Learner’s conceptions of ‘common place’ computing activities: a case in word processing

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Abstract

Over the last 25 years or so, there has been a major shift in science education attributable to science educators taking constructivist ideas seriously. This paper argues that whilst computers have been increasingly used in classrooms over this same period, and there have been some efforts to portray learner’s understandings of computing concepts, remarkably little attention has been paid to how people learn information technology from the point of view cognitive development. A variant of the Predict-Observe-Explain protocol was used to probe understanding of a word processing task, and student responses were analysed using a knowledge framework. The results raise some challenges in terms of the content and pedagogy of ICT classes, and more carefully scaffolded probes to elicit learner understanding.

Introduction

A generalised constructivist position (Ben-Ari, 2001; Matthews, 1994; Skamp, 2008; So, 2002) asserts that all people have some kind of knowledge which guides how they work in the world (and with the things) around them and how they perceive the limitations and possibilities. Increasing attention has been paid to constructivist ideas of learning in recent decades. In the subject area of science, for instance, Osborne and Freyberg (1985, p. 12) observed that:

- from a young age, and prior to any teaching and learning of formal science, children develop meanings for many words used in science teaching and views of the world which relate to ideas taught in science;
- children’s ideas are usually strongly held, even if not well known to teachers, and are often significantly different to the views of scientists; and
- these ideas are sensible and coherent views from the children’s point of view, and they often remain uninfluenced or can be influenced in unanticipated ways by science teaching.

Engagement with what it means to learn in science, through ideas such as these, has led to nothing short of a paradigm shift in science curriculum over the last 20 years or so (So, 2002). Countless numbers of investigations and publications in science education have addressed the idea of strongly held notions being hard to influence and often not apparent to teachers (eg Duit, 2009, whose bibliographic work numbers in excess of 8400 entries). Textbooks on how, from this perspective, science teaching should be different today to what it was typically a few decades ago abound (eg Skamp, 2008).

The authors, as teachers of both science and information and communications technology (ICT), have an interest in applying these constructivist ideas to the learning of ‘common place’ computing activities, for example: word processing, e-mail, graphics, file management, virus checking, accessing pages on the Web, facebook, youtube, google or engaging in e-commerce. We stress that these are ‘activities’ - working interactively with a computer, not knowing ‘about it’ or its place in the world. We firstly develop the case for taking such approach, review relevant literature and then report on a small-scale study of students understandings. The discussion of the results leads to a consideration of
wider issues such as content and pedagogy of ICT classes, and the need for more carefully constructed data gathering instruments.

**Learning in ICT**

In the field of computing, students of the present era are frequently described as “ICT savvy” (Christopherson, 2006) or “digital natives” (Prensky, 2007) - that is, they are presumed to ‘be knowledgeable’ - and so it might be thought that the teaching and learning of ICT would be fertile ground for an approach which values prior knowledge and cognitive processes related to understanding. On the whole, such an approach does not yet seem to be evident. Yan and Fischer (2004) have observed that insufficient attention has been given to how people learn to use computers from the perspective of cognitive development, and Hammond and Rogers (2007) have also observed the relative lack of research into children’s understanding of computers and computing concepts compared with the very large literature on teaching and learning with information and communications technology (ICT). The teaching of ICT seems to continue to value the learning of a catalogue of skills (see both the popular ICDL¹ and INGOT² programs), a situation lamented by, for instance, Galloway (1999) and Urban-Lurain (2003). Even large scale projects, such as the netbook trial in Victorian government schools, seem quite content that students can (and should) ‘learn all about the technology themselves’ (Ellul & McGarry, 2009), without the teacher needing to be much concerned with what is learned (or how). When conceptual understanding is considered, it is at the ‘higher level’ of using ICT to create solutions to real world (or simulated) problems (Hammond & Rogers, 2007, p. 4) or the purpose, design and context of computer-produced artifacts (eg Victorian Curriculum and Assessment Authority, 2008).

Constructivism has been enormously important in computer education, particularly through the work of Seymour Papert (eg Papert, 1980) and its derivatives. In such work, use of computers in schools was not valued for its own sake, but as a means of developing knowledge in another domain, such as mathematics. The computer thus became a somewhat invisible partner in the learning enterprise, which was situated in constructivism. What we would argue for is to make the knowledge of the computer as the object of study. That is not to say that use of computers in schools should be valued for their own sake rather than as tools to promote learning. Rather, it is to acknowledge that students in our schools (and the community more generally) interact more-or-less successfully with computers on a regular basis, and it is therefore important to garner some understanding of what they ‘know’ of computers and related technology. That is, to grasp the learner’s conceptions of the technology which have developed through interacting with the technology (amongst other things) through psychological processes which we assert are broadly constructivist.

