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ABSTRACT

The REPRESENTATION Project, 1998-2000, carried out research within elementary schools in six European countries: Denmark, France, Greece, the Netherlands, Spain, and England. Altogether, 31 schools participated, ranging from large inner city schools in Paris and Amsterdam, to a 20-student school in a Greek village. In each school, one class of students and their teacher was selected to participate. The students were all aged between 10 and 12. This paper reports on research carried out in England within the framework of REPRESENTATION. The overarching objective of the project was to deepen understanding of the way in which fifth grade students perceived new technologies and related concepts. The specific objectives addressed by the English research and reported in this paper were: to deepen understanding and track the development of fifth grade students' conceptual representations of new technology over the period of one year; and to explore the role of the school, the home, and wider socio-cultural experience, including national culture, in the development of students' knowledge of new technology. (Contains 31 references.) (MES)

Children's Representations of New Technology:

Mismatches between the Public Education Curriculum and

Socio-Cultural Learning

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A paper presented at the American Educational Research

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Children's representations of new technology: mismatches between the public education curriculum and socio-cultural learning.

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The REPRESENTATION Project[1], 1998-2000, funded by the EU Multimedia Task Force (MM1045) carried out research within elementary schools in six European countries: Denmark, France, Greece, the Netherlands, Spain (Catalonia), and the UK (England). Altogether 31 schools participated, ranging from large inner city schools in Paris and Amsterdam to a 20 student school in a Greek village. In each school one class of students and their teacher was selected to participate in the project. The students were all aged between 10 and 12 (variations in age were due to differences in the age of transfer to high school in the different countries). (Somekh, Kikis-Papadakis et al. 1999)

This paper reports on research carried out in England within the framework of REPRESENTATION. The overarching objective of the project was to deepen understanding of the way in which 5th grade students perceive new technologies and related concepts. A second objective of the project, which is not the focus of this paper, was to develop a computer-based concept mapping tool for use in schools. The specific objectives addressed by the English research and reported in this paper were:

1. To deepen understanding and track the development of 5th grade students' conceptual representations of new technology over the period of one year.
2. To explore the role of the school, the home and wider socio-cultural experience, including national culture, in the development of students' knowledge of new technology.

Theoretical Frameworks

The starting point for the work of the REPRESENTATION project was a constructivist theory of learning, in the tradition of Piaget and Vygotsky, that conceptualises meaning making as a process of progressively building a view of the world from observations and experiences (Baron, Bruillard et al. 1999 p. 9). Learners engage in a process of constructing representations of phenomena and experiences, which are temporary and incomplete and are changed and reconstructed as novices move towards becoming experts. The production of a computerised concept-mapping tool, available in a range of European languages was seen as a potentially valuable educational tool to be used by teachers and students to support the construction of representations.

The starting point for the work in England was an extension of this constructivist theory along the lines of Bruner's later socio-cultural work, in particular his 'culturalist' theory of mind, which 'concentrates on how individual human beings construct "realities" and meanings that adapt them

[1] REPRESENTATION was coordinated by Kathy Kikis-Papadakis, FORTH, Institute of Applied and Computational Mathematics, Greece. The partners were INRP France, The University of Amsterdam, Orfeus Denmark, the University of Huddersfield England, the University of Crete Greece, Universite de Pompeu Fabra, Catalonia and MAC Ireland. Associate partners were IUFM de Creteil France and the University of Mons-Hainaut Belgium. Further information is available on the Project web-site at http://hermes.iacm.forth.gr

to the system, at what personal cost, with what expected outcomes.' (Bruner 1996 p.12). Ten year old students' education is the result of their participation in the experiences of home, school and the society in which they live day by day. The routines and passions of life in the family and at school, the excitement and normative pressures of youth culture, and the constantly shifting array of experiences from television and the mass media demand compliance as well as exploration. The interventions of schooling are but one small part of the momentous, and frequently bruising business of moving from childhood to early adolescence.

New technologies play a major part in the social system in which ten year old students are developing their sense of identity and their understandings of what it means to be human. The period of the project's work coincided with a sudden exponential growth in the take-up of new technology in the UK, resulting in a transformation of the practices of human communication and access to information, and fundamental changes in the formal and informal structures of UK society (e.g. banking, shopping, access to information, leisure activities). (** It is important to note here that initially the UK lagged behind the USA in the take-up of digital technologies and the Internet. Conference participants should be able to advise us on the exact period of this lag, which we are assuming to be about a year to eighteen months.) The work of Vygotsky (1978) and Wertsch (1998) explains how access to new technology tools changes the nature of human activity in this way. Our actions are always 'mediated' by tools and their outcomes emerge from a constant tension between agency and the affordances of mediating tools. The powerful, often disruptive, effects of new technologies on our societies, for example through the effects of globalisation, should be reflected in similar radical changes and disruptions on our education systems (Sharples 1999), yet there is so far little evidence that this is the case (Becker 2000) (Somekh 2000). This raises important questions about the impact that these technologies are having on the way that young people are constructing 'realities and meanings' as participants in today's world, and the role that schools are playing in assisting in, or resisting, this process.

