Children’s Thinking About Computers

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Abstract

It is now almost 20 years since Hughes, Brackenridge and McLeod, writing in 1987, lamented the rapidly passing opportunity to investigate 'computer-naïve' children and examined the views of seven year-old children on their experience of computers, their attitudes towards them, their conceptions of how computers function and whether there was sex-stereotyping in those views. Little further work has been done in the area of children's thinking about computers and this paper will report on the start of work to remedy this.

It will concentrate on one of the above aspects; children's views of how computers function. Given the fascination that computers appear to hold for children and the amount of time that children spend exploring and using computers, it would be surprising if they had not developed sophisticated conceptions and mental models in this area. Understanding of such perceptions may serve to inform teaching and learning in ICT and other subjects.

One class of 26 seven year-olds and one of 26 eleven year-olds was studied over the period November-December 2002 using a variety of approaches including drawings and interviews. This paper reports the results and the conclusions, contrasting them with the earlier work.
Introduction

Constructivism (Piaget, (1929), Driver and Oldham, (1986)) and Social Constructivism (e.g. Vygotsky (1978) and Solomon (1987)) offer appealing theories of how children learn and have, for many, a satisfying logic, though the theories have some critics (e.g. Solomon (1994), Suchting (1992) Gil-Perez et al (2002)).

Research shows that, in recent years, many children have spent a great deal of time interacting with computers both at home and at school (Impact2 Strand 3 Report (2002), Wellington (2001), Selwyn (1998)) and the Constructivist might expect that they will have developed complex mental models of computers and their operation in order to assist that use. It is also likely that some of those mental models will include errors, misconceptions and alternative frameworks (Driver et al, 1985). Indeed, teachers of ICT (as of all subjects) are required by the Teacher Training Agency to “identify common misconceptions and intervene to address pupils’ errors” (TTA, 2002).

In this paper, previous work in the area of children’s thinking about computers will be examined and some recent small-scale work in this area will be reported. Reporting in 1987 on work carried out in this area in 1983 and 1985, Hughes et al (1987) state “Our... motive... was to obtain some baseline data at a time when children’s exposure to computers was still fairly limited. ... Unfortunately, few researchers appear to have grasped this opportunity... “.

Hughes et al (op cit) examined and reported on four areas:

1. “...the extent to which children had already encountered computers in their daily lives... “

2. “... the extent to which children held ‘positive’ or ‘negative’ attitudes towards computers.”

3. “...sex-role stereotyping ... the extent to which computer technology is seen to be the prerogative of the male sex.”

4. “ the child’s mental model or conceptual model of how the computer operates.”
It is the fourth of these areas which this paper addresses. The lack of published research in this area does not appear to have changed in the intervening period: according to the Social Science Citation Index, this seminal discussion has been referenced only twice in the intervening years and both of those citations have referred to the gender issues which the authors discuss.

In the light of the view of Mawby et al (1984): "If child novice models of computer functioning are badly flawed, then they may acquire low-level skills, but the deeper conceptual understanding that allows skills to develop and generalize may elude them", this paper reports an initial attempt to examine children's thinking about computers and to look further to see whether such thinking demonstrates evidence of misconceptions and alternative frameworks developed by children working with computers.

**Background**

**Children's Thinking About Computers**

To shed light on the questions listed previously, Hughes et al studied approximately 100 children in November 1983 (53 seven year-olds and 49 ten year-olds). Largely the same sample of children was studied again in March 1985. Children were interviewed individually using a semi-structured approach and, on the first occasion, children were also asked to 'draw a computer'.

Early computer use, such as that described by Mawby et al (1984) concentrated on programming the computer, often using LOGO and their research concentrates on pupils’ conceptions of programs and how programs control computers.

Computers remained relatively rare, and at the time of Hughes’ first study only a minority of children had actually used one. Sage and Smith (1983) had already drawn attention to a shortcoming in research: "We have no baselines against which future developments may be interpreted, and if no research is carried out in this field very soon the opportunity for studying comparatively 'computer-naive’ children may be lost completely."

This was underlined by Lepper (1985): “If we do not act quickly, we may miss the 'research window’ on microcomputers as we did with television".
Mawby et al writing in 1984 state: “In the not-too-distant future, computer use will be so pervasive in our society that the idea of a computer-naïve child will seem antiquated, no more understandable than a school-aged child who does not know about books.” Arguably, that position was reached some years ago and all children studied currently are likely to have a rich, though varied, experience of computer use.