An example from Ben-Ari (2001) helps reinforce this point. He asks the reader to … consider … the paste operation … the word whose original meaning is “form a permanent chemical bond between one item and another” must be related to the operation “insert a copy of the material held in an internal buffer into the current working document at the place pointed to by the cursor” (p. 59).

Ben-Ari writes from the point of view of a computer science specialist, which would inform us that there is exactly one authoritative model for copying and pasting, and this is what should be conveyed to learners. We would contend that there are people who regularly use “copy and paste” who have never heard of the term ‘internal buffer’, and it might be instructive for the researcher or teacher to gain some real insight into understandings they do have of what is going on.

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¹ The International Computer Driving Licence, http://www.icdl.com
² An abbreviation of “International Grades - Open Technologies”, http://www.theingots.org
Key ideas

There are two ideas which are important in this situation, which the above brief quotation from Ben-Ari (2001) illustrates. The first is the distinction between ‘ostensive’ and ‘non-ostensive’ objects (Artigue, 2002, pp. 249, 270). Mathematical objects, for instance, are non-ostensive because they are not directly accessible to our senses. The above quote about ‘pasting’ indicates that using a computer is fundamentally about interacting with non-ostensive objects (eg internal buffer). The familiar user interface, with its mouse, menus and icons, is an ostensive reality and Artigue goes on to assert that our work with an ostensive representation shapes our understanding of the non-ostensive objects. This ostensive/non-ostensive distinction is important in that it clarifies that what is of real interest is learner’s understanding of a non-ostensive ‘world’.

The second idea is the distinction between ‘data structure’ compared with ‘operations on that data structure’ (Ben-Ari, 2001, pp. 47-48). This is a fundamental distinction in computer science - in other words, to the computer scientist the non-ostensive reality is described in large measure through data, how it is structured, and the range of operations applicable. Some essentials of computer science (such as von Neumann architecture and the universal Turing machine) are largely invisible to anyone but the engineer or low-level programmer, but this data/operation distinction impacts on day to day computer use. For instance, letters and their formatting in a word processing document comprise the data, and actions such as ‘copy’ or ‘paste’ are operations. Ben-Ari suggests that in order to learn how to use a word processor (for instance) one must create a mental model of the data structure and the effect of each operation.

The constructivist position asserts that interacting with the ostensive world of using a mouse to reposition graphics and text in relation to each other would lead to some formulation of a non-ostensive world. In general, it is valid to firstly enquire of the extent to which users are aware of both an ostensive and non-ostensive reality, and that the interaction with the latter is through the former. Subsequently, the enquiry should be in relation to the nature of the user’s formulation of the non-ostensive reality - is it structured in terms of data and operations, or in some other way? If it is structured in terms of data and operations, in what way? What are the implications of that structuring on other applications?

The enquiry

This brief study is an enquiry into the learner’s understanding of a non-ostensive ‘world’ as they impact on how text and graphics may be related to each other in terms text wrap and other formatting controls. There are several reasons for this. Firstly, it is a ‘common place’ computing activity. Secondly, it draws inspiration from Ben-Ari’s work with word processing (Ben-Ari, 1999, 2001; Yeshno & Ben-Ari, 2001, 2006), and as the literature review (below) makes clear, this is not something which has already been well researched. Furthermore, the use of a word processor would be a universal experience for secondary students, and adequate competency was a classroom objective for a particular class taught by Gesthuizen, and so the study formed part of that class’s work.

Prior to describing the study in detail and reporting results we proceed to review the relevant literature.

Literature Review

Hammond and Rogers (2007) have described the literature in relation to ‘common place’ computing activities as sparse, something with which we would not disagree and in which there is no apparent flourishing of publications over the last three years. It is helpful to review the literature somewhat generally drawing also on studies into learner understandings of Video Cassette Recorders (VCRs), materials technology, autonomous robots, internet searching and mobile devices such as cellular phones.
The following review is based on searches developed from key words such as ‘understanding’ and ‘computing’ or ‘technology’.

