Tool, tutor, environment or resource: Exploring metaphors for digital technology and pedagogy using activity theory

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Abstract

Describing digital technologies as tool, tutor, environment or resource in pedagogical contexts is common, and this paper examines the metaphorical nature of these descriptions and their implications for digitally-based teaching and learning practices. To compare the metaphors, the paper first develops a model of pedagogy derived from Activity Theory. It explores the implications of these metaphors in practical situations by examining a set of 60 digitally-based activities, collected as part of a snapshot survey of a representative sample of maintained schools in England, to draw out their pedagogical characteristics. In conclusion the paper discusses the issues raised by the analysis for the relationship between use of digital technologies and learners’ attainments, and the efficacy of the model that has been developed.

Keywords: Teaching/learning strategies; Intelligent tutoring systems; Interactive learning environments; Pedagogical issues

1. Introduction

Metaphors play an important role in enabling people to make sense of and learn how to use software applications (Norman & Draper, 1986). Conversely, finding the correct metaphor to help users understand digital technologies is a key aspect in designing and implementing new applications. “Desktop” and “window” are familiar to every user of a PC, enabling them to understand and interact with the technology, and yet it is also clear that the terms are used metaphorically. Metaphors both reveal and conceal, or lie, depending on one’s point of view, but they play a significant part in our lives both with and without digital technology (Lakoff & Johnson, 1980). Unlike similes metaphors bring together apparently unrelated objects in a dynamic synthesis that illuminate both objects in new ways. As Aristotle put it, metaphors “convey(s) their information to us as soon as we hear them”. (Rhetoric 1410b14-24). He goes on to argue that they are more than rhetorical devices, having a cognitive function which gives the hearer new insights into a situation (Eco, 1984).

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This paper examines four of the more common metaphors for digital technology used in pedagogical settings: tutor (e.g. Underwood & Brown, 1997); tool (e.g. Somekh, 1997); environment (e.g. Papert, 1980); and resource (e.g. Scrimshaw, 2004). They have arisen partly as a result of applying different theoretical approaches to learning in technological settings, and partly out of the ways in which digital technologies have been integrated into education. A central issue discussed in this paper is the nature and extent of the impact that these approaches have on digitally-based pedagogical activities. To this end the paper first develops a model of pedagogy derived from Activity Theory as a framework for comparing the metaphors, before exploring their implications using a data set of 60 digitally-based activities, collected as part of a snapshot survey from a representative sample of maintained schools in England (Stevenson, 2004). In conclusion the paper discusses some of the issues raised by the metaphors for the use of digital technologies in teaching and learning, and their relationship to learners’ attainments.

2. Modelling pedagogy with activity theory

Pedagogy can be understood pragmatically as “any conscious activity by one person designed to enhance learning in another” (Watkins & Mortimore, 1999) or as understanding – “the ‘science of teaching’” (Simon, 1999). Central to any conception, however, is the relationship between teachers and learners which develops over time, driven by the dynamics of the activity (diachronic aspect), and the relationships that they create across time (synchronic aspect). Learning takes place through the interplay of context, purpose, action sequences, and personal relationships. A framework derived from Activity Theory is described in this section to model this relationship, which brings together both the diachronic and synchronic aspects of pedagogical activity.

Activity theory (AT) is useful in situations using digital technology because it provides a systematic means of describing and analysing artefact-based interactions within a social context. Since the seminal collection by Nardi (1996), AT has been used in variety of ways to design, model and evaluate contexts that make use of digital technologies. As well as frameworks for designing learning environments (Jonassen & Rahrer-Murphy, 1999), and e-learning content (Mwanza & Engeström, 2005), AT has been employed to evaluate the impact of digital technologies in an Australian Primary School (Romeo & Walker, 2002); Singapore Schools (Lim & Hang, 2003); UK Higher Education (Issroff & Scanlon, 2002); and ICT-based research projects (Bottino, Chiappini, Forcheri, & Molfino, 1999). More recently it has provided a framework for analysing the use of mobile devices such as PDA (Scanlon, Jones, & Waycott, 2005), and the interpretation of graphs by scientists (Roth & Lee, 2004).

In this paper, AT is used to generate a model of pedagogical activity which combines intentionality, processes and outcomes in a single system. Leont’ev’s (1978) concept of an activity structure is used as a framework to model how pedagogical activities develop over time. Engeström’s (1987) notion of an activity system provides the structure for describing pedagogy across time. The model presented in this paper has developed over a number of years, and has been used as the basis for a pedagogical extension of the LOM metadata framework (Stevenson, 2003) and a Becta-funded project (Stevenson, 2004).

2.1. Pedagogy over time (diachronic aspect)

Pedagogy is purposeful behaviour with specific motives and desired outcomes, which means it can be analysed as an activity structure. In Leont’ev’s (1978) scheme, an activity is broken into a series of actions, forming a sequence of discrete processes with their own clear goals, that together are needed to achieve an activity’s overall aims. Actions themselves are made up of operations with material objects which form a set of conditions that enable the action sequences to be achieved. Table 1 illustrates how these three interconnected

<table>
<thead>
<tr>
<th>Activity: purpose expressed in aims and outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action: stage 1</td>
</tr>
<tr>
<td>Operation</td>
</tr>
<tr>
<td>The numbers of actions are operations are purely illustrative.</td>
</tr>
</tbody>
</table>
aspects—activity, action, and operation—all contribute to achieving a desired outcome by their mutual conditioning of one another. The number of actions and operations shown in Table 1 is purely to illustrate how an activity is structured. In practice, an activity may consist of several actions and their associated operations.