The socio-cultural theories of Bruner, Cole and Wertsch provided a framework for interpreting children's conceptual representations of new technology during this period of rapid change. In particular, it was possible to look at the (lack of) influence of the school on the development of children's knowledge of the role of new technology in their world. Of particular importance, in understanding how children conceived of new technology, was the theory of primary, secondary and tertiary artifacts, which Cole (1999 p.91) develops from the work of Wartofsky. Computers, the Internet, email and other tools are the primary artifacts, but in order to use them human beings need to develop secondary artifacts 'which consist of representations both of primary artifacts and of modes of action using them.' Tertiary artifacts are 'possible worlds (which) provide candidates for conceivable change in existing practices'. Our research explored the nature of 5th grade students' representations of new technology, by looking specifically at their secondary artifacts and at indications of any development of tertiary artifacts – that is their awareness of the implications of digital technologies for transforming the way we live and work. The latter are, of course, highly problematic in children, who have not yet established routines and habits of practice, and for whom much that takes place in the world is still a recent or new experience.

The six schools in which we worked were located in a post-industrial area of West Yorkshire where the built environment is a mixture of decaying textile mills, built on gigantic proportions during the industrial revolution, and small workers' cottages, nestling side by side in the valley bottoms and hillsides of the Pennines. The textile industry has suffered rapid decay as a result of competition from the Far East, and industrial regeneration into engineering and chemicals has not occurred on any large scale. Agricultural land on the hillsides is poor. Some of the nearby towns are home to large communities of British Pakistanis, but the children in our schools were predominantly white working class. The schools were chosen in consultation with the local

education authority (LEA). At the time of writing the proposal for EU funding in 1997, all schools in the LEA were equipped with British-made Acorn computers and were connected to an on-line email and data base service, Campus World, provided by British Telecom. However, when project work commenced in September 1998, Acorn had ceased production of computers and Campus World had been re-launched as an improved, independent service with higher charges. At the same time, the major UK government internet initiative, the National Grid for Learning, had just been announced and the LEA had bid successfully for money in the first round of awards. In other words, major changes taking place in the national infrastructure had caused a sudden fracture in the LEA's policies for providing and supporting ICT in its schools. The six project schools were due to receive between 6 and 15 (dependent on school size) internet-enabled PC computers, located in specialist 'suites', sometime during the next eighteen months; and in the meantime connection to the Internet, through a new internet service provider, might be possible using existing Acorn computers. In practice, ICT activity in the schools had been at a very low level during the months running up to the project's start. Disruption in provision is, of course, a common feature when major new technology innovations first come on stream, but nevertheless lack of connectivity posed problems for the English researchers at the project's start. Our schools were much less well equipped than the project schools in most of the other countries, as well as having much larger classes (more than 30 students compared with an average of around 25 in the other countries).

The positive outcome of this disruption in ICT provision in the schools was that we began our research into 5th grade students' socio-cognitive representations of new technology (secondary artifacts) at a time when Internet-enabled computers and connectivity infrastructures (primary artifacts) were not available in the schools. We were then able to track the development of their representations over the period when the NGfL equipment was installed in the schools and incorporated into the teaching programme. It is significant that, throughout this period, ICT activity in the schools, whatever its level, followed the national curriculum for England and Wales, which requires teachers to focus upon giving students traditional computer-use skills in word processing, data handling (data bases) and computer modelling (spread sheets). The aim is to enable students to use these skills in learning, but the primary emphasis, as students' experience it, is on skills acquisition.

Methods

The REPRESENTATION project's work, as a whole, drew upon the early work of Novak and Gowin (1984 p. 20) who devised concept mapping as a tool 'for negotiating meaning'. It drew also upon recent developments in computer-based tools for concept mapping and their use to support students' learning (see for example, McAleese 1998). One of the project's main aims was to develop a new computer-based concept mapping tool with versions in several European languages. A parallel strand of the research would look at the impact on students' learning of using the REPRESENTATION prototype and other concept mapping tools. The research into classroom uses of computer-based concept mapping was intended to inform the software development. Our computer-based concept mapping tasks built on work at the University of Oregon, described by Anderson-Inman and Ditson (Anderson-Inman and Ditson 1999). Like the Oregon researchers, we mainly used the commercial product Inspiration, but a small number of students also used the REPRESENTATION prototype tool[2] when it became available in the late spring of 2000.

[2] The development of the REPRESENTATION concept mapping tool, including classroom trials, within a two year period was a considerable achievement, but inevitably the production of a proto-type sufficiently robust for classroom use was somewhat delayed.