Nearly 20 years ago, Krendl, Clark, Dawson, and Troiano (1993) considered preschoolers and their use and conceptions of Video Cassette Recorders (VCRs). They found that children do not think of television as a medium but as a delivery system. It delivers movies on tape, television programs on tape and other programs not on tape. The distinction in children’s minds between tape viewing and broadcast/cable viewing is not a critical one – television to them is a delivery system only (p. 309).

There may be parallels here with users’ perceptions of the difference between data resident on a hard drive, DVD or the internet, but what is more interesting is researchers being concerned with investigating users’ understandings of the device beyound a ‘surface level’ appreciation - and finding that there really wasn’t any.

In another early work, Lloyd (1996) made a study which is interesting both in terms of methodology and findings. She studied the mental models students have of computers as expressed through both literal and figurative speech, through responses to sentence stems such as “a computer is like ...” or “programming is like ...”. The outcome of the study was that “it allowed me to ‘see’ the computer through my students’ eyes - and most alarmingly, to realise that what we were all seeing were very different things” (p. 23), though the detailed findings are potentially not relevant over a decade later.

In the same era, Williams and McKeown (1996) studied teacher’s views of the Internet from a social constructivist perspective, investigating how their understanding of the Internet (in particular, its value applicability to their life and work) was shaped through the communities with which they interact (both online and face-to-face).

In other related fields, but more recently, Davis, Ginns and McRobbie (2002) have described students’ understandings of concepts associated with materials technology. Young student's perspectives in explaining the ‘behaviour’ of a mechanical, autonomous robots have been studied by van Duuren and Scaife (1996) and Levy and Mioduser (2008). Zammit (2000) considered the iconic literacy of computer users and found that the meaning of icons was not always immediately apparent, a sentiment echoed by Ben-Ari (2001, p. 56). Kafai (2008) explored students’ conceptions of a computer virus, and found that that the large majority of online users have little understanding of a computer virus, and that explanations concentrated on ‘behaviour’ features of virus, not on their underlying structure. It was also found that though visual representations might work well for exploring many concepts in science learning, they did not work well in this context. Efthimiadis, Hendry, Savage-Knopshield, Tenopir and Wang (2004) also report on work which asked to draw: in order to identify how people conceptualise internet search engines and how they work, university students were asked to draw sketches of how they work.

Closer to the idea of ‘common place computing’, it needs to be observed that constructivism is steadily being embraced by computer science educators (that is, there is a growing realization that their students are not empty vessels waiting to be filled). Ben-Ari (2001) and Nordström (2002) have discussed the importance of this perspective in computer science. More specifically, Chesñevar, Maguitman, Gonzáles and Cobo (2004) have employed such ideas in the teaching of highly abstract topics associated with the theoretical fundamentals of computing. Chen (2003) has used constructivist principles teaching computer networking including some innovative teaching procedures using items such as rope, key rings and post-it notes to represent elements of a computer network and allow students to put their understanding on display. Conceptual understandings have had some attention, too - there is a suite of papers published in the field of the psychology of computer science which address school student understandings of programming and computer science concepts (eg. Ben-Ari & Yeshno, 2006; Pea, 1986; Powers & Powers, 2000).

Notwithstanding this background, there is little work done with ‘common place computing’. Ben-Ari (1999), Yeshno and Ben-Ari (2001) and Ben-Ari (2001) studied the mental models of word
processing of academic staff in a university, and whilst Ben-Ari and Yeshno (2006) extended this work to school students, the data available at http://portal.acm.org/ illustrates that Ben-Ari’s work has been predominantly cited in research into programming and computer systems, not at school-level computing. Hammond and Rogers (2007) did consider school-level computing, interviewing 13 children in relation to questions such as ‘What is a computer?’, ‘What is logging on?’ and ‘How does a mouse work’. They used a ‘levels of knowledge’ framework (described in more detail later in this paper) to analyse results which were admittedly very tentative, but raised questions about whether students can develop adequate explanations of computing concepts unaided.

Influenced by Ben-Ari’s work, Powers and Powers (2000) conducted research into student preconceptions related to Computer Science and Information Systems (CSIS). They observed that little work has focused on identifying the initial ideas that students bring with them to the door of their first computing class. Some related work on student conceptions has been done, but it differs from ours in the following important ways. First, these works primarily consider the conceptions that students construct once in the CSIS classroom, not the conceptions that they bring with them to the door. Also, most of this work is limited in scope to programming per se, as opposed to CSIS generally (p. 1).