Pedagogical activities are defined by their purpose, expressed as intended aims and specific outcomes in a particular epistemological domain. Outcomes can be classified in terms of the factual knowledge, conceptual understanding and/or skills to be developed by the activity, using statements drawn from a formal curriculum. Alternatively, they could be goals set by learners for themselves with no formal expression at all. In both cases, having some criteria and methods for deciding whether and to what extent the outcomes have been met is important, and needs to be specified either explicitly or implicitly.

Actions, referred to in Table 1, form the structure and sequence of a pedagogical activity, and connect its “over time” dimension with the “across time” aspect. A detailed description of their structure and function will take up Section 2.2.

Operations cover a range of different factors related to the context in which the activity takes place. They include who participates, how the digital technology is organised and distributed, and the nature of software functionality and learning materials that are available. Using the categories of ImpaCT2 (Comber et al., 2002), the configurations of hardware can be identified as:

- Single machines and/or wireless laptops which might be used by teachers or learners either on-line or face-to-face.
- Clusters of computers (2–5 machines) which may be part of a classroom or be available in different places for learners to use.
- Small suites of machines (5–12 machines) located in a classroom or wirelessly connected for group activities.
- Rooms with more than 12 machines.

Software functionality refers to the various types of applications that might be used during an activity. Developed from the Becta software survey (2000), these include:

- Programming environments (e.g. Logo; Java; Visual Basic).
- Generic applications (e.g. word processor, spreadsheets and databases).
- Presentation and delivery applications: (e.g. VLEs; Powerpoint type applications).
- Communications tools (e.g. synchronous and asynchronous, email, SMS).
- Topic specific applications (e.g. tutorial packages).
- Content-free environments: (e.g. CAD/CAM, Video editing, Dynamic Geometry, data capture and logging, graphing).
- Web browsers.

Finally any material used in the activity is referred to by some unique identifier which could be a URL, bibliographic information, or reference to a database of materials.

2.2. Pedagogy across time (synchronic aspect)

The “across time” (synchronic) aspect of pedagogy is concerned with how teachers and learners interact with one another within the social context of an activity, and is modelled using the idea of an Activity System (Engeström, 1987). Modelling an artefact-based activity as a system of seven interconnected elements shown in Fig. 1, an activity system’s dynamism arises from resolving the tensions and contradictions that exist within and between these seven elements. These elements mutually condition one another, with the outcomes acting back on the system to change the relationships between the elements.

In Fig. 1, the Subject of this system is the individual or groups of teachers and learners who are the focus of analysis. Together they work on their Object which is a task designed to produce Outcomes in terms of knowledge, skills and understanding. Teachers and learners form the Community, which is the human context of the activity, as they engage in tasks using shared Artefacts. Management is organised horizontally between the
members of the community and vertically in terms of power and status. Finally Rules covers a range of conditions that both enable and constrain the activity, including the digital infrastructure, norms and conventions of behaviour at the site of learning, and any explicit and implicit regulations such as the curriculum or policy decisions. It is not a linear, input–output model, but tries to capture the complexity of interactions which determines a system’s, usually unpredictable, trajectory (Kuutti, 1996).

The Activity Pentagon, shown in Fig. 2, is a re-organisation of Fig. 1 above. It is topologically equivalent to the more familiar triangular representation, containing the same relationships and elements. It is useful in two ways since it makes explicit three sets of connections that are only implied by Engeström’s model – rules and artefacts, rules and management, and management and artefact – and draws out different facets of the system for analysis. Rules and artefact bring into focus the relationship between the functionalities of technology as

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Fig. 1. Pedagogical activity system for synchronic interactions.

Fig. 2. Activity Pentagon. This is topologically equivalent to the triangular representation in Fig. 1, but makes explicit three sets of key relationships: rules & artefacts, rules & management, and management & artefacts.
indicated by its designers and its possibilities for its practical use (Squires & McDougal, 1994). Management and artefact highlights the connection between how the technology is managed in practical situations, and its intended use. Finally the relationship between rules and management is significant for pedagogical activities since these are often norms and policies decisions that have a direct bearing on what is acceptable in terms of how activities are embedded and develop in specific contexts. The pentagon places the “object” at the centre of the relationships with outcomes in the plane perpendicular to the page, capturing the symmetry and equality of factors. Second, different facets of the activity system can be identified to aid with the practical analysis. Five facets are shown in Fig. 3, which bring together different sets of elements in a systematic way to show the internal structure of the relationship between teachers and learners.

The principle use of the Activity Pentagon is to model the actions associated with an activity, referred to in Section 2.1. Each of the five labels shows a particular facet of an action, and how they relate to the objects and outcomes. From this point of view, an action consists of:

- **Roles** that shape the relationships between teachers and learners. For example, formal contexts such as lectures have relatively simple roles involving exposition, questioning and summarising with a linear development over time. Discussions, on the other hand, are more complex both in terms of their organisation and development, since both learners and teachers adopt multiple roles at different stages (Stevenson & Wetterling, 2003).
- **Organisation** identifying how teachers and learners are grouped and managed. For example teachers can work with whole groups on their own or in teams, and learners can work in small groups or on their own.
- **Use** dealing with how a range of artefacts including digital technologies, chalkboards, and materials designed for learning, are actually employed in practice. This can range from the teacher through to individual or groups of learners using the artefacts.
- **Functionality** identifying the range of possible uses for artefacts as specified by their designers, which are made available to an activity’s participants (Squires & McDougal, 1994).
- **Operations** that represent the space of possibilities for an action provided by the technologies and the site being used. It is built on the interplay between the physical distribution of resources such as hardware, software and learning materials, and their management within a given context which both enable and constrain activities.

Turning this outline into a practical tool for describing pedagogical activities implies relating the model’s categories to actual actions and operations in a systematic way. A framework developed and validated by the OECD/CERI (1999) case studies of ICT, gives a series of statements that describe ICT-based activity relate to the roles, organisation and usage. These are shown in Table 2.