To explore students' representations, however, we did not use the standard approach to concept mapping derived from Novak and Gowin. Instead, we used a particular form of paper-based concept mapping involving drawing images or icons to represent objects rather than writing textual labels to represent concepts. The approach to concept mapping as a method for capturing 'snapshots' of students' constructions of their mental representations was akin to the work of Buzan (1993). In preliminary work in July 1999 we piloted a paper and pencil concept mapping task in which students were invited to draw a 'spider map' of a 'computer system' (Crawford, Neve et al. 1999). The main sample of 176 students, in six schools, did a 'benchmark' paper and pencil task in October 1999 in which they were asked 'to draw a concept map of your ideas about computers in today's world'. This was repeated in June 2000. Students were also asked to write a short text 'describing a computer system to an extra-terrestrial being who has no knowledge of such things'. Quantitative analysis was carried out on the concept map data using a scoring system based on counting the nodes and links and allocating a category type. We drew in particular on the work of Crawford in Australia (Crawford 1996) (Meloche and Crawford 1998) who collaborated with us in the development of our paper and pencil research instruments and methods of analysis. Elsewhere we have written a detailed account of these methods of data collection and analysis (Pearson and Somekh 2000).
The quantitative concept mapping data were analysed in relation to a range of other data relating to the students' age, socio-economic status of their homes, home ownership of computers etc. to explore the impact of these factors on the development of their representations of new technology. In the UK the socio-economic status of the students was generally low as all of the schools used in the study were from deprived areas. Computer ownership among students was also low with only 28% of students having regular access to a computer at home. Both the students' writing and the concept maps were also qualitatively analysed. After the main analysis was completed, follow-up interviews with a sub-sample of students, using their concept maps as a starting point, enabled much deeper qualitative analysis of their conceptual representations of new technologies. These interviews also enabled exploration of the students' 'tertiary representations' where these existed (see Cole, 1999 op cit). Both quantitative and qualitative methods of analysis were developed using phenomenographic theories derived from the work of Marton (1994 pp. 4424-4429) (Marton and Booth 1997). The early work in phenomenography showed that human beings develop representations of phenomena through a process of focusing awareness on some aspects of them and leaving other aspects in the background. Awareness is, thus, 'layered' into the figural 'core', the surrounding 'fields' and the background 'fringe' (Marton and Booth, 1997, p. 123). Phenomenographic analysis of university students' accounts of their learning, in open-ended, non-directive interviews, showed that they had 'four or five distinctively different ways' of experiencing any body of knowledge, depending on which aspects were at the forefront of their awareness and how other aspects were layered. For a full account of the implications of phenomenographic theory for the approach to concept mapping described in this paper, see (Mavers and Somekh 2001).

Evidence

The data set consists of:

- 171 concept maps collected in October 1999 (Benchmark 1)
- 171 written descriptions collected in October 1999
- 153 concept maps collected in June 2000 (Benchmark 2)
- 153 written descriptions collected in June 2000
- Follow-up interviews with a sub-sample of children

A complementary data set from a further 25 schools in five other European countries provided additional evidence. These data, fully analysed using SPSS within the REPRESENTATION Project (Baron, Dansac et al. 2000), enabled comparisons in relation to national culture. However, the current paper addresses mainly the English data. The full set of English concept maps and writing are available from the authors in HTML format on CD-ROM.

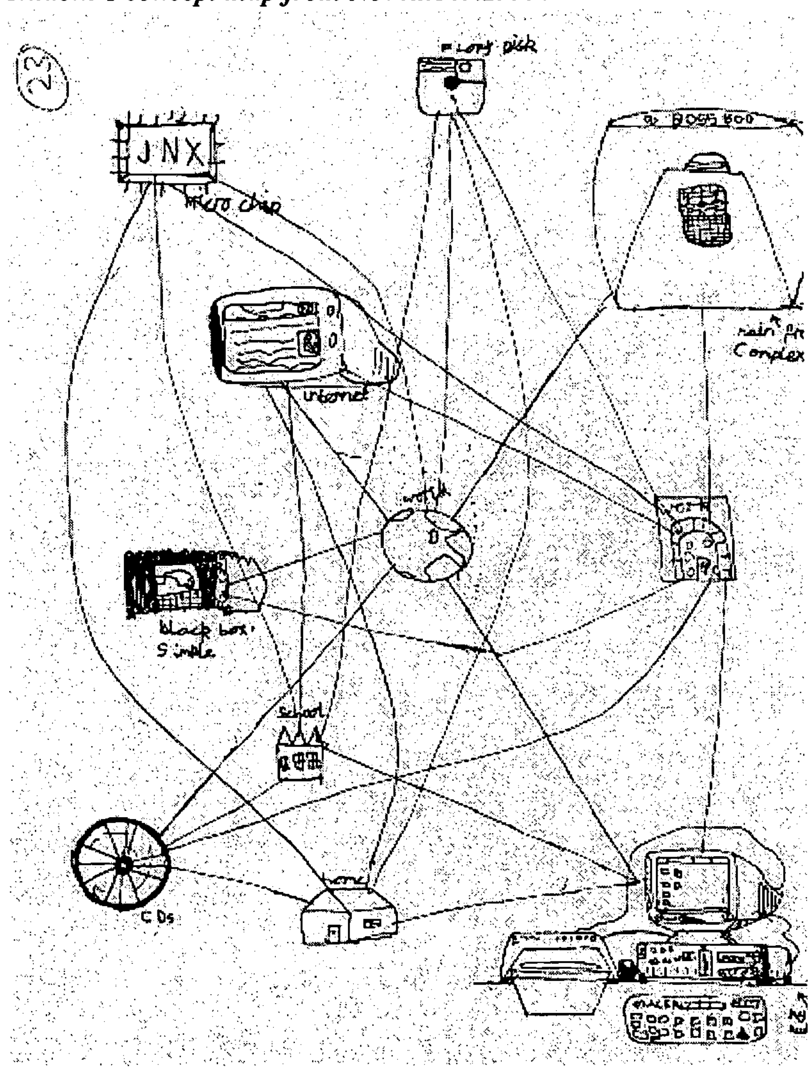
Presentation and discussion of the outcomes

Overall, the research has produced a map of the development of 5th grade students' conceptual representations of new technology at a unique moment in time – when the Internet was being rapidly assimilated into UK culture and society but it had not yet been introduced to them at school. The outcomes of the three specific objectives of the English research, within this broad framework, are presented here.

1. In relation to deepening understanding and tracking the development of 5th grade students' conceptual representations of new technology over the period of one year, the research suggests that:

a) 5th grade students have a much richer and more complex experience of new technologies within their lives as a whole than they do at school.

