reason that problems arise, as stated by Jonassen, is that "students do not learn from technology; they learn from thinking" [Jon06:pxiii]. Therefore a tension exists between those concerned with the benefits of technology enhanced learning and those interested in how we learn. Jonassen's work is special in this respect as he starts the premise that meaningful learning involves conceptual change and then he goes on to show how modelling with technology can bring about conceptual change.

Jonassen's notion of *conceptual change* originates from the work of educational psychologists Strike & Posner [SP85]. The basis for viewing learning as conceptual change begins with the assumption that humans are natural theory builders; from an early age we build "intuitive personal theories" to explain the external world in which we live [Jon06:p4]. When these theories, or *concepts*, conflict with new experiences or cannot be used to solve problems then *change* can sometimes occur [Jon06:p5]. As Jonassen describes, "Conceptual change occurs when learners change their understanding of the concepts they use and of the conceptual frameworks that encompass them." [Jon06:p4]. For Jonassen, this change occurs best when learners are engaged with building models.

If a conceptual change view of learning is adopted then the focus of education should be on creating experiences that 'prod' at our current concepts and make us reconsider our personal theories in everyday life—what we need is an approach to learning emphasising *everyday sense-making*.

This leads to two tensions in the paradigm conflict: the difficulties of technology enhanced learning stem from the mismatch on a high-level between the rich potential for enhanced learning afforded by new technology and the constraints of old-style educational practice; and also between formalised virtual learning environments and everyday sense-making.

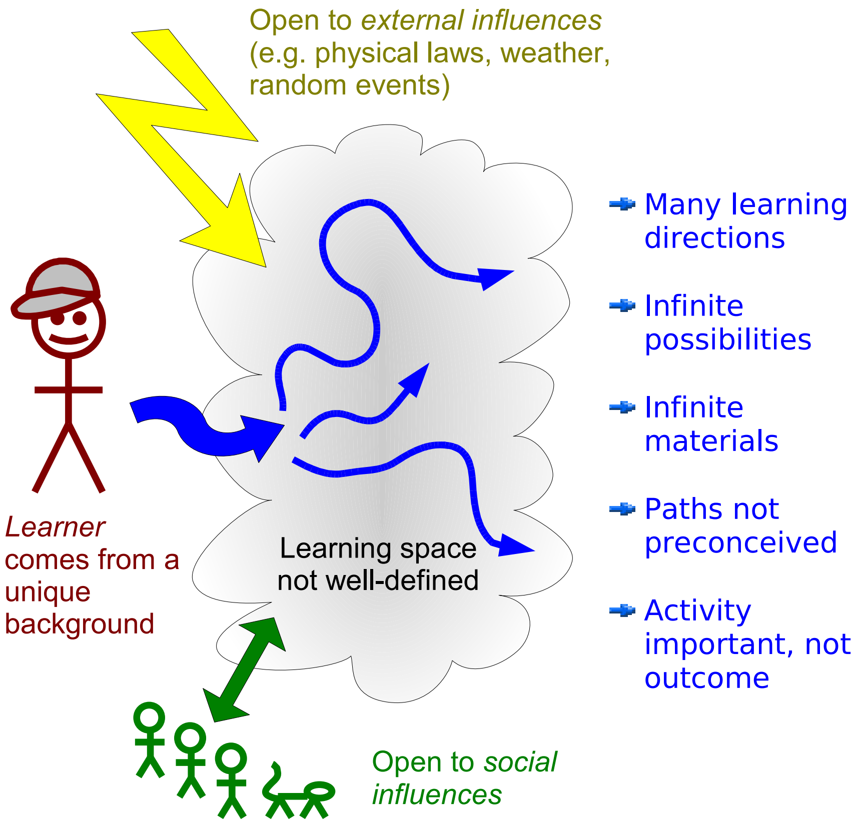

Figure 1.1: Learning in the world in everyday life.

The first tension in the paradigm conflict results in ET being concerned with higher-level issues of transmission, delivery and communication. This leads to the second tension that ET is not appropriate for everyday sense-making or learning in everyday situations which is actually concerned with the primitive activity of conceptual change. The paradigm conflict can be examined in more detail by comparing the nature of 'learning with ET' and 'learning in the world' in an everyday sense. Contrasting Figure 1.2 with Figure 1.1 illustrates the differences between these two paradigms that many educational technologists are attempting to combine.