![Fig. 3. Aspects of the Activity Pentagon, which are used to model actions.](image-url)
Table 2
Descriptors developed for case studies of digitally-based activities by OECD/CERI (1999)

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Roles</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Teachers working with whole group</td>
<td>(1) Teachers giving information</td>
<td>(1) Teacher using ICT</td>
</tr>
<tr>
<td>(2) Teacher’s teamwork</td>
<td>(2) Teachers directing questions and answers to reproduce facts</td>
<td>(2) Learners using ICT initiated by the teacher</td>
</tr>
<tr>
<td>(3) Learner’s teamwork</td>
<td>(3) Teachers directing conversation</td>
<td>(3) Learners using ICT initiated by themselves</td>
</tr>
<tr>
<td>(4) Learners working individually</td>
<td>(4) Teachers stimulating reflections or other critical analysis</td>
<td>(4) Learners interacting via ICT, initiated by the teacher</td>
</tr>
<tr>
<td>(5) Learners working with whole group</td>
<td>(5) Learners directing conversation with peers or teacher</td>
<td>(5) Learners interacting via ICT, initiated by themselves</td>
</tr>
</tbody>
</table>

Table 3
Sample types of pedagogical actions obtained from Table 2

<table>
<thead>
<tr>
<th>Pedagogical Actions</th>
<th>Roles</th>
<th>Organisation</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>(1) Teacher gives information</td>
<td>(1) Teacher working with whole group</td>
<td>(1) Teacher uses the ICT</td>
</tr>
<tr>
<td>Exploration</td>
<td>(5) Learners directing conversation with peers or teacher</td>
<td>(4) Learners working individually</td>
<td>(4) Learners using ICT initiated by themselves</td>
</tr>
<tr>
<td>Collaboration</td>
<td>(4) Teacher stimulating reflections or other critical analysis</td>
<td>(3) Learner’s teamwork</td>
<td>(4) Learners using ICT initiated by the teacher</td>
</tr>
</tbody>
</table>

Each column in Table 2 shows a spectrum of possibilities in each category, which ranges from teacher-centred through to learner-centred behaviours. By selecting combinations of statements from each column of the table, different pedagogical “building blocks” can be identified. Table 3 illustrates some of these possibilities, labelled “Presentation”, “Exploration” and “Collaboration”.

A sample pedagogical structure built from the “blocks” in Table 3 starts with a presentation, goes on to learners exploring on their own, and finishes with the teacher working alongside the learners to help them develop their understanding. The structure is summarised as a sequences of phases [[1 1 1] [5 4 4] [4 3 4]], where the order of the numbers in each bracket is always [Roles, Organisation, Tools]. In fact any permutation of the order can be used provided it is consistently applied, and each triple represents an independent pedagogical form.

Other forms of activity can also be captured. For example, a “synchronous on-line discussion” could be described as a “presentation phase” followed by a “collaboration phase” in which learners work together and direct conversation with peers or teacher, interacting via ICT initiated by themselves. Finally a “report-back” phase in which learners work with the whole group directing the conversation using ICT. Labels for these phases can be debated, but they illustrate how a whole activity can be summarised by a sequence of one, two or more actions described using the triples.

2.3. A model for pedagogy

Combining the “across time” and “over time” dimensions of pedagogy gives a model, shown in Fig. 4, which links intention, structure, and outcomes within a context defined by a range of practical affordances and constraints.

Over time the structure of an activity is expressed through a sequence of actions aimed at achieving its outcomes, with the operations aspects of Fig. 4 referring to the practical possibilities and constraints for any particular type of action. Other key factors that determine how activities unfold include curriculum requirements which determine the required-desired outcomes, together with pedagogic preferences of teachers and institutional beliefs and decisions about how digital technologies can/should be used. Across time elements are made
up of the interplay of roles, tools and organisation, conditioned by the context. As “slices” corresponding to the actions of the activity they capture its detailed evolution, providing a way of relating pedagogical processes with its outcomes. However the slicing is not determined by the passage of time but by the internal logic of an activity, represented by specific combinations of roles, tools and organisation, dynamically related to the activity’s outcomes.

3. Modelling digitally-based pedagogical activities

The model described in Section 2 was used in a Becta-funded project, which aimed to develop measures of attainment for Information and Communication Technology (ICT) (Stevenson, 2004). Building on ImpaCT2 study (Harrison et al., 2002) this study aimed to create a measure(s) capable of tracking ‘snapshot’ data to monitor how ICT could be used to support attainment. Following consultations with the Local Authority responsible for education in and around a large northern UK city, and after viewing school inspection reports by OFSTED, a representative sample of 24 sites was selected. The sites covered all: compulsory age phases (5–18); sizes of site; locations (inner city, town, semi-rural and rural); types (comprehensives, grammar, Technology Colleges, Special Schools); and socio-economic compositions as measured by the number of pupils receiving Free school meals and the level of English language support. 60 ICT-based activities were observed at random across all English and Welsh National Curriculum Key Stages during a three-month period, involving 48 teachers and 58 groups of learners. Three aspects of the study are presented in this section to provide background on how the model was used, and to outline some measures and concepts that will be used in the final part of the paper to discuss the metaphors. The first part of this section describes the process of data collection and storage using the model, implemented as a relational database. Next, two sets of scores that were created to summarise teachers and learners’ experience of ICT are described, and the final part outlines the pedagogical “building blocks” that emerged from the activities using statements from Table 2.

