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Author(s): Patrick Dillon

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TRAJECTORIES AND TENSIONS IN THE THEORY OF INFORMATION AND COMMUNICATION TECHNOLOGY IN EDUCATION

by PATRICK DILLON, *School of Education and Lifelong Learning,
University of Exeter*

ABSTRACT: For largely historical reasons, information and communication technology in education has been heavily influenced by a form of constructivism based on the transmission and transformation of information. This approach has implications for both learning and teaching in the field. The assumptions underlying the approach are explored and a critique offered. Although the transmission approach is entrenched in procedures and pedagogies, it is increasingly challenged by an action-theoretical form of constructivism. In this 'ecology of ideas', the value of the two theoretical stances might be judged in terms of their practical utility and the contributions they make to understanding ICT.

Keywords: information and communication technology, information theory, learning theory, curriculum theory, ecology of ideas

1. INTRODUCTION

Educational computing and its variants – information technology (IT), information and communication technology (ICT), educational multimedia and telematics in education – hereafter collectively 'ICT', is a problematic field. It emerged rapidly with little time for a robust intellectual tradition to be established. In its formative period it was heavily influenced by computer science and partly annexed by the longer standing field of educational technology. It has been shaped substantially by a disparate but powerful coalition of public officials, corporate executives, manufacturers and educationalists operating through both rhetoric and policy (Conlon and Simpson, 2003; Cuban, 2001).

The main locus of inquiry in ICT has been the integration of computers into educational institutions at the levels of teachers and students (Dillon, 1998; Selwyn, 1999a; Reynolds *et al.*, 2003). Very little

attention has been given to its theoretical foundations (Selwyn, 1997), nor its applications in related fields of education. Distance education, for example, with no clearly articulated philosophy and no conceptual coherence, tended to seize on technology as a panacea for ill-defined problems (Marsden, 1996). Only now is a rationale emerging for ICT as an integral part of flexible and distributed learning (Heinecke *et al.*, 2001).

With no foundational theory of its own, ICT has had applied to it theoretical perspectives developed elsewhere in education and, to a lesser extent, from instructional design, a boundary area that utilises both educational and technological theories (Reigeluth, 1999). Most practitioners of ICT would say they work in a social constructivist context which takes account of the situatedness of learning (Lave and Wenger, 1991) and its collaborative nature (Dillenbourg, 1999). Emphasis in the design of computer-based learning environments has shifted from information transmission to knowledge construction (Scardamalia and Bereiter, 1994). Despite this, the relationship between educational processes and technological means is still heavily influenced by fundamental assumptions about the nature of information.

These assumptions, derived from information theory, are predicated on processes of deconstruction and construction in the systematic transmission and transformation of information (hereafter 'information transmission') in the course of learning. The intervention of technology in learning processes is seen as adding value to sensory range, the processes of coding, selecting, categorising and abstracting information, and to educational interventions and transactions. The view of learning that, in turn, is implied by this approach has shaped the way ICT is taught. Seldom have the assumptions been articulated; they are implicit rather than explicit and are evident, for example, in the design of much educational software.

In this paper, theoretical assumptions about information transmission in learning, the role of technology in the process and the implications for teaching are examined and critiqued. As Lankshear *et al.* (2000) observe, the relationship between education and knowledge needs to be re-thought in profound ways *within the mode of information*, by which they mean that new conditions require us to look again, and in different ways, at what counts as knowledge and truth. Action-theoretical constructivism based in sociocultural thinking now influences work in ICT. In contrast to information transmission, action-theoretical constructivism sees information as an outcome of the way in which individuals are in constant interaction with their environment. Again, this theoretical stance has implicit assumptions

about information, learning and the role of technology. In reconceptualising ICT, we should recognise the tensions between the two theoretical stances and the competing claims they make about information. In this 'ecology of ideas', the value of the individual stances might be judged in terms of their contribution to understanding ICT and their practical utility.

Although the paper is primarily about information and approaches to learning in the wider frame of educational theory, it incorporates some discussion about what is and ought to be taught and thus visits some issues in curriculum theory.