The issues resulting from attempting to mix 'learning with ET' and 'learning in the world'—as depicted in Figure 1.2 and Figure 1.1—suggest ET lacks attention to the primitive aspects of learning in the world. These aspects are not difficult to find, they are a part of everyday living, and are evident from the things we learn in the world on a day-to-day basis. It is learning that means something to us, or enables us to do something. It is learning that brings about conceptual change [Jon06]. Some of the relevant characteristics of such learning is what I shall attempt to describe in the next section. Carl Rogers, best known for his role in the development of client-centred therapy or counselling, might describe this everyday learning as 'significant learning' referring to its characteristics as

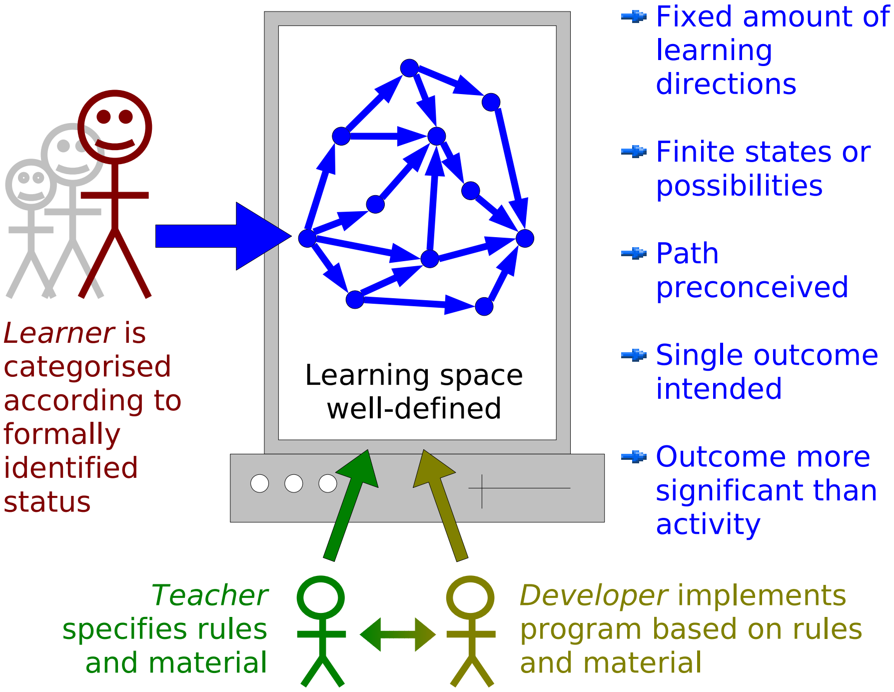

Figure 1.2: Learning with educational technology.

a genuine type of learning [Rog61]. By this Rogers means "learning which is more than an accumulation of facts ... it is learning which makes a difference—in the individual's behaviour, in the course of actions he chooses in the future, in his attitudes and in his personality" [Rog61:p280]. The struggle to construct this thesis is an example of the learning that is apparent in the problems of our everyday lives. We juggle ideas, try to formalise our thoughts, experiment with trials, modify our model based on errors or mistakes—these aspects are familiar to everyday activities. (This thesis represents only the outcome of a learning process which has involved a significant amount of experimentation, trial and error, wrestling with thoughts and formulating new ideas.) The relevant properties of everyday learning are that the learning space is not well-defined, it is open to external and social influences, the learning may take many directions, the possibilities are endless, the learning space contains an infinite amount of material, there are no preconceived paths for the learning, and it is the activity of learning—not the outcome—that is important. Figure 1.1 attempts to illustrate the nature of everyday learning in the world: that the learning ebbs and flows with one's life in response to internal and external influences.

The problems with existing ET surround an attachment to learning as transmission, delivery, and communication [Jon06], as well as being built on a foundation of computer science. The properties of learning with ET are that the learner is categorised according to a formally defined status, the learning space is well-defined, the learning space can only be changed by the teacher who specifies the requirements and the developer who implements the requirements. Thus the learner can only explore a fixed number of preconceived learning paths, containing a finite number of possibilities, leading to a specific learning outcome, the result of which is often treated more important than the activity of learning. Figure 1.2 shows the nature of learning with ET. Such learning does not encourage the making of meaning, or 'significant learning' as Rogers describes, in an individual as put bluntly by Jonassen: "Technology-centric approaches to education ignore the sole purpose of technology in classrooms: to support meaningful learning." [Jon06:pxiii].

Jonassen's suggestion, which shall be followed up in this thesis, is that "rather than analyzing how technology can teach better, educators need to consider how students must think to learn most meaningfully." [Jon06:xiii]. Put in the terms used in this thesis, in order to resolve the paradigm conflict, ET must support learning on a more primitive everyday level.