And furthermore:

considerable research has focused on the erroneous ideas that beginners develop in the process of learning to program. But to our knowledge, the idea of considering the intellectual framework that existed before the learner engaged the subject has not been explored. To what extent might their erroneous ideas be the result of general knowledge, formed in the general social setting, which is either inaccurate or misapplied? CSIS educators must confront the erroneous preconceptions that students bring to the discipline from general society, and these preconceptions cannot be confronted until they are identified (p. 4).

In describing the “Fluency with Information Technology” (FIT) initiative, Urban-Lurain (2003) explained that some argue that it is not going to be necessary to teach FITness because, as computers become ubiquitous, students will arrive at college already FIT. This argument goes back to the 1980s … However, we have found that students are not arriving at our course any more FIT than they were in the 1980s. Students have a great deal of exposure to using computers, but have little conceptual understanding (p. 69).

In response, the FIT initiative designed instruction around an analysis of critical computing concepts, their inter-relationship and the types of problems that epitomise these concepts at each stage of the learning process. Unfortunately, the bank of resources developed through this program seems to be no longer available, and the concepts addressed seem more to be those derived from computer science theory than those emergent though investigation of prior knowledge.

The one field which impacts on the concerns expressed in this paper which is quite extensive is what Hammond and Rogers (2007, p. 5) refer to as the Human Computer Interaction tradition (HCI). HCI typically frames thinking about issues of student knowledge in terms of mental and conceptual models. A conceptual model is one which is invented to provide an appropriate representation of a target system; the mental model is what the user ‘presently has in his/her head’ about the target system (Cardinale, 1991). From this emerges several strands, but a consistent theme is about ‘engineering’ the optimal performance of an individual. Whilst this approach recognises that users are not empty vessels waiting to be filled, it tends to emphasise effective ‘transmission’ of the conceptual or target model, and not be particularly concerned with the mental model (eg. Hagmann, Mayer and Nenninger, 1998; Yeshno and Ben-Ari, 2001). Nor does it pay much heed to the possibility that the mental model might be strongly held, sensible and coherent views from the learner’s point of view, difficult to influence, or influenced in unanticipated ways.
Notwithstanding this perspective, there are some papers of particular interest. Scott Brandt has discussed the mental models of learners as relevant to the role of the reference librarian (Brandt, 1997; Brandt, 2001), including a study entitled “Insight into mental models of novice Internet searchers” (Brandt & Uden, 2003). There have been numerous studies into student’s hypermedia and web navigation (eg. Fenley, 1998, Chiu and Wang, 2000) and Papastergiou (2005) considered students’ mental models of the internet. Ziefle and Bay (2004) have considered the mental models of a cellular phone menu. In the work by Brandt and Uden (2003), the mental/conceptual model literature adds another research method to the repertoire – that of cognitive task analysis.

Nearly all the studies referred to so far have been small scale ones. There are two large scale studies which are of interest. Firstly, Papastergiou (2005) investigated high-school students’ conceptions of the internet. There were some 340 participants from 11 Greek public high schools who participated in interviews, completed surveys and drew diagrams. The main conclusion drawn was that “high school students form simplistic, utilitarian rather than structural mental models of the Internet” (p. 356). The second large scale study is the ImpaCT2 study carried out between 1999 and 2002 involving 60 schools in England (ImpaCT2, 2002). One component was a research task which students being asked to draw a concept map of ‘What is a computer?’, and analysis of some 2000 maps is reported in Mavers, Somekh and Restorick (2002). A subsequent study involving 6 European countries is report in Pearson and Somekh (2003). Researchers contributed some very powerful ways analyzing concept maps and also concluded that students had detailed and complex cognitive representations of networked technologies.

In summary of this review, several things can be said. Firstly, there is no major corpus of work in the field of ‘common place’ computing activities. Whilst the larger scale studies contribute importantly in terms of results and methodology, they are concerned with knowledge about the computer or its place in the world, rather working interactively with a computer. There is little published in academic journals, even in related fields. A small group of seminal works stand out: Ben-Ari (2001); Mavers, Somekh and Restorick (2002); Papasteriou (2005); Hammond and Rogers (2007); and Kafai (2008). Secondly, a range of research methods have been identified, and these include: analysis of literal and figurative speech, learner articulation of their basis for working as they do (eg think aloud protocols), cognitive task analysis, concept maps and drawing and explanation. There is no data gathering technique which stands out as more productive or more relevant than the others.