Ten year old student's concept map from November 1999:



The preliminary quantitative analysis of this map was as follows:

- Type of map (unconnected, linear, one-centred, several-centred, 'spaghetti') = spaghetti
- Number of nodes (elements and concepts on the map) = 11
- Number of links (counting 1 for each line emanating from a node) = 45
- 'Depth' (longest number of links counted consecutively from a central node) = 3

Preliminary qualitative analysis of this map suggested that there were two main foci of the student's representation of new technology: first, its power, suggested by the presence of a PC, a main frame computer, a JNX chip, and a 'black box' and second its interconnectedness/global connectivity, suggested by the global icon, the Internet, and the links between all these objects and home, school and the workplace. The objects are all drawn with considerable care, so that many minute features of the technology artifacts are distinguishable. The central position of the global icon and the linkages drawn between it and all the technology objects show the student's awareness that computer power lies at the heart of global connectivity. Links between home, school, workplace and the global icon are indirect, through technology, rather than direct.

We were faced with the considerable challenge of interpreting these maps in a way which simultaneously gave credit to the richness and variety of representation and provided a valid and reliable framework on which to base quantitative interpretations. Follow up interviews were conducted with a selected number of participants in order to explore more fully the ideas captured in the maps. This child was interviewed as part of the schedule. Much of the interview confirmed that the immediately apparent richness of the map was matched by a depth and complexity of understanding on the child's part. The interview with the boy who drew this map lasted 25 minutes and the researcher used the map to stimulate ideas. The child was able to explain the inclusion of every element on the map; the black box was:

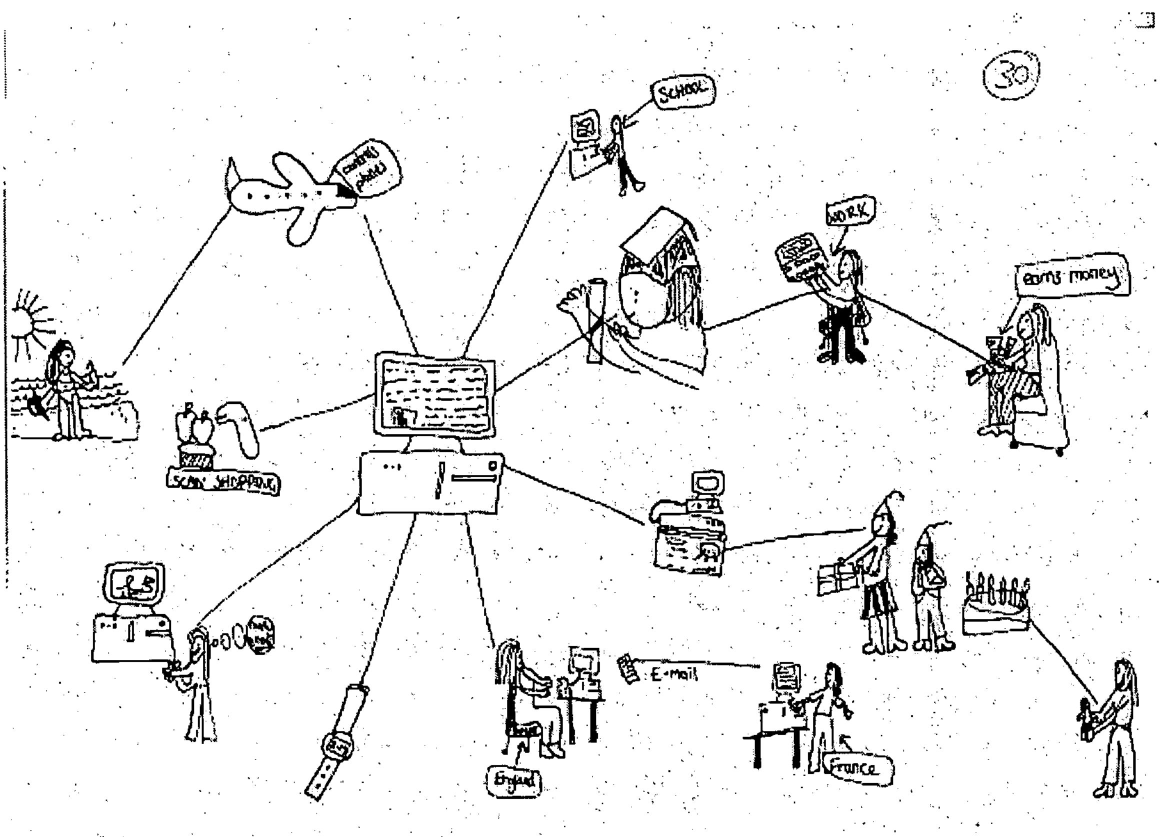
> I put the black box in because they are used for recording information for something like an airplane or a car crash and they are a small simple computer just for recording information. (Interview SH#12)

The item just above the world icon in the centre of the map was explained thus:

> That was meant to be a server for the Internet, an Internet server which is connected to most things, because it like controls most internet based things, mm and sends the information to computers all over the place. (Interview Sh#12)

The child found answering these question easy; and there was no anxiety about blending specialist terms "internet server" with a more relaxed vernacular style "because it like controls...". This informal tone characterised all of the interviews conducted, and a major finding was that children of this age are confident discussing new technologies. Children appear to rarely worry about applying technical terms in exactly the correct context as older people often do, and their explanations of the functioning of technology, although sometimes prosaic, are often highly accurate. The interviews allowed the data from the concept maps to be triangulated and we have reached the conclusion that the maps are not random assemblages of various pieces of technology, but rather representations of digital technology which combine both primary and secondary artifacts.