1.2 Eight significant characteristics of learning

In order for EM to challenge the current approaches to technology enhanced learning, the above discussion points to the need to focus on supporting the primitive aspects of learning that occur in everyday situations. This section introduces *eight significant characteristics of learning* that feature in everyday learning.

The eight characteristics are the result of the observed need to make 'learning with ET' as depicted in Figure 1.2 more like 'everyday learning' as depicted in Figure 1.1. These characteristics reflect the kind of learning that ET should promote in order to alleviate the tensions surrounding the paradigm conflict. This section introduces each characteristic in relation to theories of learning originating from a wide range of educational and philosophical thinkers. As introduced in the next chapter, the eight significant characteristics of learning share a close affinity with the characteristics of EM.

The eight characteristics are broken down into three strands. The first of these strands, explained by the first three characteristics, views learning as essentially *experimental*, both on a practical level and in terms of knowledge. The second strand is associated with a view of learning as open-ended or *flexible*, as described by the middle two characteristics. The last strand is associated with learning that is relevant or *meaningful* to the learner, as implied by the last three characteristics. Figure 1.3 illustrates the breakdown of the *eight significant characteristics of learning.*

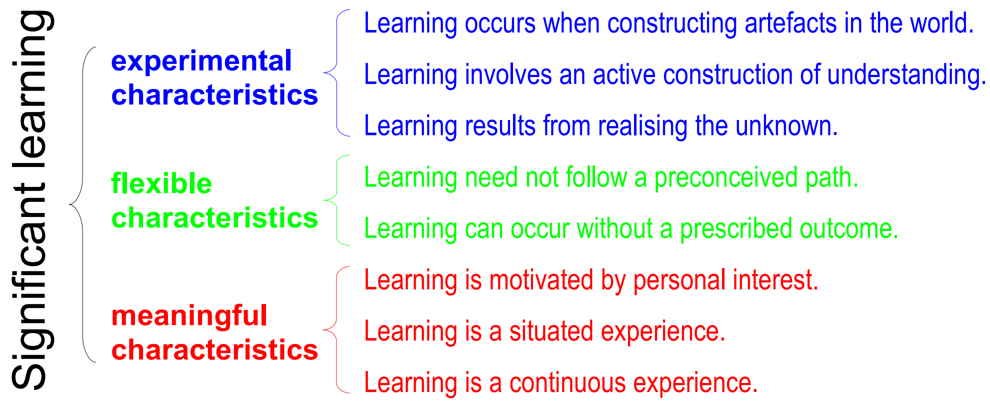

Figure 1.3: Eight significant characteristics of learning in three strands.

1.2.1 Learning occurs when constructing artefacts in the world

The first characteristic to be described is one that is particularly relevant to ET. It has its roots in 'learning by making' and was first explained by computer scientist and educator Seymour Papert as constructionism. The idea behind constructionism is that learning occurs "especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe" [PH91]. Papert claims that the constructionist idea is an extension of constructivism, in that the latter is concerned with the construction in the head and the former links this to construction in the world. However, given the many conflicting flavours of constructivism (discussed further in Chapter 7), I shall avoid describing constructivism and simply talk about constructionism as an activity in which the construction of artefacts in the world can lead to the development of understanding. Papert's particular emphasis is on the construction of artefacts using computers, such as the LOGO environment [Pap80].

The concept of 'learning by doing' only captures Papert's idea of constructionism in very general terms. 'Learning by doing' as an idea has a long history—the great Chinese philosopher Confucius is widely attributed as having said "I hear and I forget. I see and I remember. I do and I understand." and Aristotle is quoted as having said "What we have to learn to do, we learn by doing." [Ari12]. Although Papert might be more likely to think of constructionism as 'learning by making', both forms of thinking absolve the teacher somewhat from their traditional teaching role. Such ideas are linked to the great education reformist John Dewey:

> "I believe that much of the time and attention now given to the preparation and presentation of lessons might be more wisely and profitably expended in training the child's power of imagery and in seeing to it that he was continually forming definite, vivid, and growing images of the various subjects with which

he comes in contact in his experience.” [Dwo59:p29]

Through Dewey we can see that construction can be linked to imagination and the forming of ideas. It is Dewey that argues for the importance of learners being able to investigate things for themselves, and not take the teachers’ words as absolute. The role of the teacher (and now, of ET) is not to constrain the thinking of the student, but to prompt in the student’s imagination the construction of new ideas in relation to their everyday experience.