Thirdly, some small hint of the nature of learner’s knowledge about computing is given in a few papers. Ben-Ari (1999, 2002) and Yeshno and Ben-Ari (2001) have found that, in the absence of an explicitly-taught conceptual framework, students were unable to articulate their bases for working as they do. The sentiment is echoed by Papasteriou (2005) and Hammond and Rogers (2007). If knowledge about computing is incoherent, then that would be in marked contrast to the “sensible and coherent views” which learners are said to present of science as a result of their life and experience. At least, this possibility deserves some attention.

From the literature review, what is clear is an emerging appreciation that learners come to computing (or related) activities with understandings, and that it is important to value these. What follows, then, is an opportunity to further develop data gathering techniques and to systematically collate views of learners understanding of computers.

The Study

White and Gunstone’s (1992) Probing Understanding discusses a range of techniques and approaches, including concept maps, predict-observe-explain (POE) tasks and interviews about instances (IAI). Some of these have particular application to the scientific knowledge (eg POE and IAI) but their work is applicable to the full range of disciplines. It could be argued that POE and IAI encapsulate what is central to a science education from a constructivist perspective. The literature review above has shown that there is no such ‘seminal method’ relating to computing. The authors
decided to explore whether a POE strategy could be adapted to probing understanding of a ‘common place’ computing activity.

Research instrument

Predict-observe-explain (White & Gunstone, 1992, ch. 3) is a strategy to uncover individual learner’s predictions, and their reasons for making these, about a specific event. As the essence of science is observation and prediction so it is very well known in that field. It also works well in mathematics, particularly in statistics, and we would suggest that there are similar opportunities in computing. A POE consists of the following stages:

- Prediction: A situation is demonstrated to the learners up to the point of something ‘about to happen’ (eg ball being dropped as a science experiment, or characters being typed into a word processor). They make a prediction of what will happen, giving reasons if possible.
- The experiment or demonstration is performed
- Observation: Learners describe what they have observed
- Explanation: Learners provide an explanation in relation to their original prediction, possibility forcing a re-evaluation of ideas and challenging personal knowledge relating to the situation

The research instrument in this study consisted of students being shown an ‘original’ portion of a word processing document (see below), and it being indicated where some additional characters would be inserted. The characters were then inserted, and the student described what they thought was happening. Three different (pairs of) examples were shown, as illustrated in Table 1. In variation 1, the picture was anchored relative to a character within the paragraph, and as the insertion of text moved this character, the picture moved as well. In variation 2, the picture was anchored relative to the page, and as text was inserted, the picture was unmoved. In variation 3, text was inserted at the end of the paragraph and for this reason it did not matter how the picture was anchored.

<table>
<thead>
<tr>
<th>Original</th>
<th>Variation 1</th>
<th>Variation 2</th>
<th>Variation 3</th>
</tr>
</thead>
</table>

Table 1: Sample paragraph and graphic from a word processor
Participants and data collection

The participants were the 30 year 10/11 students in Gesthuizen’s senior Information Technology class, 15 males and 15 females, average age of 17. The demonstration consisted of being shown a brief video of each of the examples described above. After being shown each video, students were asked to “watch the video and answer the question, ‘what do you think is happening’”. The responses were collected using an online form.

Results

Analytic framework

Student responses to this task were categorized according to the levels of the knowledge framework developed by Hammond and Rogers (2006):

- Knowing that (Kt) - awareness that an item or process exists
- Knowing how (Kh) - shows knowledge of how to carry out a process
- Knowing of (Ko) - knows the purpose of the process and is able to explain its use beyond that which has been first observed
- Knowing why (Kw) - can reason their arguments and make appropriate choices