2. INFORMATION TRANSMISSION AND LEARNING

The information transmission approach to learning with computers has its origins in B.F. Skinner's work with programmed instruction in the 1950s and 60s (Heinich *et al.*, 1999). Despite considerable changes in technology and ideas about how people interact and learn with it, not least through the advent of the Internet, the information transmission approach to learning still has a profound influence on ICT. It views learning from an *information* perspective: learning arises out of the way data are coded and transformed by people in their attempts to make sense of the world and their experiences in it. This 'progressive' view of data transmission, derived from information theory, is based on a Kantian epistemology that assumes that the individual receives data from the external world and processes these data by categorising them. The following account of progressive data transmission is adapted from Boisot (1995).

The first line of interception of data from the external world is through the five senses of sight, hearing, taste, smell and touch. The totality of the external world cannot be captured, so data are coded, that is, simultaneously selected and categorised. Categorisation is either perceptual or conceptual. Perceptual categorisations arise from the coding of activities that are rooted primarily in local, immediate stimuli through the senses. On their own, perceptual categorisations give only a limited and fragmentary classification of immediately available phenomena. But they are enriched with constant interaction with conceptual categorisations. Conceptual categorisations arise from coding activities dependent on non-local stimuli originating in memory and experience, that is, data complexions that represent generic concepts such as objects, situations, events and actions. Interactions between the two categorisations mean that perception is never wholly free of a conceptual context,

in other words, perceptual coding of sensory data invokes prior theoretical knowledge.

The use of concepts greatly reduces the amount of information the cognitive system needs to encode. Like coding, conceptualisation through abstraction is a selective process that offers further economies on data and categories. Abstraction involves choosing categories that best capture a perceptual attribute. Beyond a certain level of abstraction, clusters of relationships sometimes acquire cohesiveness independently of the perceptual attributes they arise from. These clusters may in turn become symbolic forms that are amendable to yet further coding and economising. Through symbolic coding, new structures can be built from elements that refer to other more complex structures without having to represent their detail. The whole, progressive process is based on economies in handling data: reducing both the quantity that must be handled as attributes and the number of categories to which it must then be assigned.

Educational theorists will recognise this essentially as a laboured re-formulation of constructivism. The whole process constitutes learning, of making progressive selections from and categorisations of available data until they are meaningful to the person involved. Data are coded and become information, integrated and contextualised with what previously has been learned information becomes knowledge. Purposeful intervention can happen at any point through the agency of the learner, other individuals, or technology. The limitations of this view are discussed in section 4 below.

3. ASSUMPTIONS ABOUT THE ROLE OF TECHNOLOGY

The information transmission approach to learning in turn generates further assumptions about the role of technology in the process. Information transformations are mediated by intervention in the process of learning through a task or activity and associated transactions. In formal educational settings, teachers, peers and other educational and social actors, utilising a variety of human and material resources, mediate intervention. Even in self-study and distance education situations, human mediation in the form of instructional designers, for example, is no more than a few steps removed from the learner.

The role of technology in intervention is seen in terms of increasing production or adding value. In economic terms, production means anything that happens to an object or set of objects that increases its value. This action is most often a change in form, but it may be a change in space or time. Data are economised by converting them into information. Information is not a factor of production in its

own right; it is the outcome of economising on data. Data themselves are the input into the productive activity. Information for one person is data for another (Boisot, 1995). Technology may add value to learning at a number of points: at perceptual source, in extending the sensory range, to the processes of coding, selection, categorisation and abstraction, and to educational interventions and transactions. The implication is that things will be done more efficiently, effectively or in new ways.

Extending the Sensory Range

Technology can extend the amount of data an individual can access from the external world well beyond what is immediately available to the senses and what can be readily processed by the human mind. Remote sensing and electronmicroscopy, for example, extend the scales, resolution and speeds at which spatial configurations can be explored. Technology also provides the means of developing more discriminating codes allowing for differentiation and integration of sensory stimuli. A further assumption here is that the development of these technologies draws on knowledge of physical phenomena that is theoretical in nature and thus conceptual; in other words, the data are only as good as the theoretical models on which the technology is based (Boisot, 1995).

Adding Value to Coding, Selection, Categorisation and Abstraction

Information technology is remarkable for the amount of data it can make available, for the mass of data it can handle, and the speed with which it can do it. It affects what can be found, what is looked for, where it is looked for and how it is evaluated (Macdonald, 1998).