Creativity therefore plays an important role in learning when there is an emphasis on constructing. Negus & Pickering, in a book devoted to explaining creativity [NP04:p22], discuss the nature of creative experiences being something often not describable but ‘intensely felt’ in the same way that Confucius sees true understanding as only arising out of doing. Negus & Pickering quote the controversial American poet John Ashbery as saying, “If I did not write, I would have no idea of what I can write. I suppose that I write so as to find what I have to write.” [NP04:c4]. The close connection between creativity, imagination and significant learning is reflected in constructionism. Papert believes strongly that these elements should be imbued in ET as emphasised in a talk relating to educational change: “Wild imagination, passion, being close to nature, and believing in magic—that is what we need. I think these are all the elements that we need to bring into the otherwise cold version of use of computers called ‘ICT’.” [PS05].

Papert’s constructionism and the idea of learning by doing highlight very general practices that may bring about change in education. Riley’s idealised use of ET for functional innovation [Ril07] provides a more focussed idea based upon ‘learning by building models’ as discussed earlier in this chapter. Riley takes up Jonassen’s standpoint that model-building brings about ‘conceptual change’ in the learner, and further argues that model-building offers the potential for cultural change in education [Ril07]. Jonassen demonstrates on a primitive level that modelling environments are tools for ‘conceptual change’ that can bring about significant learning [Jon06]. In this scheme a wide variety of computer-based tools can be used for learning, such as spreadsheets, databases, and concept maps, so long as there is an element of model construction. Jonassen’s main justification for this thesis is that ‘if we cannot construct a model then we do not understand it’ [Jon06].

A criticism of constructionism and learning by doing is that if a child is allowed the freedom to build whatever they like then there is no guarantee that the learner will engage with the material that is required by the curriculum. This is evidence that constructionism alone is not a solution to bridging the gap between education and educational technology. Thus these eight significant characteristics of learning offer a holistic approach for thinking about education that is well-aligned to computer-based model-building.

1.2.2 Learning involves an active construction of understanding

The idea that a learner *actively constructs their own understanding* is partly represented in the old adage "you can lead a horse to water but you cannot make him drink", meaning that a teacher can provide information and demonstrate skills but the student must be active to develop an understanding so that they can benefit from the teaching. Bruner, an influential cognitive psychologist, suggests that learners who actively engage with the domain are more likely to be able to recall information and apply the understanding in different contexts or to new domains [Bru66]. The following quote from Bruner captures this characteristic of learning:

> "To instruct someone... is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as a historian does, to take part in the process of knowledge-getting. Knowing is a process not a product." [Bru66:p72]

Swiss biologist and psychologist Piaget first described what later became known as constructivism in his theory of cognitive development, proposing that the world is not full of latent knowledge ready to be gleened, but that learners construct understanding for themselves [Pia71]. Knowledge, or understanding, is built up through experiences and intelligence is shaped by experience. Piaget describes two processes that occur whenever an experience occurs: assimilation and accommodation [Pia71]. Accommodation is the process of accommodating a concept in the mind to an experience in the world [Pia71]. An experience changes previous understanding of things (changing an idea in the mind). Assimilation is the process of assimilating an experience in the world to a concept in the mind [Pia71]. In other words, an experience is 'squeezed' to fit in with previous experiences and understanding of things (thus reinforcing an idea in the mind).

Piaget's later work began to address problems in education, and he was critical of school as a means of leading a child "to resemble the typical adult of his society" [Bri80:p132]. Instead, he suggested that education should be about "making creators... You have to make inventors, innovators, not conformists" [Bri80:p132]. Thus supporting learning as an active process.

Further support for learning as active construction is found in other conceptions of learning such as given by the Austrian philosopher of science Popper [Pop72]. Educationalists Swann and Burgess argue that Popper's learning theory can be of benefit in todays' education systems: "the educator with a prescribed learning agenda must also come to terms with the fact that there is no direct transfer of ideas from her to the would-be learners. Therefore, the would-be learners still need the opportunity to engage in trial and error-elimination, and they must have the will to do so." [SB05:p15] Even with a behaviourist conception of learning, such as given by Skinner [Ski74], active learning is encouraged because the learner must actively engage with a behaviour (or repetitions of a behaviour) in order to strengthen (or weaken) a skill, understanding or behaviour.