Examples of how this analytical framework is used to interpret student responses is given in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Kt</th>
<th>Kh</th>
<th>Ko</th>
<th>Kw</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does a mouse work?</td>
<td>Aware that most computers are connect to a mouse</td>
<td>Can use a mouse to control a cursor or arrow</td>
<td>Can explain how a mouse controls a cursor through relative movement</td>
<td>Can explain that a mouse is an input device and describe other input devices</td>
</tr>
<tr>
<td>(example from Hammond &amp; Rogers, 2006, p. 12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where does saved work go?</td>
<td>Knows that saved work can be accessed</td>
<td>Can save own work</td>
<td>Can save work in appropriate ways so that it can be easily accessed</td>
<td>Can explain attributes of commonly used storage devices</td>
</tr>
<tr>
<td>(example from Hammond &amp; Rogers, 2006, p. 12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How text and graphics can be positioned in relation to each</td>
<td>Knows that text and graphics can be positioned in relation to each</td>
<td>Can position text and graphics in a range of ways in own work</td>
<td>Can reliably apply formatting properties to change the way in which text and graphics are positioned in relation to each other</td>
<td>Can explain the attributes which determine the different ways in which text and graphics are related to each other</td>
</tr>
<tr>
<td>each other (example developed by the authors)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: The analytical framework

Results

The vast majority of responses were categorized as ‘knowing that’ (Kt). Only 9 responses were categorized as ‘knowing how’ (Kh). There were no responses categorized as ‘knowing of’ (Ko) or ‘knowing why’ (Kw). Table 3 shows a typical ‘knowing how’ (Kh) response, and all the ‘knowing of’
(Kh) responses.

<table>
<thead>
<tr>
<th>Student</th>
<th>Student Response</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 yo Female (typical Kt response)</td>
<td>The picture didn't move, the words moved. The sentences moved to the side but because the space bar button was used instead of the return button, it didn't skip a line and just continuously moved to the side.</td>
<td>Kt</td>
</tr>
<tr>
<td>16 yo Female</td>
<td>In video 3, he was typing in some words, and everything was kind of moving with it, the words were moving even the picture. Which even went out of sight at one time. The computer is acting like this because it has a different setting to the other ones.</td>
<td>Kh</td>
</tr>
<tr>
<td>15 yo Male</td>
<td>The words being typed does not affect the picture. The processor treats the picture as a border to the text. When the words reach the picture, it moves them down to the next line.</td>
<td>Kh</td>
</tr>
<tr>
<td></td>
<td>The word processor still treats the picture like border. However, after each line, the words are moved to the next line with the ENTER/RETURN key. This was done deliberately by the person who typed this, either by a particular format or done manually.</td>
<td>Kh</td>
</tr>
<tr>
<td></td>
<td>The picture is not treated as a border to the words. Instead, the word processor treats the picture as a piece of text. The picture is moved by the text into the edge and disappears, before appearing again after a few more words are written.</td>
<td>Kh</td>
</tr>
<tr>
<td>17 yo Female</td>
<td>The picture didn't move, the words moved. The sentences moved to the side but because the space bar button was used instead of the return button, it didn't skip a line and just continuously moved to the side.</td>
<td>Kh</td>
</tr>
<tr>
<td></td>
<td>The picture didn't move but the words did. Instead of using the space bar button the return button was used making the computer assume that the user wants it skip a line in between the paragraph.</td>
<td>Kh</td>
</tr>
<tr>
<td>16 yo Male</td>
<td>This time when the words were typed in the rest of the paragraph changed, but it got distorted from its original from unlike the first one. This time the paragraph was just left aligned and the picture still aligned to make it not move.</td>
<td>Kh</td>
</tr>
<tr>
<td>19 yo Female</td>
<td>When he types, the writing moved to right then down. I think it happens because of the program that he was using.</td>
<td>Kh</td>
</tr>
<tr>
<td></td>
<td>When he started typing some words the picture moved in the middle. The picture was moving maybe because he started typing in from the end of the sentences and not in the middle which makes the picture move to the middle. But I'm not sure.</td>
<td>Kh</td>
</tr>
</tbody>
</table>

Table 3: Results
Discussion

The results show that students were observant, showing an awareness that an item or process exists (Kt). A few made suggestions as to the underlying reasons for the observation (Kh), but no-one showed a knowledge of the purpose of the process and an ability to explain its use beyond that which has been first observed (Ko) or with deeply reasoned arguments or productive choices (Kw). Admittedly, in hindsight, the task was not one which lent itself to students being drawn into discussing or demonstrating reasoning at the more sophisticated levels of Ko or Kw. The suggestions made for the underlying reasons were variable, but each is genuinely interesting:

- The computer has a different setting
- The processor treats the picture as a border to the text
- Use of the enter key to modify formatting
- Use of the space key to modify formatting
- Where the insertion is made (beginning, middle, or end) makes a difference