Ten year old student's concept map from November 1999:



The preliminary quantitative analysis of this map was as follows:

- Type of map (unconnected, linear, one-centred, several-centred, 'spaghetti') = one-centred
- Number of nodes (elements and concepts on the map) = 16
- Number of links (counting 1 for each line emanating from a node) = 14
- 'Depth' (longest number of links counted consecutively from a central node) = 5

This map shows a central computing terminal which is clearly the centre of the map (hence its designation as single centred). The central computer in this map appears to be only an organisational centre for the drawing and does not create large amounts of meaning when considered alone. The meaning of this map is best expressed by examining the large number of actors in the scene, and the amount of human activity being mediated by the computers. Certain of the links have an ineluctably logical quality to them. A graduate is linked on one node to a person sitting at a computer terminal at work, and beyond that the simple label "earns money". Such formations give a structure to the information which draws us into a narrative. Kress and Van Leeuwen's explorations of the grammar of visual images stresses the importance of both *represented participants* and *interactive participants* (1996). Represented participants are the people who are depicted in images, and this map is rich in these. This map contains a multitude of people doing things and therefore shows a well developed secondary artifact which makes technology available to this student as a selection of possible actions and a repertoire of possible interactions. Unlike the student above, who was able to give considered verbal explanations of

his map, this student gave short responses when interviewed. When asked about why the map was drawn this way, the answer was:

> Well I just sort of...I like computers.. and I've just got a new computer, and I have some email friends abroad and I email them sometimes, so I quite like email as well. (Interview Sh#15)

This explanation seem rather "off-hand", and it is tempting to see this response as not really doing the complexity of thinking and the finely nuanced meanings of the original map justice. And this is exactly the point. The original map is rich because the student was freed from the constraints of textual expression and could express ideas using a different grammar of expression from that of linear prose. The interview was an attempt to get the student to verbalize content, and whilst this was of prime interest to the researchers, it did little to interest the student who gave short, sharp answers which showed her slight sense of frustration at an adult asking her to express in words what had already been expressed in pictures.

b) The socio-cultural background of the children has a significant impact upon their direct access to new technologies outside school, but even without such access children are able to develop new technology 'secondary artifacts'.

It was the judgement of the researchers, following discussion with teachers and extensive observation in the schools, that these students came, almost universally, from working class backgrounds. It was unfortunately not possible to get formal data to confirm this as, under the Data Protection Act teachers were not prepared to provide information on individual students' home backgrounds. More global data, such as the proportion of students who qualify for free school meals, is no longer considered reliable as various government schemes provide poor families with funds that over-ride their right to school meals – moreover their poor quality has led to many eligible students refusing to take them up.

Given the low socio-economic status of these students' families in November 1999, it is of great interest that their representations of new technology in today's world are so rich and complex. The maps themselves suggest that students are drawing on a wide range of cultural experience, particularly television, advertising hoardings, and the technology artifacts of value in youth culture. Many of the maps indicate particular features of an individual student's experience, such as for example a drawing of a cow linked to a knife and a computer in one map from a boy who had close ties with a farm. Some children represented their parents or carers using technology, and labels like "Mum using the computer to do the accounts" and "dad working on his laptop" were found. Many children's representations of new technology included computers in offices, shops, banks, and even in cars, trains and aeroplanes. These were often shown linked to allow the exchange of information and in some cases children were anticipating future technological developments as well as reflecting current ones. One child drew a computer in a car which was linked to the garage where the car was serviced and which could send data about the car's current state direct to a central computer. The children we studied, despite many of them living in relative technological poverty had grasped the underlying paradigm of the age of the Internet, that is "connectivity". Computers collect, store, process and forward data on to other computers in an all encompassing network of digital connections. We had originally set out with the intention of ascertaining the levels of children's knowledge about standard desktop computing, but the children themselves redefined our research agenda with their complex and multi-layered understanding of the ways in which digital technology is transforming the world. And we found

only minimal evidence that this knowledge was being gained in school or as the result of formal schooling processes.

c) During the period of the research the children's knowledge of new technology became more systematised and factually accurate

An unexpected outcome of the analysis of the concept mapping data was the nature of the differences between the two sets of maps, those produced in November 1999 and those produced six months later in May 2000. Some interesting differences and similarities between the maps were noted.

Benchmark 1

	N	Minimum	Maximum	Mean	Std. Deviation
Number of links	171	.00	50.00	6.96	8.31
Number of nodes	171	.00	29.00	11.98	6.07

Benchmark 2

	N	Minimum	Maximum	Mean	Std. Deviation
Number of links	153	.00	41.00	10.59	8.34
Number of nodes	153	1.00	28.00	12.42	5.44

Considering the numbers of links and nodes between the first and second benchmark, it is interesting to note what has, and has not, changed. The mean number of nodes did rise in the second set of maps, but by less than one node. This suggests that in the 6 month period between BM1 and BM2, the children had not been able to access significant amounts of new knowledge which could be translated into new items appearing on maps. The mean number of links, on the other hand, had risen significantly, although the maximum number of links in any one map had actually fallen. What the statistics do not show is the way in which a typical child's representation changed over this period. The number of 'unlinked' maps had decreased almost to nil (thereby increasing the mean score). Conventional computing items: printers, scanners, and digital cameras made a stronger showing in the second maps, and items not directly associated with desk-top computing, such as mobile phones, games consoles and virtual pets tended to figure less often in the second maps. It appears the children were conforming far more closely to a school based vision of computing, and were representing those items of technology which could be found in schools, whilst relegating other items which had interested them previously.