1.2.3 Learning results from realising the unknown

This characteristic recognises that learning is often random and can take place when and where it is least expected. As expressed in the quote by A.A. Milne, author of Winnie the Pooh, "One of the advantages of being disorderly is that one is constantly making exciting discoveries." In terms of scientific discoveries, when performing experiments it is not the elements that are understood that are of interest but the phenomena that are surprising and do not fit the hypothesis. However, it is essential to exercise the predictable patterns of agency in order to *realise the unknown*. It is when the unknown aspects of understanding are realised that some significant discovery (or learning) can take place. In a study of model-building in humanities [McC03], Willard McCarty uses the word 'residue' to describe the unresolved—but useful—issues that arise from building models and making formalisations†. It is the bit that is left over, the *residue*, that provides valuable learning experiences. These sentiments are expressed by the American educational theorist Kolb in his account of experiential learning [Kol84]:

> "I move through my daily round of tasks and meetings with a fair sense of what the issues are, of what others are saying and thinking, and with ideas about what actions to take. Yet I am occasionally upended by unforeseen circumstances, miscommunications, and dreadful miscalculations. It is in this interplay between expectation and experience that learning occurs.' [Kol84:p28]

† "modelling treats the ill-fitting residue of formalization as meaningfully problematic and problematizing" [McC03]

William James, a philosopher who spoke widely on the subject of experience and whose work shall become more familiar in the course of this thesis, said that there are two ways in which we take new ideas on-board from others: when we hear a new idea, either it fits in with our previous understanding or it contradicts our previous experience [Jam92]. Sometimes the idea is too far removed from our existing experiences (we have nothing to compare or associate with it) and then, as long as it is from a credible source, it is generally accepted [Jam92]. This type of learning is without first-hand experience of the idea that is being learned (cf. learning by rote). Learning which involves examining objects, phenomena, and situations for one's self—an experiential form of learning in line with activity as described in Kolb's learning cycle [Kol84]—leads to personal understanding because it is experienced experimentally first-hand. Just as Plato said, "knowledge will not come from teaching but from questioning" [Pla55], so too it is an important characteristic of learning that the residue (the unknown) is realised and examined.

The idea that the residue is where the learning occurs further relates to Popper's theory, as explained by Swann & Burgess [SB05]. Popper's account of learning is described in terms of creative imagination—the process of taking a problem, forming a trial solution, and then observing the error in the solution, leading on to another problem [SB05]. Following from this, it is explained that the educators role is "to encourage would-be learners to engage in open-ended trial and error-elimination". This is in order "to identify mismatches between their current expectations and experience" [SB05].

In his book *Learning to Learn*, Novak states that "meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures." [Nov84:p7]. Novak's work is based on the assimilation theory of Ausubel, a psychologist and follower of Piaget, who stressed the importance of prior knowledge in being able to learn new concepts: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly." [Aus68]. Therefore this characteristic is not solely about going in search of the unknown, but also the need to look at what is already known, in order to realise the unknown. Vygotsky's Zone of Proximal Development [Vyg78] is a way to describe the 'current' residue, for it is the perception of 'stuff' on the boundary of the learner's attention that is not yet understood.

1.2.4 Learning need not follow a preconceived path

Learning can be spontaneous in the same way that our experience is. Learning can be altogether unstructured. At any one moment there is no knowing what the next moment will bring. There is no knowing what subject will take our attention, what questions will be raised in our mind, what personal feelings will arise. Neither the teacher, nor the learner himself, can predict what path their learning will take.

Contrast the above statement with the reality of schools and education systems. The curriculum not only sets out what should be learnt, but the order and timing of what is to be learnt. Every student is expected to follow the exact same pattern, the same preconceived path. It seems clear that an experimental approach to learning, as expounded in §1.2.1–§1.2.3, cannot be aligned to a traditional approach to education. The need for open-ended and flexible experimentation is essential.

Kolb, in his introduction to experiential learning, says that human beings are special in their ability to identify and adapt to change [Kol84:p1], just as Darwin claims in his most famous work, *On the Origin of Species*: "It is not the strongest of the species that survive, nor the most intelligent, but the ones most responsive to change" [Dar59]. For Kolb, "learning is *the* major process of human adaptation" [Kol84:p32]. Therefore the aim of traditional education, defined by Dewey as the acquisition of the essentially static knowledge incorporated in books and the heads of elders [Dew59:p5], is contradictory to experiential learning [Kol84:p32]. Kolb's thinking resonates with Rogers' observation of his own education that significant learning occurs when we are most open to change [Rog61].

It should perhaps be made clear that Kolb or Dewey or Rogers are not advocating that the teacher is redundant and that the student should have complete control of their learning. As Dewey points out, "on the contrary, basing education upon personal experience may mean more multiplied and more intimate contacts between the mature and the immature than ever existed in the traditional school, and consequently more, rather than less, guidance by others." [Dew59:p8]

The characteristic of learning drawn from this section is that learning *need not follow a preconceived path*, that a process of adaptation should be respected for significant learning to occur.