The current computing landscape with computers in common use in schools and high levels of school ownership of computers (5.4 pupils per computer in secondary schools and 7.9 pupils per computer in primary schools (DfES Statistical Bulletin 2003)), and high domestic ownership (49% of UK households in 2001/2 (Office for National Statistics, 2003)), the explosion of connectivity, Internet use ((40% of UK households in 2001/2 (Office for National Statistics, 2003)) and sophisticated application and gaming software has transformed the uses to which computers are put by children and reduced the part played by programming activities.

There have been no subsequent attempts to explore children’s mental models of computers and how they work, but there has been recent interest in children’s mental models of wide area networks (WANs, the Internet etc.) and how they might be explored using a variety of graphical methods, both drawn by hand and produced using computer tools.

Project REPRESENTATION, an EU-funded consortium of 11 partners co-ordinated by FORTH in Crete between 1998 and 2000 looked at the use of such techniques to examine pupils’ concepts of networked computers and included in its objectives “To investigate into the causes that allow for the formulation of mental images so as to increase understanding of children’s rationalization” (REPRESENTATION website, 2000) The project extended the idea of concept mapping as a text-based ‘knowledge representation tool’ (Novak, 1998) to include drawings of computers, peripherals and associated networks and their connections. In addition, the project developed an ICT tool to support the production of this type of ‘concept map’. The tool “provides a Concept Mapping visual collaborative learning tool for use by 9-12 year old primary school children and their teachers, as an integral part of their curriculum and learning development” (REPRESENTATION Tool Web Site). Pearson and Somekh (2000), reporting on the British phase of the project worked with children to produce drawn images. They take the view that what is needed to use ICT tools effectively, “is access to ICT plus a complex mental representation of ICT ...”. 
The maps drawn showed children’s ideas about ‘Computers in Today’s World’, i.e. they concentrated on external connections and networking rather than mental models of the computer itself and how it works. The drawings were analysed quantitatively in terms of the number of links, the type (complexity) of the drawing and its depth (in terms of the number of nodes). Considerable attention was also given to the interpretation of individual drawings that were of interest. The authors conclude that pupils have "well developed representations ... of ICT" and that their work supports the view that pupils use ICT best “as a tool for self-directed project work in which pupils ... use ICT to help them reach targets they have set for themselves under teacher guidance.”

Crawford (1999) reporting on linked research in which pupils were asked to “draw a computer system” adds: “When given an open-ended opportunity, 68% of the children described a system beyond a stand-alone computer system. It is notable that 78% of children included the Internet in their accounts. 53% included email and one small girl included interactive communication in chat rooms.”

This methodology was further developed for use in the ImpaCT2 study (which will be further discussed later). In describing the technique, Mavers, Somekh and Restorick (2002) conclude that “young people in England, aged 10-16, currently have detailed and complex cognitive representations of networked technologies” and that "most pupils have sophisticated ... mental models ... of the nature of networked technologies and their role in today’s world."

The ImpaCT2 study (Harrison et al, 2002) involved 3 ‘strands’, one of which (Strand 2) used the techniques referred to above to examine pupils’ concepts of “Computers in my World”; i.e. their concepts of computers and their connection to WANs. The study identified ‘spheres of thinking’ (e.g. communications, games etc.) and ‘zones of use’ (e.g. home, workplace and school). As might be expected, pupils with greater experience of using ICT produced more sophisticated ‘maps’ and, when the process was repeated with the same pupils one year later, maps had increased in complexity.

In keeping with the researchers’ intentions, the drawings produced tend to show ‘the computer’ as one single element in a (literally) world-embracing picture and thus do not attempt to examine pupils’ conceptions of the device itself and its immediate peripherals. The reports refer to the drawings as illuminating pupils’
‘awareness’ rather than their mental models: “Pupils have an extensive awareness of the role of computers in today’s world. Awareness varies between individuals but many are knowledgeable about a wide range of equipment and how it is used, as well as the varied purposes of its use by all kinds of people in many different locations.”

Mumtaz (2002) interviewed a sample of 10 pupils aged 10-11 on a wide range of topics about their use of computers and ICT, including some discussion of how computers work. The conclusion was that pupils who had access to computers at home had a more sophisticated understanding of how computers worked that those who did not and they were able to conceive of a wider variety of uses for the computer and its associated technologies.

Methodology

The work reported in this paper is the result of a small-scale pilot study in two schools, one primary (Year 3, 7 year-olds) and one secondary (Year 7, 11 year-olds).

Hughes et al (op cit) adopted a strategy of semi-structured interviews: “The questions covered such topics as whether they themselves had used a computer and, if so, whether they had one at home; what they felt about computers … how they thought computers worked; and whether computers could think, remember and carry out operations by themselves.” All children were individually interviewed on two occasions separated by a period of 18 months and, on the first occasion, children were asked to draw a computer. The drawings produced were a rich source of information about how the children saw computers, unfiltered by the agency of an interviewing adult.