Value is added to data through the processes of coding, selection, categorisation and abstraction that turn it into useful information to the person receiving it. This is information transfer as a process of construction. But it may also involve deconstruction. Data may exist as tacit knowledge in already constituted practices and flows. To become information, this knowledge must be shorn of context and turned into something abstract. Information in this sense is deconcretised knowledge rather than processed raw data. Through further deconcretisation, according to formal rules, information may be represented as discrete items of data (Dahlbom and Mathiessen, 1993; Hakken, 1999). In addition to adding value to processes, information technology may also be used to model and simulate reality and abstractions of it. As with extending the sensory range, the outcomes

of these activities are dependent upon the theoretical models used to generate them.

Adding Value to Educational Interventions and Transactions

Sensory perception, and conceptualisation through coding, selection, categorisation and abstraction, may be enhanced by technology but happen within a social context. In educational terms, the context is provided through interventions and transactions. Educational transaction may involve giving and receiving information, the performance of certain skills, the construction of knowledge, social interaction, and self-expression, including expression of beliefs and creativity (Dillon and Prosser, 2003).

Much of the day-to-day use of ICT involves doing things with greater efficiency and effectiveness, especially working with information, skill and knowledge. In the ICT literature in education, there are many examples of adding value to routine interventions and transactions in all disciplines.

Examples of innovation, of doing things in genuinely new ways, are less common. There may be innovative approaches to access in terms of both widening participation and making content more comprehensible, and quality in terms of improving knowledge and understanding. But most claims of innovation are associated with creativity, involve the social and expressive dimensions of learning, and take in the wider cultural concerns of context, meaning and discourse. Innovative qualities are more likely to be associated with the way the social actors involved in the educational situation work with the technology, rather than with the technology itself.

The wider perspective encompasses the symbolic forms of language, images and, especially from a technological viewpoint, multimedia. The five senses of sight, hearing, taste, smell and touch are re-visited for ways in which they can be adapted through technology to provide educational experiences. Multimedia design is an extension of instructional design. Both utilise educational and design principles but whereas instructional design is concerned primarily with text, multimedia design is concerned with the interaction of text, imagery and sound. Virtual reality adds other sensory experiences to the mix, but as yet is not part of mainstream educational experience.

4. IMPLICATIONS FOR TEACHING

The information transmission view of learning is a form of constructivism based on Kantian epistemology, one that assumes that the

individual receives data from the external world and processes these data by categorising them. It assumes that data are objective entities that, through the senses, enter the mind. The 'act' of construction is located in the mind. Moreover, if the data are objective entities, then they can be pre-specified and their assimilation quantified. The assumptions embodied in this view impact on matters such as: how we teach about information and communication and their associated technologies, how we use ICT in our teaching and where in the curriculum these responsibilities should be located.

Teaching about Information, Communication and Associated Technologies

The emphasis here on *information, communication and associated technologies* is deliberate. Arguably, this is the arena through which it should be possible to give definition to the notion of the specialist teacher in ICT. What knowledge and expertise would such a teacher have? By definition this is a transdisciplinary field, that is, it operates across and between disciplines. The specialist would understand the fundamentals of information and communication theories and their relation to theories of both learning and teaching. An understanding of educational theory and practice would enable him or her to make decisions about what is educationally desirable. A sound grounding in media and cultural studies would provide a context for information in society and the ways it is communicated. He or she would also understand the fundamentals of computer science, would know something of the design of educational multimedia and virtual learning environments and the types of educational transaction they support.

Few teachers have these credentials; there are not the courses to provide them. Most teachers of ICT come to their work *via* circuitous routes. Even if they had the ideal specialist background, there is seldom an opportunity of utilising such expertise in a coherent way since responsibility for some, but by no means all, of the specialist parts of ICT are scattered elsewhere in the curriculum. Instead, the widely held but seldom articulated information transmission view of learning has led to a preoccupation with efficiency and effectiveness in information transmission and processing. Often the two are conflated with the result that there is a general lack of clarity about what constitutes an educational benefit from ICT (Reynolds *et al.*, 2003). This in turn has led to a selective focus on certain 'measurable outcomes', notably proficiency in using the technology, that is, with skills.