1.2.5 Learning can occur without prescribed outcomes

It is Dewey who points out that traditional education is concerned with learning that has a prescribed outcome: "The subject-matter of education consists of bodies of information and of skills that have been worked out in the past; therefore, the chief business of the school is to transmit them to the new generation" [Dew59:p2]. This, in Dewey's opinion, is the wrong view for an educational system that is supposed to be conducive to developing a democratic society. In a traditional system of education the outcomes are prescribed by a higher authority and forced upon the student. Exploration, self-discovery, and personal learning are not encouraged in such a system unless they are within the confines of the prescribed.

Rogers, in his personal account of education [Rog61], takes a strong position against prescribed outcomes: "It seems to me that anything that can be taught to another is relatively inconsequential, and has little or no significant influence on behavior". Rogers' use of the word 'significant' reflects the importance of learning being linked to changing behaviour and thus that 'significant learning' is what is important for education. It is this type of learning that occurs without a prescribed outcome: "I have come to feel that the only learning which significantly influences behavior is self-discovered, self-appropriated learning." [Rog61].

Kolb builds on Dewey's idea for education without prescribed outcomes. Kolb says that the emphasis on the activity not the outcome is what distinguishes experiential learning theory from traditional education and behavioural theories [Kol84:p26]. As discussed in §1.2.4, Kolb talks of learning as a process where the emphasis is on adaptation and not content or outcomes. Thus, this characteristic of learning moves away from a view of knowledge as certain and to-be-received, to a view of learning as open-ended and flexible.

A caution by Dewey on the characteristic of learning as not having prescribed outcomes is that complete ignorance of outcomes may also not be the correct approach (if morality is ignored for example) [Dew59:p17]. Thus, this characteristic is described as 'learning *can* occur without prescribed outcomes'.

1.2.6 Learning is motivated by personal interest

Most teachers would agree that it is easier to teach a subject the student is interested in than one that the student is not interested in. This phenomena is not only found in education, but at a more primitive level, as James describes in *Psychology*: "Consciousness is always interested more in one part of its object than in another, and welcomes and rejects, or chooses, all the while it thinks." [Jam92:p170]. It is part of the human condition that we select to investigate that which interests us most. What interests us is very much a personal preference, no doubt guided by previous experience. Often we choose that which will benefit us or, more often than not, that which gives us pleasure:

> "We dissociate the elements of originally vague totals by attending to them or noticing them alternately, of course. But what determines which element we shall attend to first? There are two immediate and obvious answers: first, our practical or instinctive interests; and second, our aesthetic interests. The dog singles out of any situation its smells, and the horse its sounds, because they may reveal facts of practical moment, and are instinctively exciting to these several creatures. The infant notices the candle-flame or the window, and ignores the rest of the room, because those objects give him a vivid pleasure" [Jam92:p363]

By recognising that we show more enthusiasm for that which interests us (either practically or aesthetically), the implication for education is that either teachers should try to get the students interested in the subject, or teachers should only teach what the student is interested in (what they can relate to their experience). The latter seems more likely to succeed, as suggested by James in a later work aimed at teachers:

> "From all these facts there emerges a very simple abstract program for the teacher to follow in keeping the attention of the child: Begin with the line of his native interests, and offer him objects that have some immediate connection with these" [Jam25:p63]

To appeal to the students' interests it is necessary to look for elements of a subject that relate to the students' previous experience, looking for material that relates to their life. As Dewey points out, this might be something at home or at play:

> "I believe that the school must represent present life—life as real and vital to the child as that which he carries on in the home, in the neighborhood, or on the playground." [Dwo59:p22]

This maxim that learning be motivated by personal interest is not to say that students must only engage with a narrowly defined static set of interests that are relevant to them. Individuality is not static, but is constantly changing, growing and evolving as we encounter new experiences. This type of learning is not only concerned with letting the students learn about what interests them, but also enabling them to learn what it is that interests them—as proposed by Rousseau in his famous account of education through the story of *Emile* [Rou11].

From an ET perspective, Papert acknowledges the need to take on-board the idea that constructionist activities should be personal: "if we can find an honest place for scientific thinking in activities that the child feels are important and personal, we shall open doors to a more coherent, syntonic pattern of learning." [Pap80:p98]. Only when the learner is placed in a position of feeling some identity with scientists, for example, will there be meaningful learning of the scientific material in a curriculum [Pap80].

1.2.7 Learning is a situated experience

This characteristic of learning acknowledges that learning *takes place in a situation, context or culture*. That learning is fundamentally concerned with experience, and experiences occur in a situation, implies learning must be linked to the context in which the experience occurred. Dewey recognises that situations cannot be separated from experiences [Dew59:p42]. The interdependence of a social situation and an individual's experience of it is expressed by Dewey thus:

> "I believe that the individual who is to be educated is a social individual and that society is an organic union of individuals. If we eliminate the social factor from the child we are left only with an abstraction; if we eliminate the individual factor from society, we are left only with an inert and lifeless mass." [Dwo59].