As part of the larger European Project REPRESENTATION (op cit), which looked at computer-based concept mapping, Pearson and Somekh (op cit) used a paper-based mapping exercise: “The concept mapping tasks … were all carried out with sheets of A3 paper and pens. … The pupils were first instructed in how to produce a concept map … The task was then administered using an agreed ‘script’ to ensure that as far as possible all children carried out the same task. They were asked to ‘communicate their ideas through drawing’…”
In the later ImpaCT2 study, Mavers et al (op cit) employed a development of concept mapping (Novak, 1998): "It consists of placing textual labels for concepts in boxes and linking these by means of text links, so that the connections can be read as part of the graphic representation of the conceptual map.” The ImpaCT2 researchers developed this specification: "In ImpaCT2 concept mapping has been used rather differently … a mind map’ as an ‘external mirror’ of the ‘internal structure and processes’ of ‘radiant thinking’. The concept maps, consisting simply of drawings of objects linked by lines, were produced quickly by pupils, following a standardised introduction and instructions delivered by their teacher.” The ImpaCT2 study related to the external networked environment of the computer and so in the maps produced, the computer tends to appear as a single element (not necessarily central) in a web of connectivity. Details of the computer itself were not sought and do not appear to have emerged.

The ImpaCT2 Final Report (op cit) concludes (p 100) that "The positive outcomes achieved in this study suggest that concept mapping is a worthwhile research tool for further development.”

For the present study, this methodology was adapted to focus children’s attention on the computer itself. A set of guidance notes was produced for the teachers who were to administer the task, including a standard script to be used with the children. The script used by Mavers et al was taken as a basis and developed to reflect the changed emphasis of the task, once again with the intention of ensuring that all children carried out the same task under the same conditions. A3 paper and black pens were provided for the exercise. Children were asked at the end of the exercise to label the items they had drawn, to make interpretation easier.

The key instruction was "We want to know your ideas about computers; what’s connected to them and what’s inside them.”

Subsequently, small groups of children whose drawings showed particular features of interest were interviewed about their drawings and wider topics, including such questions drawn from the Hughes study as remained relevant in the current computing environment. The results of the interviews are not included in this paper.
Two schools were selected for the pilot study. The primary school is a suburban school of approximately 450 pupils with 19% of pupils having identified SEN. The latest OfSTED report (2001) classifies the school as "a very good school with some excellent features”, though it also describes “some elements of information and communication technology” as capable of improvement. There is no computer suite and computers are distributed throughout the school. All computers are networked and have Internet access.

The secondary school is an urban community comprehensive school with Technology School status. There are some 1000 pupils and the 2002 OfSTED report states: “The overall social and economic background of pupils is below average. The overall level of attainment of pupils on entry to the school at age 11 is well below the national average. The proportion of pupils with special educational needs is a little smaller than usual, whilst that with statements of such need is broadly average. About 17 per cent of pupils come from families of ethnic minority heritage, ... This is a good and improving school. Information and communication technology (ICT) is a substantial strength of the school.” The school has a low pupil:computer ratio (3:1), a highly networked environment and easy and widespread Internet access.

One pilot was carried out in the junior school, but the first pilot in the secondary school was rejected owing to its having taken place in a computer room and a second one was carried out with a different Year 7 class in a room without computers. It was clear from the first secondary pilot that, if the drawings were done in a computer room, the children concentrated on producing a detailed “art lesson” drawing of a machine near them.

The images obtained were assessed qualitatively to establish significant areas of interest and then key features of the images were assessed and coded for further analysis and consideration.

**Results**

In the primary school, 26 images were produced by a class consisting of 10 boys and 16 girls. In the secondary school, 26 images were produced in a class of 12 girls and 14 boys. In each school, one image was produced that lacked any recognisable features and was beyond interpretation.
A striking feature was that, subjectively, there was little or no increase in the sophistication of the images produced between the ages 7 and 11. A possible quantitative indicator of this was the ‘number of valid input/output devices shown’. These included basic peripherals such as the monitor, keyboard and mouse. The average number of ‘valid items’ shown by the 7 year-olds was 4.2 and for the 11 year olds 3.4.

Pupils’ representations of keyboards are shown below:

Most pupils at both ages show a blank keyboard, but many 7 year-olds show an ‘ABCDE’ arrangement of keys. Curiously, a large number of 11 year-olds, whilst producing otherwise ‘complete’ drawings did not show a keyboard at all.