As with any technology, there is a body of procedural knowledge that has to be learnt and put into practice. This can be acquired

through training, but will only be refined and perfected through constant use in professionally relevant situations. The obsession with skills at the expense of developing a viable theory of ICT in education, a meaningful academic content for the ICT specialist and a curricular niche for ICT has constrained education systems worldwide.

Teaching with Information and Communication Technology

All disciplines use ICT. Just as it is possible to say something about the role of the specialist in ICT, so it should be possible to say something about the things that subject specialists need to address within their disciplines.

A paradox of information is that those who know a lot about a subject are more aware of what they do not know than those who know less. The more an individual knows, the more aware he or she is about the information he or she needs to acquire (Macdonald, 1998). Those who have information are better placed to demand information than those who do not, hence the importance of meta-cognitive knowledge. It has been said that education should protect us from information: in other words it should provide the individual with the means to make informed and discriminating choices about information and the way it is used.

Making discriminating choices requires teachers to re-examine the fundamental premises on which their subjects are based and how access to the increasing amount and variety of information, and the technology for working with it, is challenging those premises. They might then be better placed to help students understand some fundamentally important and interrelated matters such as: the nature of disciplines, their methodologies, and how they use information; ways of addressing validity and provenance of information, how it is corroborated and its limitations; the cultural and social values underpinning information and its use; frameworks for connecting ideas and concepts from different disciplines.

There is little evidence that this examination of subject matter from within is taking place. Not only is there considerable variation in the use of ICT within different subjects (Selwyn, 1999b), there has again been a preoccupation with procedural knowledge and skills: knowledge of software and applications and proficiency in using them. The representations of software of many non-specialist teachers are idiosyncratic, fragmentary and transient, with imperfectly learnt links and false assumptions, that are manifest in what Hale (1998) calls 'hazyspace'. Not surprisingly, these teachers are concerned that the skills of their students are more advanced than their

own. There will always be students with more technical ability than their teachers. They have the time and they take risks. If education is viewed as a partnership, it should be recognised that students bring to it a lot of raw skill. What teachers bring is wisdom and guidance. They have the craft knowledge of teaching and learning. They are the experts and enthusiasts in their subjects. They provide the contexts in which students make sense of information. They help students make sense of who they are as individuals and in relation to others.

5. TOWARDS A RECONCEPTUALISATION OF ICT IN EDUCATION

The transmission approach treats information as 'bytes' that can be assembled and disassembled, its assimilation in learning measured and quantified in certain ways, with attendant forms of accountability that give rise to particular emphases in teaching. It belongs with the generation of stimulus-response, drill and practice educational software. Because it has some utility, and because the inter-relationships between information theory and educational theory are seldom explored, information transmission has become entrenched in procedures and pedagogies as complex forms of, for example, embodied (how we do things here) embedded (in systemic routines, roles and formal procedures) and encoded (conveyed by signs and symbols) institutional knowledge (Blackler, 1995; Saunders, 1998).

However, it will be apparent from the foregoing that the information transmission approach to learning has serious limitations: it is theoretically inadequate, it is epistemologically limited and, as it narrows our perceptions of the field, it is educationally restrictive. The practical inadequacies of the approach give rise to very specific ways of dealing with information and communication and, as we have seen, these in turn impact on our conceptions of the nature of subjects relative to information and communication, and of the specialist teacher of ICT and how he or she works with ICT.

Nowadays software is increasingly 'intelligent' and 'intuitive'; it is adaptive to both the user and context in which it is being used. An infrastructure of global networks has reduced the linearity and path dependency of information flows. Soon, the World Wide Web will be structured 'semantically' where software agents will carry out sophisticated tasks tailored to the needs of individual users (Berners-Lee *et al.*, 2001).

New conceptions of constructivism have been proposed that are more in keeping with both technological developments and current thinking about the nature of learning. One such is as follows: data

are seen as the outcome of the way in which individuals are in constant interaction with their environment. In this view data are not objective but are the result of human–environment transactions. The act of construction, the ‘selection’ of information, is not something that the mind does in processing all the data it receives through the senses, but is constituted in the interaction, and thus may be termed ‘action-theoretical’ constructivism. In linking knowledge to action, action-theoretical constructivism is compatible with Dewey’s transactional theory of knowledge where the transactions are situated socially and culturally (Vanderstraeten, 2002).