Bruner (introduced in §1.2.2) talks in the same way that learning is always linked to culture: "Learning and thinking are always situated in a cultural setting and always dependent upon the utilization of cultural resources." [Bru96].

Prominent educational theorists Brown, Collins & Duguid [BC89] point out, in their work on situated cognition, that students are often forced to think and to learn about ideas and activities with a context or culture different from where the idea or activity developed: "Unfortunately, students are too often asked to use the tools of a discipline without being able to adopt its culture. To learn to use tools as practitioners use them, a student, like an apprentice, must enter that community and its culture. Thus, in a significant way, learning is, we believe, a process of enculturation." Brown, Collins & Duguid [BC89] use the idea of 'useful learning being like an apprenticeship' to emphasise that the learning is an activity with a particular context or situation: "the term *apprenticeship* helps to emphasize the centrality of activity in learning and knowledge and highlights the inherently context dependent, situated, and enculturating nature of learning." These ideas relate very closely to Lave and Wenger, best known for their work on situated learning, who see learning as a deepening process of participation in a community of practice [LW91].

Each of these thinkers is developing a metaphor for learning as participation. As discussed by Sfard [Sfa98] whose interests lie in mathematics education, this metaphor can be contrasted to the 'acquisition metaphor' that thinks of learning as acquiring and having knowledge. Such materialistic thinking has been criticised by some authors (e.g. [BC89] [LW91]) as not leading to meaningful learning, whereas the participation metaphor is praised with being linked to the world and our experience of it. Sfard warns that to disregard either of these metaphors completely is a mistake, and in some respects the ideas behind situated learning can be too extreme, just as often the 'acquisition metaphor' is taken too far in traditional education. It has been shown in §1.2.2 that at least one of the significant characteristics of learning takes into account the acquisition of understanding as an active construction process.

1.2.8 Learning is a continuous experience

This, the most primitive of the eight characteristics, acknowledges that learning and education is bound up with the experience. As John Dewey, in the opening chapter of Experience and Education pronounces: "there is an intimate and necessary relation between the processes of actual experience and education" [Dew59:p7]. With this in mind, Dewey recommends the need for a theory of experience in order that "education may be intelligently conducted upon the basis of experience".

The philosopher whose work is perhaps most concerned with a theory of experience, and whom was most influential on Dewey, is William James. At the root of James' principles of psychology is an idea that consciousness arises, and that our experience can be attributed to an awareness of the succession of 'consciousnesses' [Jam92]. James says that this is something that we can confirm by looking at our own experience.

> "The first and foremost concrete fact which every one will affirm to belong to his inner experience is the fact that *consciousness of some sort goes on.* 'States of mind' succeed each other in him." [Jam92:p152]

In his book *Experiencing and the Creation of Meaning*, Gendlin recognises that it is difficult to describe 'experiencing' using language and symbols because it is the fundamental process occurring in our minds at the most basic level [Gen97]. The best he can do is describe situations in which we become aware of our experiencing, and he does this by talking about the concretely present flow of *feeling* or *felt meaning.* Gendlin's informal experiential description serves as a simple illustration of the nature of experience, shared by James' philosophy:

> "First, feel your body. Your body can, of course, be looked at from the outside, but I am asking you to feel it from the inside. There you are. There, as simply put as possible, is your experiencing of this moment, now." [Gen97]

Delving further into our experience, James points out that we can discern that this sequence of 'states of mind' or 'consciousness' is not discrete, it is continuous: neither can it be stopped and started, nor can there be any definite beginning or end to our experiences [Jam92]. Even when we wake up first thing in the morning, the mind is occupied with a continuation of thoughts from the previous day, or possibly a thought resulting from a dreamy state [Jam92]. Hence James likens consciousness or experience to a river that ebbs and flows, always continuously evolving†:

> "Consciousness, then, does not appear to itself chopped up in bits. Such words as 'chain' or 'train' do not describe it fitly as it presents itself in the first instance. It is nothing jointed; it flows. A 'river' or a 'stream' are the metaphors by which it is most naturally described. *In talking of it hereafter, let us call it the stream of thought, of consciousness, or of subjective life.* " [Jam92:p159]

Dewey takes James' principles of psychology into the domain of education by saying that it is the continuous nature of experience that enables us to learn: "the principle of continuity of experience means that every experience both takes up something from those [experiences] which have gone before and modifies in some way the quality of those [experiences] which come after." The continuity of experience also means that learning begins at a very early age. Experiences during the first moments of life have the potential to affect experiences in the future. Vygotsky, famous for his insights into child development, pointed out that by the time a child reaches school age he has already encountered, and potentially learnt from, an exceptionally large array of experiences [Vyg78:p84]. He says, "children begin to study arithmetic in school, but long beforehand they have had some experience with quantity" [Vyg78:p84]. It is wrong to assume that a child attending school for the first time is a 'clean slate'—the sense-making of experience began a long time ago, and those learnings are likely to effect experiences in school.