Representations of the ‘CPU’ of the computer fell into 4 groups: pupils who did not show it at all, pupils who showed only the external features, pupils who produced some representation of the internal workings. and those who showed both.
Primary pupils in general showed more connected devices and a surprisingly large number of secondary pupils showed only one or two devices: the monitor always and the mouse usually, though the keyboard was often omitted. Devices such as scanners and digital cameras rarely appeared in either group and few pupils showed a joystick or other games device. The most frequently shown device after monitor, keyboard and mouse was a set of speakers.

Children’s attitudes to connections were cavalier: most showed the connections for the peripheral devices, few showed mains connections or network connections. None of the primary children showed a connection to the Internet, though 68% of the secondary pupils did so. One primary pupil and one secondary pupil represented a network connection. Eight primary pupils and only one secondary pupil showed any form of mains connection, though 20% of primary pupils and 48% of secondary pupils showed ‘wires’ as a specific component.

36% of primary pupils showed an image on the monitor and in 12% of cases the image represented a specific application. The corresponding figures for secondary pupils are 48% and 4% respectively. In the secondary school, 64% of pupils appeared to make no distinction between hard- and software, showing packages such as ‘Word’ and ‘MS Publisher’ as connected peripherals. This was entirely absent from the representations produced by the primary pupils.

76% of primary pupils and 48% of secondary pupils showed some kind of mass storage device, almost always a CD-ROM device. Two (8%) secondary pupils specifically showed a hard disc.
All pupils were much less clear about the inner workings of the computer. One primary pupil and four secondary pupils drew a human-type brain, but 24% of both primary and secondary pupils represented the interior of the computer as a tangle of wires. Three primary and two secondary pupils specifically showed ‘plugs’ as significant components and a ‘chip’ was shown or mentioned by 24% of secondary pupils and not at all by primary pupils.

**Discussion**

Mavers et al (2002) concluded that "most pupils have sophisticated ... mental models ... of the nature of networked technologies and their role in today’s world.” This is in sharp contrast to children’s view of the computer itself. Despite extensive acquaintance with computers in both the home and the domestic context, children’s representations of them were surprisingly limited in many aspects and 11 year-old pupils produced representations that were no more detailed or extensive than those of the 7 year-olds: indeed in some ways they might be judged to be less sophisticated. In a world where scanners, digital cameras and video, games equipment, web cams and many other peripherals are common, children represented only a narrow range of connected items. Speakers were the device most commonly shown after the basic essentials and this may reflect the uses that children make of computers and the large number of ‘interactive’ CD-ROMs used in the primary school.

Mawby et al (1984) asked “... the central processing unit is more like a brain. Like the brain, it is not normally visible ... Since it is out of sight, will children even mention it as part of the computer?” and Hughes et al (1987): “For most of the children, though, a computer consisted of a keyboard (with a large number of buttons) attached by wires to a TV screen...” The computers of the 1980s generally did not have a ‘CPU box’ as the components were integrated with the keyboard, making a unit which was conveniently portable and which could easily be connected to a domestic television set as a display.

In this study, the vast majority of children either did not show the CPU, or showed its external features only. It may be that children represent only the parts of the computer that have meaning to them, that is, the parts with which they interact and which are important to them in terms of function. Children do not interact directly with the CPU and, as will be discussed later, have a very limited view of its
functions. It might be argued that those who represented the CPU box did so as either a ‘monitor stand’ or as the location of CD-ROM drive and floppy disc drives. Speakers, on the other hand are important to the multimedia role played by most computers in recent years.

The majority of input to a computer is text entry via a keyboard, and this is increasingly so as children grow older. Despite the amount of use that the children must have made of the keyboard, not one accurate representation of it appeared in terms of the ‘QWERTY’ layout of keys. Almost all of the drawings that showed a keyboard with letters showed an ‘ABCDE’ layout which may reflect the mobile phone keyboard with which children are increasingly familiar. It is hard to imagine that a child will not at least be aware that the order of keys on the keyboard is not the standard alphabetical one. A notable feature was the 44% of 11 year-olds who did not show the keyboard at all: this will require further investigation.