3.1. Data collection

The aim of the study was to undertake a “snapshot” survey of digitally-based activities, and examine them for factors that seemed relevant to developing learners’ attainments. To that end data was collected from each activity, related to all aspect of the pedagogical model, by:
• Interviewing teachers before and after an activity about its aims, and to jointly assess the extent to which its intended outcomes were achieved.
• Observing and recording activities, taking account of their sequencing, organisation, and the roles adopted by leaders and learners as they used ICT according to the categories of the model.
• Surveying sites of activities and their participants to build up a profile of the those taking part, and the conditions in which the activities occurred.

The observation and interview data collection instruments were taken from the model fields, shown in Fig. 5, which gives an example of how each activity was recorded in the database.

Fig. 5 shows a complete activity in which each section corresponds to an aspect of the model:

• **Activity: purpose and domain focus** contains the fields stating the knowledge, skills and understanding; the purpose; domain focus; and ICT development that are intended by the activity. A description of, and preparation for the task are also given.

![Fig. 5. The full description of an activity obtained through observation, and entered into a database. Each part of the entry is related to the aspect of the model.](image-url)
- **Activity: outcomes** contains an evaluation of what learners have achieved through the task in terms of the domain focus, agreed by the teacher and the observer. Activities were rated on curricular, ICT and personal factors using a scale from 1 (all achieving desired outcomes) through to 6 (most achieved some of the outcomes).

- **Actions: structure and sequence** on the right-hand side of Fig. 5 shows the pedagogical structure of the activity including how the roles, organisation and tools were used, together with short text descriptions.

- **Operations: context** at the bottom of Fig. 5 on left-hand side is the section associated with the details of date, time, level of participants, domain pre-requisites, and hardware/software used. Details of the site and the URLs for the resources used have been removed to anonomise the example, but they can be added easily.

Data was also collected about the sites and the profiles of the teachers and learners, which when summarised, were set against the outcomes and structure of the activities observed. Two sets of scores for teachers’ and learners’ experiences of using digital technologies for pedagogical purposes were created. These are described in the next two parts, and the section concludes with an analysis of the pedagogical structures that were observed across all the activities.

### 3.2. Teacher ICT experience score

Forty-eight teachers took part in the survey, divided equally between primary and secondary sites, and covering the main curriculum areas (Mathematics, English, Science, History, Geography, ICT, and Design and Technology). Information was collected on the teachers’ academic and professional backgrounds, together with their experience of using ICT in formal settings and their home access. Given the importance of teachers’ experience and confidence in using ICT for teaching and learning, a score was developed to summarise their experience of using ICT. The score was obtained by taking an average of their responses to questions about the type of their ICT usage in school, the type and frequency of their access to technology, whether they have been formally trained in ICT, and the proportion of their teaching career that they have used ICT. The teachers had experience of ICT in teaching ranging from one to 20 years, and they fell into one of three distinct groups:

- **Teacher ICT experience group A** represented those with a long teaching career, but who made comparatively little use of ICT for teaching or administration. 10% of the teachers were placed in this group.

- **Teacher ICT experience group B** represented those with a long teaching career but who used ICT extensively for both teaching and administration. 43% of teachers were assigned to this group.

- **Teacher ICT experience group C** consisted of teachers who had used ICT for their entire career. 47% of the teachers fell into this category.

Teachers in groups A and B had gained ICT experience relatively recently in their comparatively long teaching careers, while those in group C had ICT as an integral part of both their initial training and teaching experience.

### 3.3. Learners’ groups ICT experience score

Fifty-eight groups of learners took part, ranging in age from 5 to 18 year-olds, split 50:50 between primary and secondary age phases. A score was developed for each group’s ICT experience by averaging their experience of software applications (small software, content-free, programming, integrated learning systems, CD-ROMs, presentation, handheld technology, web browsers, generic), and their frequency of ICT use in school. (e.g. everyday, more than three times per week, twice per week, once per week, once per fortnight). The score did not deal with learners’ non-formal experiences, since this proved difficult to collect systematically. Although less reliable than the teachers’ scores since the data was collected for groups of learners, nonetheless the scores still provided an indication of learners’ collective experiences.
3.4. Pedagogical structures

From an analysis of the database two basic teaching and learning structures emerged as “building blocks” for activities:

- **Teacher-centred**: teachers introduced the task using the ICT to the whole group of learners, and asked learners questions to check facts or to confirm that they had understood what they had to do.
- **Learner-centred**: learners were directing the conversation as they worked on the task using ICT that they were set or chose, either individually or in small groups. Teachers worked with individuals or small groups, asking questions that encouraged critical reflection or to confirm understanding.

Given that Table 2 gives 150 different possibilities, it is interesting that these two types emerged. On the one hand it matches expectations that these activities, sampled from formal schooling contexts, should fall into these structures, and on the other gives support for the reliability and expressive power of the model. The 60 activities observed had one, two or three phases, which were identified and described by the observer using combinations of statements from the Table 2. Ninety percent of the activities had at least two phases, usually with a teacher-centred introduction and a main body involving learner-centred activities. Sixty percent had three phases, which usually involved a final section of teacher-centred activity.

4. Analysis of the metaphors

What are the practical consequences for pedagogy in using the four metaphors of tool, tutor, environment or resource? This section reports and analyses the set of activities observed during the snapshot survey described previously, classified according the metaphors. Each of the following sections begins with a description of a metaphorical approach derived from literature. This is followed by the criterion used for the categorisation based on the tasks undertaken, together with examples to illustrate how they were applied. Details of the number and location of each category, learner and teacher confidence scores, and pedagogical structure then follow. Finally there is a discussion to draw out the implications of each metaphor for pedagogy, which sets it in a wider context.