There are three possible explanations for this: first that the students did not understand why they were being asked to do the same task a second time and were less motivated to do it well; second that the experience of using the *Inspiration*[3] computer-based concept mapping software – and in some cases the REPRESENTATION prototype software – in the intervening period had imposed a more rigid approach to the expected appearance and contents of a concept map (e.g. *Inspiration* defaults to starting with one central node; and the project had presented them with other tasks that

[3] The REPRESENTATION Project is very grateful to the makers of *Inspiration* for providing licenses free to all the schools for a one year period during 1999-2000.

required them to construct a computer system by selecting objects from a standard library of computing objects thereby perhaps suggesting a pre-determined set of 'acceptable' objects that should appear in a map of a computer system); and third, their schools had been equipped with new networked PCs in a computer suite during the intervening period and they had begun to receive teaching of the computer skills specified in the national curriculum. It would seem that all three factors played a part in the differences between the two sets of maps. This effect of the standardising influence of the school environment, can best be charted by looking at the UK results for the types of maps.

Type of Maps: Benchmark 1

	Frequency	Percent	Cumulative Percent
not a concept map	17	9.9	9.9
one centre	21	12.3	22.2
several centres	99	57.9	80.1
linear	21	12.3	92.4
spaghetti	13	7.6	100.0
Total	171	100.0	

Type of Maps: Benchmark 2

	Frequency	Percent	Cumulative Percent
not a concept map	2	1.3	1.3
one centre	53	34.6	35.9
several centres	81	52.9	88.9
linear	16	10.5	99.3
spaghetti	1	.7	100.0
Total	153	100.0	

These two charts show how the one-centred map increased in frequency from BM1 to BM2. As this type of map is strongly suggested by the affordances of a tool like Inspiration, it was interesting to note that over twice as many participants drew maps in the second phase which had a single central node. The spaghetti characterisation (an evocative label created by the French research team to describe a map where almost all nodes are linked to all other nodes, creating a "spaghetti" effect), had accounted for 7.6% of maps in BM1 but by BM2 we found just one map which most closely fitted this model. In the work on BM1 a category of "not a concept map" was created to account for productions which showed little or no characteristics of a concept map. Some children drew pictures which showed no connection with computing in BM1 (the most bizarre being a picture of a desert island, which the child later explained was because he had

heard the expression "an island of computers". By the time of BM2, the number of drawings in the "not a concept map" category had dropped to just 2 maps.

d) Computer-based concept mapping, although effective in helping children to develop their factual knowledge of new technology, proved to be constraining as a tool for the development of their conceptual representations.

Computer-based concept mapping is a very different activity from pencil and paper concept mapping. As a tool for mapping conceptual representations it appears to limit the children's creativity. This is almost certainly because their attention is drawn to existing libraries of icons, and the production of new icons is only possible for planned rather than spontaneous tasks. This suggests that computer-based concept mapping is better suited to use as an aid to formal, teacher-directed learning, e.g. to assist in the categorising of concepts in hierarchies (as suggested by Anderson-Inman and Ditson, op. cit.)

2. In relation to the role of the school, the home and wider socio-cultural experience, including national culture, in the development of 5th grade students' knowledge of new technology, our research suggests that:

a) The introduction of Internet-capable PCs into the schools during the period of the research had an impact on the children's representations of new technologies; in particular there were indications that 'what counts' as new technology in schools (i.e. school knowledge) served to limit children's conceptual representations.

The introduction of state-of-the-art PCs and internet connectivity in schools during the intervening period was only one of three factors that may have influenced the change in the nature of the second set of concept maps. Nevertheless, our results suggest that this significant change in their schooling had not had the effect of increasing students' understanding of the variety and range of the functions and uses of new technology in today's world. Indeed, it seems likely that the reverse was the case. A considerable body of research has shown that schools define knowledge narrowly and that features of the school curriculum and pedagogy may unintentionally inhibit students' learning. The first problem is that learning in school is encompassed in assumptions and practices which can have the effect of introducing misconceptions (e.g. Engeström 1991). Secondly, learning in school is not 'situated' in contexts which support students' learning through 'legitimate, peripheral participation' (Brown, Collins et al. 1989) (Lave and Wenger 1991). Thirdly, teachers work under the kind of pressures that make it essential to give priority to the difficult problems of people management and task organisation rather than students' learning (Jackson 1968 pp. 1-38). Cuban (1995) summarises the reasons why the culture of American classrooms are generally antipathetic to science reform.

> *Teachers ... have invented and polished a repertoire of teacher-centred instructional practices that have emerged as resilient, imaginative, and efficient solutions to dealing with a crowd of students in a small space of extended periods of time. They have created a practical pedagogy that reconciles the dilemma of two conflicting values: maintaining order within a classroom and getting students to learn subject matter and skills they would not ordinarily learn elsewhere.*
> *(Cuban, op cit p. 8)*

Responses to new technology innovations fare no better than science reform, for all the same reasons. Moreover, Popkewitz, in a recent paper (Popkewitz 2000), points out that once

knowledge becomes part of a defined disciplinary field it is constrained by cultural and political factors that manifest themselves in sets of assumptions about what does and does not 'count' as knowledge.