Every child showed a monitor in the drawing but only 36% of primary children and 48% of secondary children showed an image on the monitor. Generally these images were of cartoon characters (or perhaps representations of the ‘personality’ of the computer?) or of the ‘Windows’ desktop. Three primary pupils drew a representation of specific CD-ROM software on the screen. Illustrations shown by Hughes (op cit, p14) show monitor images that might be felt to give some indication of what the children most associate computers with: the present study looked for a similar indication, but it is not possible, on this evidence, to draw conclusions.
An interesting feature of the drawings produced by 64% of the 11 year-olds was a lack of distinction between hardware and software. Whilst a number of children drew monitor screens showing a desktop with recognisable software icons, these children showed a mixture of hardware devices and software packages as connected components. One can only speculate as to whether this was a simple misunderstanding or a genuine integration of hard- and software tools into a seamless functional whole.

Children’s perceptions of the working of the computer were intriguing. As Hughes et al say: "It is certainly true that many children in our study were puzzling over these notions ... Our impression, however was that it was our questioning, rather than the computers by themselves, which had instigated this puzzling - indeed, many children appeared to be thinking about these issues for the first time." and that is also the impression conveyed by the children in this study. Few were able to provide a conventional view of either the workings or the interior components of the computer and both drawings and descriptions show features reported by the other researchers. When interviewing children about their models of the computer, Hughes et al note the appearance of particular themes; ‘wires’, ‘electricity’ and ‘plugs’.

Mawby et al note the following remarks: "There are lots of wires and batteries", "It works by the wires inside" and "There is a whole bunch of stuff and little things inside". Children in the present study frequently represented wires and plugs as entities in themselves, that is not as mere connectors for the various components in which they were interested, but as important and significant parts of the computer. Despite this, there were few clear indications of mains connections to the computer and the issue of power for the machine does not appear significant for most children. Both schools had a networked environment but only two pupils in total showed a network connection. Similarly, both schools had good Internet connections: no 7 year-olds showed this but 72% of 11 year-olds in the highly network-aware Technology School included a web or Internet connection.
Children who made an attempt to represent their views of the workings of computers resorted to "tangled wires" as a metaphor; this was shown by 24% of pupils at each level. Some pupils showed the outline of what was recognisably a motherboard, a ‘chip’ or ‘memory’, but in all cases the internals were once again represented by “tangled wires”.

Both Mawby et al and Hughes et al note animistic or anthropomorphic attitudes to computers: in this study, one primary and four secondary pupils drew a clear representation of a human-like brain, one 11 year-old showed a “brain in the hard drive” and represented processing as “little people pressing buttons” and another, mysteriously, showed the “info whale” as processor. Turkle (1984, p41) discussing the attitudes of (at the time) highly computer aware children in the US suggests: "when children get used to (computers), the language they use to talk about them becomes more, not less psychological.”

**Conclusion**

Some research has been carried out in similar fields or by using similar techniques, but there has, as yet, been little research that has directly addressed the area of children’s’ thinking about computers and the existence of errors, misconceptions or alternative frameworks.

From this study, it is clear that children have no clearer image of the workings of a computer than those studied almost 20 years ago. When thinking about how a computer works, the predominant images are of ‘wires’ or a human-like brain.
The results suggest that, when asked to represent computers, children show the features that are most important to them and the omission of a CPU or the characters on a keyboard may well indicate that such items have little relevance to the uses that children make of computers. Following this line, one might speculate that the low level of representation of the keyboard in 11 year-olds’ drawings is because they find that the mouse (which controls the operating system and most CD-ROMs) unlocks a more interesting world than the keyboard. Equally, the only significance of the CPU may well simply be as the “the place the discs go”. “The computational core of the computer is not visible and children have few good analogues with which to grasp it... Thus, children lack any solid idea of the computer as a machine which computes.” (Mawby et al, 1984)

The drawing sessions were in some cases followed up by interviews immediately afterwards. These interviews attempted to replicate such of the questions asked by Hughes et al as remained relevant in today’s computing environment. However it is clear that, in order to obtain maximum understanding of what children are thinking, the interviews should be conducted only after a careful analysis of the drawings and that, among other things, they should seek clarification of the puzzling elements of the drawings.

This preliminary study may point to a number of conceptions that children hold about computers, or to a number of metaphors that children have constructed to assist their thinking about computers. The future direction of these enquiries is clear, though there is still some way to go to meet Mawby’s aspiration: “.. to identify misconceptions about computers that could interfere with computer use and learning, and that could be addressed by instruction”. As children grow older, it is increasingly difficult to decide whether their drawings represent their description of reality, metaphors that help them to think about the workings of computers or a little gentle irony at the expense of the adults who ask silly questions.
References


Brian

of the little computer inside

inside

brain cabinets

boxes of ideas and websites

Brain in the hard drive

The image contains a comic or drawing with various captions and labels, including:

- Brian
- Brain in the hard drive
- Of the little computer inside
- Inside
- Brain cabinets
- Boxes of ideas and websites