4.1. Digital technologies as resource

Known variously as e-learning, or technology-enhanced learning, this approach involves adapting digital technology to purposes defined by some form of curriculum. Ranging from teachers using presentation software with interactive whiteboards in face-to-face sessions through to completely on-line courses, choice and control of the technology are determined by the needs of the curriculum, institutional policy and commitments, and the discretion of teachers (Scrimshaw, 2004; Condie & Munro, 2007). As a metaphor “resource” identifies the sense in which digital technologies are “present-at-hand” and available for use by teachers and learners, but also highlights the need for human agency in making them “ready-at-hand” to serve some purpose (Heidegger, 1962).

Although there have been a large number of policy initiatives over the past 25 years aimed at integrating “ICT” into pedagogy, the outcomes have been variable (Harrison et al., 2002; Twinning et al., 2006; Watson, 2001). Curricular constraints, coupled with practical resource allocations and the availability of appropriate software applications within day-to-day practices, have created a complex situation. Apart from those aspects of the curriculum which make technology the object of study, there is no overwhelming pedagogic reason or other compulsion to use digital technologies in the “paper and pencil” curriculum. Leaving teachers to be the final arbiters about “when and when not to use ICT” (Preston, 2004) within this context has produced a very variable integration of technology into existing practices with a varied set of educational outcomes (Harrison et al., 2002). As a consequence, much of the research about the impact of ICT on education has been in terms of analysing teachers and their “ideologies”—networks of attitudes, beliefs and practices that have evolved over a period of time through processes of professional enculturation (Stevenson & Hassell, 1994). This approach draws together and attempts to systematise the different forms of pedagogy that have emerged from the
embedding of technology in formal educational settings such as classrooms (e.g., Cox & Webb, 2004; Kenni-
well, 2001; McCormick & Scrimshaw, 2001; Preston, 2004). Digital technology have either been adapted to
suit non-digital contexts or generated artefacts that reproduce existing practices such as Interactive White-
boards and Virtual Learning Environments.

Viewing digital technologies as a resource for pedagogy highlights the central role that teachers play in
identifying, selecting, and implementing “ICT” according to their needs. It also implies that what is acceptable
as “digital technology” for pedagogy is reliant on this choice, so that some applications do not appear in educa-
tional settings because they are perceived as not matching with the curriculum (Squires & McDougal, 1994).
Thinking of digital technologies as a resource leads to a range of unique, often ingenious, and usually idiosyn-
cratic ways of using “ICT” by different practitioners.

Tasks were placed in this category if their primary aim was to support the teaching of specific aspects of the
non-digital curriculum. These included, for example:

- An introduction to the topic of Chinese History.
- Use of interactive animations by the teacher to illustrate and discuss some difficult concepts in
  trigonometry.
- A basic introduction to electrical circuits, using presentation resources.

Forty-three percent of the total activities in the sample were assigned to this approach, and were more or
less evenly spread across the entire range of ages from 5 to 18 year-old at the 10% level, with the exception of
year 7 (age 11–12) which made up 20% of the activities. Of the 26 activities in this category, half used single
machines and 42% were in rooms containing more than twelve machines. Relating the learners’ experience
scores with their age, expressed by their year group, gave a Pearson correlation of 0.389 that was significant
at 5% level ($r = 0.330$, df = 24). This indicates some association between the development of ICT skills and
learners’ ages, but in the context of using technology primarily for teaching.

Software used in the activities consisted of: generic applications (30%); web browsers (20%); subject specific
(20%); and presentation applications (15%). Matching the task with the choices of application and location
suggest that in three quarters of the activities teachers chose applications that gave them a high degree of con-
trol. Teachers were “subversive adaptors” of digital technology (Squires, 1999) in this approach, as they trans-
lated the “present-at-hand” into the “ready-at-hand”, driven by the demands of the curriculum.

All but one activity had a three part pedagogical structure in this category. Beginning with a teacher-cen-
tred introduction, there followed a learner-centred section, which, in half the activities, did not involve the use
of technology. The three part activities concluded with the teacher directing conversation aimed at checking
pupils’ understandings that the activity intended to develop. Teachers in experience group C predominated in
this type of activity, and were twice as likely as experience group B to use this approach, and eight times more
likely than group A.

Where single machines, and, in most of these cases, whiteboards were used, they reproduced the function-
ality of the chalkboard using the new technology. Suites and rooms made the technology a central factor in the
organisation of teaching and learning environments with the corresponding change in practice. Much of the
literature on teacher’s attitudes to technology is based on accessing how configurations such as suites and
rooms have affected their practices (e.g. Preston, 2004; Stevenson & Hassell, 1994). Amongst other things these
studies report the anxiety and loss of control that teachers experience, and focus on those teachers who would
fall into Teacher groups A and B in this study. The fact that teachers in Group C predominate in this
approach to using technology suggests that the situation analysed in previous literature maybe changing.
From this point of view the impact of single machine and whiteboard on practice is not perceived as threat-
ening, and may go someway to explaining how the combination has become readily embedded in pedagogical
practices (Becta, 2006).

4.2. Digital technologies as tutor

Casting computers as tutor involves using digital applications as a pedagogical medium to coach, instruct,
 diagnose, practice, or “scaffold” learning. Drawing on a range of learning theories, digital technologies are
used for a variety of purposes from skill mastery through to developing conceptual understandings (Ravenscroft, 2001). Integrated learning systems (ILS), for example, draw on behavioural approaches to learning in developing skill mastery, and, in some cases, problem solving skills (Underwood & Brown, 1997). ILS structure and function typifies this approach, consisting of a detailed model of the knowledge to be learnt, and a record of learners’ responses in relation to an ideal “learner model”. Algorithms in ILS record, adapt, and select learners’ tasks from a pre-prepared bank of material, on the basis of learners’ prior responses.