As Dewey pointed out, the quality of the experience has an important effect on the learning [Dew59:p16]. By the quality of the experience Dewey means the extent to which

† Just as if you look at a river, even from the same point, each time the water will be different: it will never be the same twice.

the experience represents a reliable view of the world. Positive learning occurs when the quality of the experiences is high. But things can be incorrectly learnt when the experience is misleading, of low quality. This leads to the problem in education of providing an environment in which the learners can have quality experiences. Dewey does not say that traditional schooling does not give experiences, but he questions the quality of the experience.

> "Everything depends upon the *quality* of the experience which is had. The quality of any experience has two aspects. There is an immediate aspect of agreeableness or disagreeableness, and there is its influence upon later experiences. ... Hence the central problem of an education based upon experience is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences." [Dew59:p16]

1.3 Implications for technology enhanced learning

The implications for technology enhanced learning that supports these eight significant characteristics can be described in three strands: the *experimental*, the *flexible*, the *meaningful*. Starting from the final characteristic and working backwards, constructing artefacts with ET provides the *experimental* foundation from which to explore *flexible* paths towards *meaningful* learning, as explained below. When these three strands are wound together they form a strong support for ET that can lead to learning in an informal everyday sense.

1.3.1 The experimental strand

The characteristic described in §1.2.1 forms the basis for an experimental approach to learning, whereby ET—in the form of open-ended model-building—can support individual learning. The next characteristic described, §1.2.2, strengthens the experimental aspect by demonstrating that learning involves an active construction process on the part of the individual. Once combined, the active construction of computer-based artefacts leads to an individual considering that which is known in order that the unknown is realised, as described by the characteristic in §1.2.3. These three characteristics taken together form the experimental strand.

The experimental aspect is important in ET as it provides the basic environment from which learners can explore a domain. The experimental basis allows for many of the influences in everyday learning, as in Figure 1.1, to play a part in the learning activity. However, an experimental approach alone is not enough because 'you cannot make something out of nothing'. In order that there are significant implications for learning, it is essential that the approach is also flexible (in terms of the paths and outcomes) and meaningful (as in linked to personal interests, situations and experiences).

1.3.2 The flexible strand

The middle two characteristics of the eight bring an essence of flexibility to the approach to learning. With the characteristic described in §1.2.4 it is stressed that learning need not necessarily follow a certain pre-defined path, but that an individual should be able to find their own path for their own learning. The other characteristic, described in §1.2.5, strengthens the flexible aspect further by relinquishing the idea that learning should have a prescribed outcome.

The implications of a flexible approach are that many of the constraints usually associated with ET (as shown in Figure 1.2) can be forgotten and the learner can enjoy more the freedom of learning in the everyday sense. Learning supported by ET with these two characteristics does not view the outcome as being with the computer or confined to the computer, ET is the support for learning that is flexibly under the control of the learner.

1.3.3 The meaningful strand

The final strand of the eight significant characteristics of learning involves the last three characteristics, and is the most important as it is the foundation for everyday learning. The characteristic described in §1.2.6 is concerned with making learning meaningful by stating that an individual's personal interest plays a part in learning. In the characteristic described in §1.2.7 it is recognised that learning takes place in a particular situation, context and culture which has meaning for the individual. The last characteristic described, §1.2.8, dealt with the basic tenet that learning is a continuous experience which flows with, and has meaning for, the individual. Each of these three characteristics imply learning that is meaningful or relevant for the individual.

ET that supports these three characteristics has significant implications for learning that is meaningful. The meaningful strand supports more of the everyday aspect of learning, shown in Figure 1.1, as it recognises the unique experience, background and interests of the learner, as well as the external and social influences that effect the learners experience.

As highlighted above, ET that respects these eight significant characteristics of learning is appropriate for liberating the experimental, flexible and meaningful aspects of everyday learning. In the next chapter, Empirical Modelling is suggested as a suitable ET for emphasising the eight characteristics and supporting learning that is better aligned to the experimental, flexible and meaningful aspects when compared to traditional ET.