One outcome of the study is that the instrument needs refining to deliberately draw students into the higher levels of reasoning, and to collect data which students further develop their thinking in ‘interesting cases’ such as the above. With the benefit of hindsight, richer results might have been generated if the questioning schedule had more strictly followed that of the POE. However, that is not guaranteed. Following the classroom experience, Gesthuizen commented that, “It was so hard to get them to get beyond surface levels of thinking. I struggled pushing them along without putting words in their mouth”. It is possible that our instrument failed to elicit deeper understandings because students lacked the language to describe their thoughts. Therefore, if the task were scaffolded more carefully, students might have had more to say. Approaches which deliberately draw out student understandings through analogy, such as Thinkboards (Assessable Moments in Numeracy, 2009) or Primed Clinical Interviewing (Fensham & Lui, 1999), may help provide necessary scaffolding.

The issue of why the majority student responses were at the level of ‘knowing that’ (Kt), though, remains the most important point of discussion. That level of knowing certainly implies a lack of awareness non-ostensible objects, or of data structures. Despite its small scale and deficiencies in approach, this study is in line with a number of other studies in making this observation. Ben-Ari (1999, 2002) and Yeshno and Ben-Ari (2001) found that, in the absence of an explicitly-taught conceptual framework, students were unable to articulate their bases for working as they do. The sentiment is echoed by Papasteriou (2005, p. 356) found that “high school students form simplistic, utilitarian rather than structural mental models” and Hammond and Rogers (2007) wondered whether students can develop adequate explanations of computing concepts unaided.

There is the possibility, therefore, that students do not, unaided, form deep or complete understandings of a non-ostensive world, and that such levels of understanding are actually adequate for using a computer for ‘common place’ activities. If this were so, then it offers some challenges as to how learning might be understood from a constructivist point of view. Far be it for us to make that assertion, but we can certainly observe some pedagogic implications. Hammond and Rogers (2007, p. 13) wondered “what are the effective models for teaching about computer processes”, and this remains a key question. To the practicing teacher, we would make the following suggestions:

- using a computer becomes a more efficient activity if users can appreciate similarities between different situations (eg layers in HTML, text wrap and graphics)
- teachers should not be satisfied with students ‘staying stuck’ at surface levels of knowledge
- the ideas of ‘display data’, ‘control data’ and ‘instructions’ (for instance, as found in the text-wrap example) provides a powerful framework for understanding many ‘common place’ activities
- approaches such as Thinkboards and Primed Clinical Interviewing, as mentioned above, may form the basis of useful teaching procedures to make advances in these ways
Hammond and Rogers (2007, p. 13) observe that “it is unlikely that ICT teachers will want to construct the teaching of ICT around the teaching of computing ... rather, teachers will need to recognise opportunity for formal exposition and for correcting misconceptions when they occur”. We can understand that many teachers would find this a palatable position, but we would want to ask the provocative question of what ICT classes should be about, particularly as ‘understanding’ has become the central focus of many science classes and not a needs-basis add-on.

**Conclusion**

We have considered the field of learner knowledge of ‘common place’ computing activities from a constructivist point of view. As other researchers have found, we have found the published work in this field to be sparse, although there are several important studies of small groups of school-age learners. As a classroom activity, a variant of a POE protocol was used to probe understanding of a word processing task, and student responses were analysed using a knowledge framework, which was found to be a productive and efficient method of analysis. It was found that most student responses were at the lowest level, showing an awareness that an item or process exists, but no recognition of a non-ostensive reality, a result which is commensurate with the few other published studies. This raises some challenges for teachers in terms of the content and pedagogy of ICT classes. It also raises opportunities for researchers to develop more sophisticated and more carefully scaffolded probes to elicit learner understanding.

The authors have been thinking about learner’s conceptions of ‘common place’ computing, and how constructivism might inform ICT teaching, given that it has informed a significant change in approach to science teaching. This study represents a first attempt to probe student understandings, and suggests some specific directions for our future classroom and research work:

- the usefulness of the levels of the knowledge framework of ‘knowing that’, ‘knowing how’, ‘knowing of’ and ‘knowing why’ for analysing this work.
- the need for developing scaffolded, rather than open-response, probes - for instance, following the POE protocol more strictly or approaches which deliberately draw out student understandings through analogy, such as Thinkboards or Primed Clinical Interviewing.

**References**