Experts systems are applications that apply a network of rules to user-supplied sets of facts. As the name suggests this type of application interprets “tutor” as “expert diagnosis”, and relies on being able to translate human expertise into a rule set that can be applied to users’ data (e.g. Clark & McCabe, 1984). Argumentation and dialogue analysis aim to understand generic forms of pedagogical interactions in order to model and automate those processes (e.g. Baker, 1992; Pilkington, 1999). A long-term, but as yet, unrealised goal of this approach is to create adaptive applications that can personalise tutorial interactions in real time. Many of the applications that fall under this heading, casting digital applications as tutors, are modelling aspects of tutorial interactions. Current research indicates the complexity that emerges in trying to capture the practical dynamics of adaptive tutoring implied by this metaphor (Akhras & Self, 2002).

Classification of tasks in this category was based on the fact that pupils were using Integrated Learning System software, and consists of two activities or 3% of the sample. In the first activity a class of year 4 pupils (8–9 years old) started the lesson as a whole group with oral revision and solving problems using six-times table, followed by extensions to seven and eight-times tables. For the main section of the lesson groups of six pupils went to a computer suite with a Teaching Assistant to use an ILS, giving each pupil their own work project. Most pupils were at a similar level, and the remainder of the class worked on problems using addition, subtracting, and spatial reasoning. Five groups of pupils had 15 min using the computers, and the computer generated work allowed individual pupils to access interactive activities, with both ILS and the Teaching Assistant providing support and feedback. Assessment was available automatically for pupils and the teacher to help planning, and provide a sense of progression. The class reviewed their tables to conclude the lesson. In the second activity year 1 pupils (5–6 years old) used a group of three machines spread around an open-plan classroom. Using an ILS, the pupils worked through activities and games based on a book they had read previously as part of a reading scheme. Individual students were sent to the work on the computer using the reading scheme software, with their progress and level being monitored by the application. If a pupil performed well in relation to their age, progress, and level, a certificate was printed out and given to them.

In examining the relationship between ILS use and learners’ relative gains in scores for national tests taken by all 14 and 16 years old pupils, Wood, Underwood, and Avis (1999) concluded that ILS impact on pupil’s attainment needed to be examined in the context of how this technology was integrated into actual classroom practices over a period of time. They point out that it is important to consider the relationship between technologies, learners and teachers, and their designers (Squires & McDougal, 1994). ILS are designed to be used by individuals in well-defined circumstances, but Wood et al. (1999) found that ILS were used in a variety of ways, including some not recommended by the designers. Teachers’ training and attitudes to ICT played vital roles in ILS’s effectiveness, and Wood et al. (1999) also noted a significant mismatch between the format of assessment in ILS (mainly multiple choice) and those found in public examinations.

Although the notion of “computer as tutor” is highly attractive, current implementations lack the “intelligence” of human tutors to select and adopt strategies in real time according to specific needs of individuals. Developing this paradigm has to take greater account of learners’ contexts and how they can be represented (du Boulay & Luckin, 2001).

4.3. Digital technology as tool

Describing digital technologies as a tool is one of the most common ways of talking and thinking about them in everyday life, suggesting both usefulness and availability. Two senses of this metaphor are usually associated with digital technologies. On the one hand digital technologies are neutral (Somekh, 1997), rather like a pencil or pen, simply available to do a range of jobs and chosen according to what has to be achieved. On the other hand they can be “mindtools” (Jonassen, 2006) or “cognitive” (Somekh, 1997) that amplifies conceptual understanding, extends thinking, and enhances problem solving.
Ordinarily “tool” means a fixed functionality embodied in a physical implement. By contrast authors such as Verillon and Rabardel have a notion of an “instrument” as a psychological construct which draws a distinction between the material object and its integration into the actions of those using it for specific purposes (Verillon & Rabardel, 1995). This resonates with Vygotsky’s distinction between technical and psychological tools, and the role that they play in understanding and manipulating both the material and cognitive domains. (Vygotsky, 1978). Computational tools are built in a similar way to “ordinary” tools since they presuppose a background of shared knowledge possessed by both creators and users against which the function and significance of the tool is understood. Tools are an integral part of the practices which make up specific domains of expertise, with “tools” and knowledge domains mutually conditioning one another. Effective use of tools requires knowledge of the domain in which they are used and, conversely, competence in the use of tools helps to develop knowledge of a domain (Wittgenstein, 1953).

Where the metaphorical aspects become apparent is in the synthesis of the physical and the virtual that makes a digital application. Physical tools are, by definition, physical objects whose existence is bound up with their functionality, determining both their use and structure. (e.g. hammers, pencils, paint brushes, cutlery etc.). By contrast digital tools, while having a material basis, nonetheless cannot be manipulated in the same way, since they must be “accessed” via an “interface”. What the metaphor of “tool” does highlight is the functional nature of digital technology in the sense that something is achieved by their use, and they are both opaque and transparent to users. “Good” tools enable one to achieve the desired end without noticing the tool itself (transparency) and, by the same token, it is not apparent nor does one need to know how the digital tool achieves the desired result (opaqueness). In this sense whether the “tool” is virtual does not matter since the main criteria is that it achieves the desired end and is “fit for purpose” (Bodker, 1996).

Software functionality rather than curricular demands played a significant role in determining tasks for this approach, including:

- Drawing a house using a Paint package.
- Editing a database of a class’s data – adding a picture field and inserting photographs of classmates.
- Using a word processor to write up a formal coursework task.
- Using a software suite to produce multimedia presentations to show younger pupils.

Forty-six percent of the total sample used this approach, with 68% of these activities taking place in rooms with more than twelve machines. The remainder were split in roughly equal proportions between groups, suites, and single machines. No activities were reported for years 7 (11–12 years old) or 10 (14–15 years old), although the activities were split 43% and 57% between primary and secondary, respectively.