> *A disciplinary field that school pedagogy draws on exists continually in two social spaces at the same time. One is the disciplinary space in which the internal rules of knowledge production are created, sustained, and changed. (...) The second ... is the cultural and political context in which disciplines function.*
> *(Popkewitz, op cit p. 23)*

The emergent 'discipline' of Computer Studies is dominated by technical discourse and a preoccupation with skills development that mitigates against its use as a set of flexible learning tools.

b) Schools are rapidly improving children's access to Internet-capable technologies, but are unable within the constraints of the current curriculum to offer the freedom of access and the 'exploratory play' that is available to children with similar computers at home.

During the interviewing phase of the research it was often possible to ask children directly about their acquisition of computing skills and knowledge. The semi-structured interview technique employed allowed this topic to be explored whenever children mentioned doing things on computers. Children would rarely attribute computing skills to direct teaching at school, and instead highlighted learning contexts which were informal. One child was asked about how she learned to search the web for homework purposes:

> I can't remember really, I think my dad showed me how to type in words and search for hits, but I do it by myself now. It's easy really...(AG#4)

The nonchalance expressed here was real enough, this child had no problem using the web to find material and once an adult had provided a way into the task, the confidence to use the technology alone was soon built. Another child mentioned a set of folders which she kept on her computer and which she had to password protect to prevent her older brother accessing her "secret stuff", when asked to explain how she had learned this, the answer was:

> I was just playing around one day and I found out you could put passwords on. My brother was always going into my files, and this stopped him (laughs).. (Ag#17)

Password protecting files, no big deal to a 10 year old willing to play around with buttons, engage with the computer at a playful level, and then immediately see a real world application for this ad hoc knowledge. It is clear that exploratory play is a key factor in the production of sophisticated secondary artifacts of ICT and children of this age are expert "fiddlers". This play may seem like random unfocussed activity without a teleological purpose but in reality it allows children to rapidly enculturate themselves into software and operating systems without recourse to formal training, and without ever having to touch a manual. Powerful confirmation of this assertion was provided during an interview with a teacher who is also an ICT consultant for the local education authority. She regularly runs training for teachers, and also teaches children in the school ICT suite allowing her to see both adults and children engaged in computing tasks. She had this to say about the difference between the two groups;

> ...I teach Desktop Publishing, both to the kids and the teachers, same package and on the same computers. The teachers are often nervous, scared of crashing the computers and waiting to be told what to do, and panicking like mad when things don't go according to plan. But the kids are straight in there, fiddling with menus, clicking buttons and exploring the interface. If I let them, they would play around all day. But the children do manage some really clever things, the other day they were adding backgrounds to documents and a couple of them figured out how to add these as backgrounds to emails and send them to friends. I had no idea how they managed this and there's no way my teachers would have been able to do this. In fact they would never have tried to do it.
>
> (interview with LEA ICT consultant)

Teachers are reluctant to "play" with computers in the same way as their students and adopt a rigid skills driven definition of ICT which eschews the opportunity of exploring the possibilities of the computer without an immediate goal in mind. A lack of exploratory play can stifle the acquisition of confidence using computers, and to return to the theoretical framework of this paper, we would argue that it prevents the full development of secondary artifacts of ICT. Children look destined to experience frustration and disillusionment with school based ICT if learning experiences are designed which do not take their aptitude for exploration and play into account. For teachers to provide suitably challenging opportunities for learning using ICT they need to develop a sense of play and build secondary artifacts which are as rich as the children's.

c) For many children, the excitement and enjoyment in using computers that they experience out of school is not matched by their experiences with new technology in school.

In BM1 only 38% of children included a school in their drawing (this compared with 37% of drawings of houses), yet other places (which included shops, offices and banks) were present in 50% of the drawings. So at the beginning of the project, schools were not seen by the majority of children as worthy of inclusion in their maps. When the second benchmark was conducted, after 6 months of children having increased access to computers in schools, the number representing schools in drawings had actually gone down to only 25%. A reasonable assumption would see the figure remaining static or going up as the result of interventions at school. Whilst it is difficult to reach definite conclusions based on the inclusion of a single item on a map, it is certainly possible to conclude that the majority of 10 year olds in the study did not immediately perceive the school to be a technologically rich place, or somewhere which afforded them opportunities to engage with new technology.

d) Children appear to communicate easily through images and this appears to be related to their considerable experience of the Internet as well as to the fact that they have not experienced the text-based cultural history common to adults.

Kress (1996, p. 15) noted in 1996 that by the time children reached the age of 13 illustrations had largely disappeared from text books or the written work they were asked to produce in high school. Noting that this made schooling dysfunctional in contemporary society, he concluded: 'In terms of this new visual literacy, education produces illiterates.' It is still undoubtedly the case that high schools in the UK place very low priority on images as a means of communication. However, it is clear that the ten year old students in our research had already developed considerable skills in visual literacy and these skills are being reinforced by their use of new technology. In the world of 2001, if schooling after the age of 13 continues to deny the

importance of visual literacy, the disjuncture between students' culture and the culture of schools will be even more stark. During the analysis of the maps several recurring themes emerged. One of the most pervasive elements of graphical representation was the inclusion of a picture of the world (represented as a globe). This iconic configuration was not found in all maps but did occur often enough for us to probe deeper into its ontology. Interviews helped establish an explanation for the world icon which combined several factors in children's thinking about the Internet. The first was its ubiquitous status in the graphical paraphernalia of the web. It is found on several popular browsers and was used by children to indicate the "world-wide" nature of the internet. Rarely was this icon labelled, rather it was included on maps as a self-sufficient signifier of the global, and full explanations were only elicited during further interviews. The children, it seemed, were happy to use icons, graphics and pictures to represent their ideas, not as an adjunct to textual representation, but instead of it. As Kress suggests, the production of images is an integral part of contemporary culture and, rather than the meaning of images always being linked to text as Barthes claimed in 1977 (see Barthes, 1993), the image in its own right is a major means of contemporary communication .