Rather than seeing people and nature in opposition, Dewey believed in their fundamental unity. He rejected Kantian and Cartesian doctrines that respectively argued for the existence of things in themselves and a self-conscious mind that exists independently of an extra-mental realm (Edgar and Sedgwick, 2002). For Dewey, experience is the function of habits, of active adjustments and readjustments, of coordination and activities, rather than states of consciousness. In this view, human ideas and the environment in which they are generated have a reciprocal relationship.

Dewey was heavily influenced by the philosophical implications of Darwin’s ideas about evolution and natural selection. The sociocultural frame that now accommodates Dewey’s thinking is compatible with the modern evolutionary synthesis that links biological evolution and cultural change. This takes in changes made by organisms on their environments through a series of self-induced selection pressures. In the case of the human species these activities include ‘culture’ in the broadest sense (Odling-Smee, 1995). In such a synthesis, evolutionary theory needs a currency – ‘fitness’ in this case – through which adaptations to environment can be measured. A corresponding currency in sociocultural theory could be information. Information in this sense is not simply a transmitted commodity; it is integral to the constant construction and reconstruction of meaning between people and their environment.

A modern extension of Dewey’s thinking is ‘education as practical intersubjectivity’ which sees education as a process of acculturation, not a one-way process in which culture is transferred from one to another, but a co-constructive process in which both participants play an active role (Biesta, 1994). The starting point is not in the individual behaviour of the participants, but the intersubjective field in which they interact, a field that is at the same time established by intersubjective cooperation. Changes brought about in the individual predispose him or her to react in future situations in a more specific way – the acquired predispositions that Dewey called habits.

Practical intersubjectivity requires re-visiting epistemology, methodology and pedagogy *relative* to the information and the technology now available. For example, specialist teaching in ICT might involve examining the theories underpinning computer applications in subjects and the assumptions they make about the nature of knowledge. It might challenge the way software applications legitimise, ignore or even de-legitimise epistemological methods such as deduction, induction interpretation, intuition and introspection (Hodgson, 1993). And, given that the perception of knowledge as an 'objectively ordered stock of intrinsically ordered facts' is becoming one of a 'constantly changing artefact of intersubjectively mediated judgement' (Sandbothe, 2000), the specialist might explore the relationship between information and different forms of knowledge – rational, objective, tacit, problematic, experiential and so on.

6. CONCLUSION

What we now have in ICT is a mixed economy of information transmission and action-theoretical forms of constructivism. The mixed economy reflects a wider epistemological debate that takes in, amongst other things, the nature of mind and consciousness (Edwards, 2001; Murphy and Iverson, 2003), educational paradigms (Pring, 2000) and educational research (Remenyi and Williams, 1996). In order to conceptualise the ways in which the different forms of constructivism are interacting with technology and information we can utilise ecological metaphors.

The term ecology is used in the sense of the totality of interactions between an organism and its environment or, in the case of humans, the complex interactions between mind, action and environment (Cole, 2000). Just as an ecosystem can be understood through its interacting subsystems, so an ecology of education would subsume ecologies of learning, knowledge, ideas and so on. Such ecologies may provide a means of establishing how 'the weaving together of mind and action, individual and group, macro-and micro-contexts and historical framings [allow] us to see how individuals are positioned within the possibilities of the actions available to them and what they make of those opportunities' (Edwards, 2001).

In an 'ecology of ideas', competing ideas can exist simultaneously so long as they have some utility. As Small (2003) observes, a successful theory does not necessarily eliminate its predecessors: 'we still make use of Newtonian mechanics in everyday situations, while recognising that it has been overtaken by a more encompassing theory of relativity'. As ICT continues to develop in response to technological change and changes in the epistemologies of its contributing disciplines,

as it forms an identity as a field in its own right, we might expect to see a gradual decline in the information transmission approach to learning and a corresponding rise of emergent approaches better adapted to new practicalities and new thinking.

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Correspondence

Professor Patrick Dillon
The Telematics Centre
School of Education and Lifelong Learning
University of Exeter
Heavitree Road
Exeter EX1 2LU
E-mail: p.j.dillon@exeter.ac.uk