Activities ranged from a teacher showing one 5 year-old how to use a drawing package at a single machine through to groups of learners working on personal tasks individually or in pairs at computers. Tasks that took place in rooms with more than twelve machines included learners completing coursework (individual extended pieces of project work that may last several lessons), engaging in collaborative writing, personal database design, and programming. A range of software was used with learners focussed on using and developing their competencies in a digital application and problem solving. Both generic (e.g. spreadsheets, word processors, databases: 21%) and content-free applications (e.g. data logging and programming languages: 39%) were used in the majority of the activities. It is the learner-centred nature of tasks, focussed on obtaining specific outcomes, which marks out this approach.

Teachers using this approach were mainly in experience groups B (46%) and C (46%) with group A making up the remainder. Pedagogically there were two main patterns which both began with a teacher-centred section, followed by a learner-centred main section. Forty-three percent of the activities did not have a third part but learners worked to complete a task, and saved their work at their own pace when the activity ended. The remainder of the activities (57%) had a third part which involved either a teacher-pupil discussion focussed on developing learners’ understandings of their own work, or teachers helping learners to save, print or closed down their machines.

A correlation of 0.74 exists between learners’ experience scores and their age, which is significant at 1% level ($r = 0.453; df = 26$). Given that this was a snapshot survey the correlation lends support to the Ofsted (2004) findings that this approach tends to aid learner’s progression in ICT capability. Common sense suggests that if
pupils are to become “fluent” users of ICT for their own purposes, they must have the opportunity to use a variety of digital technologies. Given that just over two-thirds of these activities took place in a room with more than twelve machines, this approach suggests that the more opportunity that learners are given for these “tool-like” activities with digital technologies the more likely they are to improve their capability. By comparison with the resource metaphor, this approach fostered a combination of skills, techniques and conceptual understanding that enables learners to use ICT to solve problems in an independent manner.

4.4. Digital technology as an environment

Combining both ecological and geometric connotations, this metaphor implies a new milieu (e.g. cyberspace) in which a personally constructed niche is adapted to suit an individual’s needs and interests. Actively engaged in building their own meanings as they work with digital technologies, learners control their own trajectory through exploration, experiment and personal creativity in the new medium. Microworlds best express this approach as small, simple slices of reality where learners build their own understandings (Papert, 1980). Edwards (1995) points to the importance of both the structure and function of a microworld in the ways that the knowledge domain is made available to learners through the tools and activities that they undertake. Papert’s turtle geometry microworld, for example, enabled young children to use powerful computers as an “object to think with” for learning within a Piagetian inspired framework. It provides learners with functionalities to construct their own mathematical understandings through programming, and follow their interests through active experiment and exploration. However it can be used with more advanced mathematics (Abelson & diSessa, 1980), natural language (Goldenberg & Feurzeig, 1987), and adults (Stevenson, 2000). Papert’s early notion of a microworld aimed at tapping into the sense of intrinsic motivation and play which can drive reflective abstraction. More recently he has identified six dimensions that draw out the sense in which a microworld contains a model of a knowledge domain, a set of tools for learning, and a theory of cognitive development (Papert, 2002). In this sense, environments are mediational since they are an intrinsic part both of what is learnt and how that learning occurs; they are not simply conceptual amplifiers.

Although much use is made of the term “virtual learning environments”, which can be personalised in the sense of selecting from a range of predefined options, it does not capture the sense intended by this metaphor. Essentially VLEs are frameworks for managing content and communications together with facilities for collecting personal resources (URL’s, text, video etc.). The key difference lies in the type of learning which takes place, and the degree of active control and malleability of the medium implied by the term ‘environment’.

Activities were placed in this category if they were learner-centred, and gave learners some choice over what they did or the freedom to experiment. Five percent of the sample used this approach, covering three activities. In two of the activities learners had a free choice about what they could do with technology. Year 1 pupils (5–6 years-old) could choose from a carousel of on and off-computer activities that ran over two days, and included a CD rom that was available on a group of computers spread around the classroom. A second free choice activity involved year 2 (6–7 years old) working with literacy, numeracy and games-like applications, running on web browsers in a room with more than twelve machines. Although the third activity with year 7 (11–12 years-old) pupils was initially teacher-led, it subsequently developed into a learner-centred exploration of colour and design both off and on the computer. Learners explored creating effective designs using ‘flip and rotate’, and repeating patterns with a “Paint”-like application. Aiming to develop learners’ critical appreciation of pattern, the activity involved pupils writing a reflective account of their design process, and evaluating the role of ICT in that process.

Qualitative research into ICT as an environment, and its relationship to conceptual and personal development, has been ongoing for 25 years (Cox & Abbott, 2004). One of the most systematically researched examples of this approach is Papert’s Turtle geometry, implemented in Logo (Noss & Hoyles, 1996). It is interesting to note that primary and early secondary pupils seem to predominate in this, admittedly small, sample. Given that the initial impetus for Turtle geometry was precisely with pupils in this range, it is not surprising. Two difficulties exist in evaluating this approach. First it can lead to learners developing knowledge, understandings and skills in areas that are not covered by the school curriculum. Logo typifies the promise and the disappointment for the use of this metaphor in schools. Turtle Geometry’s “failure” to connect with schooling, (apart from drawing polygons) lies partly in the type of geometry that it enables, and what counts as geometry
within the school curriculum (Agalianos, Noss, & Whitty, 2001; Noss & Hoyles, 1996). Turtle geometry is syn-
tonic or body geometry, which translates into differential geometry at advanced levels (Abelson & diSessa, 1980), but it is not the 2-D euclidean geometry of the school curriculum (Stevenson, 2006). A second issue is the relationship between digital technologies and formats of assessment. The school curriculum is based around “paper and pencil” technologies, which do not fit easily with digital media. A fundamental separation of the medium of learning – in this case ICT – from the methods of assessment (e.g. hand-written sit-down exams) means that the role of digital technology becomes ambiguous (Twinning et al., 2006).