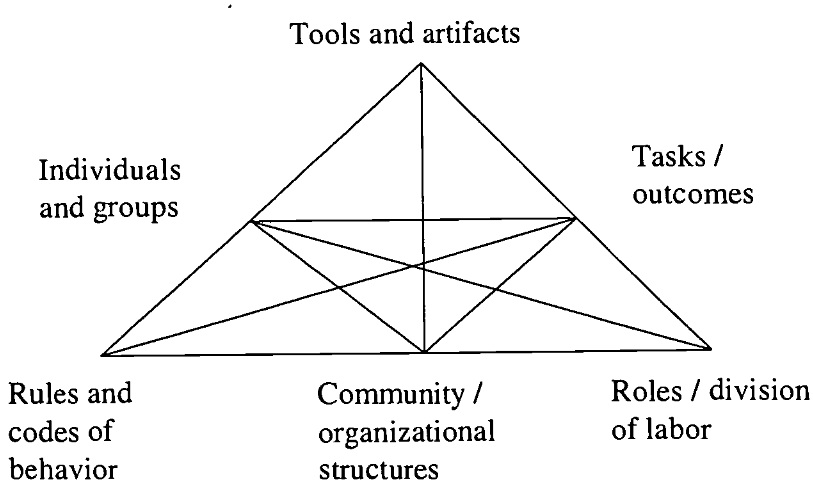
e) Children in England enjoyed representing their ideas using drawings more than the children in some other countries, such as Spain, where drawing was seen as a more specialist activity that required much more care and time.

It was noticeable that considerable differences between countries emerged during the benchmarking activities. Many students in Spain were uncomfortable with the notion of representing their ideas using images and instead used text. Many of the links on the Spanish maps were textual rather than simple lines and few of the Spanish maps achieved the complexity and richness of the UK maps. The likely explanation for this lies not in the relative levels of knowledge about ICT but in cultural and social factors affecting the children's responsiveness to this form of representation.

f) Teachers and Principals of the schools in which we worked are interested in the possibilities for changing established practices to make better use of Internet-capable new technologies in schools, but they are considerably constrained by the National Curriculum, Standard Attainment Tests and the system of school inspections by OFSTED (The Office for Standards in Education).

Discussions with some of the teachers working closely with us as research partners made it clear that they would like to use new technology in innovative ways. For other teachers, it was clear that they had little or no understanding of the possibilities that new technology tools offer to support innovative approaches to learning. The work of Engeström is particularly helpful in understanding why education systems are so resistant to change when compared with other systems such as retail, banking, the stock exchange etc. Building upon the work of Cole and Wertsch, Engeström's 'activity theory' (Engeström, Miettinen et al. 1999) provides a model for understanding the rigidity of systems with very strongly developed institutional rules, structures and divisions of labour:

The activity triangle model of human systems



(After Engeström)

In such a system, all the elements are inter-linked in the manner of a net, so that no element is able to change without consequent changes to other elements. 'Mediating' tools and artifacts, such as new technologies provide the means by which individuals and groups can change how they carry out activities. Indeed, they have their own force and logic which imposes a pressure to change the routines of practice. However, in a conventional school, with a rigid structure (one hour classes, and a curriculum leading to high stakes testing), long-established rules and codes of behaviour (seat work, submission, silence), and rigid assumptions about roles and divisions of labour (teachers teach and students learn), there is substantial inertia that resists the impetus to change. It is not teachers who resist change, it is the educational system in which they work that neither changes itself, nor provides teachers with working conditions in which change is possible. Changes in other systems like banking and the stock exchange have been painful, but they are inexorably taking place. Perhaps it is because the custodial function of schooling locks education systems into particular constraints of power and hierarchy that they are so extraordinarily resistant to change – certainly in the US and the USA and probably wherever in the world that there is provision for mass education supplied to all citizens by the state.

The educational significance of the research outcomes

New Technology is currently bringing about rapid changes in society on both sides of the Atlantic. The pace of these changes in the economic, commercial and industrial sectors is not matched in schools and there is a growing mismatch between the public education curriculum and children's socio-cultural learning.

It is of great importance to raise awareness among politicians, policy-makers and the general public of the implications of this mismatch. Many educational researchers may also still perceive new technology as a specialist field rather than one that has major implications for the curriculum and pedagogy as a whole. The public education system faces an enormous challenge and this

paper should help to clarify why the changes are necessary and some of the positive outcomes that may be gained.

Our knowledge of the use of new technologies in US schools, based on many years of close contacts with the American research and teacher education communities, suggests that this research will also be of considerable relevance and interest to an American audience. In our presentation, we will broaden the scope of our cross-national cultural comparisons between England and five other European countries to include speculative comparisons with American schools and invite audience responses.

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