5. Discussion

What is the significance of these four approaches? Part of the motivation for trying to categorise ways of using digital technologies is a continuing investigation into the issue of “ICT’s” contribution to learner attain-
ment. Along with literature reviews on attainment (Cox & Abbott, 2004) and pedagogy (Cox & Webb, 2004), the snapshot survey was undertaken as a follow-up to ImpaCT 2 project. As a complement to that study and the very recent ICT Testbed evaluation (Somekh et al., 2007), which examine the structural impact of ICT, the focus of the survey was on activities and their potential contribution to attainment. A key outcome of the ImpaCT2 project was the recognition of the need to take account of the context and use of digital technology. From this point of view identifying digital technology usage with the metaphors aims to take this a stage fur-
ther by providing a means of discriminating between uses and the type of learning outcomes that they are likely to support. Taken together the four metaphors illustrate a spectrum of pedagogical uses that vary ac-
cording the degrees of learner control, motivation and access, choice of task, approaches to learning, and epistemological focus (Sewell & Rothery, 1987). Control of these factors shifts from practitioners to learners as technology changes from being a resource for pedagogy, defined by practitioners and a fixed curriculum, to a medium for exploration and creativity defined by learners’ personal needs and interests.

An illustration of this can be found by comparing the “tool” and “resource” approaches, which together made up 89% of the activities in the snapshot survey. There are differences in:

- Who controls the technology and the development of activities.
- The range of digital technologies and software used.
- The types of outcomes intended and achieved.
- The focus of the tasks.

Corresponding differences can be found in the pedagogical structure of the activities, with a greater empha-
sis on learner-centred activities in the case of the “tool” approach, where learners controlled the types of dig-
ital technologies that were used.

These differences have a number of implications for issues such as assessing the link between technological experience and attainment. For the resource metaphor, two sets of possibilities emerge depending on whether the technology is a single machine or consists of a room with multiple machines. In the latter case there is an identifiable link between individual learners’ experiences with digital technology and their attainment of cur-
riculum objectives. Learners have access to the technology, and can have some degree of control over how they use it. However for single machines, the relationship between attainment and technology usage is less clear. In that case, teachers control access and interactivity with the technology, with learners having little say over what happens.

By contrast, the “tool” metaphor provides the clearest link between use of digital technologies and developing learners’ cognitive and skills-based attainments, since it places control and access, and, to a lesser extent, task choice directly in the hands of learners. Nonetheless, learner access and control still represent a necessary rather than a sufficient condition for understanding the function of technology in learning. Both the “tutor” and “environment” metaphors satisfy the condition of placing technology directly in the hands of learners. What Sections 4.2–4.4 indicate, however, is that the nature of the learning which each generates is different, both in relation to curriculum objectives, tasks that are undertaken, and the forms of assessment used. Their peda-
gogical structures clearly differ, with the “computer teaching the child” in the case of the tutor and “the child teaches the computer” in the case of the environment (Papert, 1980). One way to characterise the difference
between the "resource" metaphor and the other three is that, in the first case, digital technology enhances teaching and to a lesser extent learning, while in the other three cases technologies mediate learning to a much greater extent, albeit in different ways. It must be emphasised, however, that this is a matter of degree rather than kind since these metaphors can be understood as forming a spectrum of possible uses for digital technology. One consequence of this spectrum is that any analysis of technologies’ roles in developing attainment should take account of the type of learning outcomes which might reasonably be expected to be developed from the particular metaphor adopted. Different metaphorical uses are associated with different sets of learning outcomes, and these in turn define what types of attainment might be possible. From the point of view of trying to assess the contribution of "ICT" to attainment, these metaphors provide a way of discriminating between pedagogical uses of technology and their associated possible types of learning outcomes.

Models, like metaphors, are created to serve some specific purpose, which becomes the key criteria for assessing their efficacy. In this case the model is used as a framework for systematically collecting data about digitally-based activities so that they can be compared and analysed. One of the model’s strengths is its ability to articulate and distinguish the practices and associated learning outcomes for these four metaphors. What the model does not articulate is the cognitive aspects of those practices, and how the elements of the system contribute to the processes and outcomes of learning at a personal level. Activity theory is, after all, a description of a system built around mediated behaviour, which does not deal with people as individuals. What the metaphors bring to the model is precisely that cognitive dimension since the metaphors are related to different approaches to learning with their associated expected type of outcomes. Together the model and metaphors give a more complete picture of how and what individuals are likely to learn when they undertake particular forms of pedagogical activity than they would if the model and metaphors were employed separately.

Two areas need to be considered so as to give confidence in the approach. First this combination of model and metaphor need to be validated using a larger sample of digitally-based activities. On the one hand, this would increase the range of different site-types such as on-line, Higher, Further, and Community Education, and on the other hand, give a more diverse collection of pedagogical activities. On the other hand, more than one observer is needed to view and discuss each activity with those involved at each of these site, so that there can be cross-checks to aid the validity and reliability of the judgements made. Given that data for the model can be completed on-line and activities can be viewed remotely, possibilities for cross-cultural analysis also present themselves to enlarge the sample. Second, there needs to be longitudinal tracking of learners which charts their personal development in curricular knowledge, digital skills and personal understanding, set against their experiences of the metaphors in action. Originally, the data set was collected as part of a cross-sectional – "snapshot" – survey taken over a three-month period, and there needs to be a validity check that the metaphors are stable over a period of time and across sites. Conversely the contribution of the metaphors in describing the potential for learners’ cognitive and personal development through their experiences of digitally-based activities needs to be validated.

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References


