How do we know that ICT has an impact on children's learning?

A review of techniques and methods to measure changes in pupils' learning promoted by the use of ICT

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Abstract: Over the past 30 years many studies have been conducted into the effects of Information and Communication Technologies (ICT) on pupils' learning. The methods used have ranged from intervention methods where the researchers have brought specific educational software into the classroom and used subject-based tests to large-scale studies using pre- and post-tests of pupils in many different classroom settings.

Previous reviews concerning the validity of educational research findings in ICT have revealed limitations regarding the generalisability of some results and the consistency of the findings due to a number of factors: e.g., using conventional tests which may not measure the specific learning which occurs from the use of ICT; or conducting small–scale case studies, sometimes with little analysis of the wider implications of the findings. Many research studies do not take account of the possible longer-term impact of ICT on learning, which may result from the consequent learner's reflections and metacognition. This paper reviews a range of research methods and results which have been used in the past, and considers the consistency, the limitations and the implications for future research into the effects of ICT on pupils' learning.

Key words: social contexts, learning styles, conditions for learning, research, evaluation

1. INTRODUCTION

During the past thirty years many educational studies have been conducted to investigate the effects of ICT on children's learning, yet there

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is still conflicting evidence about the impact ICT has on learning under what circumstances and in what settings. The earliest of the research studies took place in the 1960's and 1970's (e.g. Merrill 1975; Bork 1981), and were conducted when researchers introduced pupils to educational software in a university environment. In those studies learners did not use ICT in a normal classroom setting or within their subject curriculum, but were using software specifically designed to address specific conceptual difficulties in subjects such as science or mathematics. In other studies conducted in the 1970's, researchers investigated the effects of subject-based software on university students' learning in a curriculum setting but the measurement of the impact on learning was conducted through traditional pre- and post-tests with an assessment of experimental and control groups' performance on conventional end-of-year examinations. Laurillard (1987; 1994), who was evaluating such studies, found that the kinds of learning which were promoted by the use of subject- based simulations were different from deriving and solving equations, the ostensible measures of the tests.

Since those early research studies into the effects of ICT on learning, there have been many studies reported in the literature which have included meta-analyses of many small-scale projects (Niemiec, et al. 1987) as well as large-scale research projects investigating the effects of ICT on children's learning (Watson 1993). Recent studies investigate pupils' learning of concepts and skills using specifically dedicated programmed learning environments such as Integrated Learning Systems (Underwood, et al. 1996). The effectiveness and limitations of some of the methods to measure the impact on learning are considered in the following sections.

2. METHODS OF MEASURING THE EFFECTS ON LEARNING

There are two main groups of research methods that have been used to measure the effects of ICT on children's learning. Quantitative studies involve large numbers of children, where additional factors such as the quality of the teaching as well as the ages and backgrounds of the pupils might be expected to be cancelled out by using large enough cohorts of different ages in a range of schools and classes, with different teachers (e.g., Cox 1993). Qualitative case studies, on the other hand, are used to collect detailed data about those additional factors as well as the activities of each learner, the nature of the ICT being used and the context in which the learning takes place (e.g., Abbott 1999).

2.1 Quantitative methods

In order to measure effects of ICT on learning that can be considered as generalisable across the wider community of learners, many studies have been designed to measure changes in conceptual or procedural understanding during a time span of pre-ICT activity to the time when activity has been completed. Those quantitative studies require setting up experimental groups using ICT and control groups not using ICT. Both groups are tested before and after the learning activities, and again usually with a delayed post-test. One of the limitations of the method is that it is difficult to determine the ways in which the control group activities might also contribute uniquely to the learning of the pupils in that group and it is difficult to isolate the ICT effects on the experimental groups. For example, other factors might be influencing the learning of the pupils. Increased enthusiasm of the teachers using ICT, the novelty of the ICT experience, etc. may play a role in subsequent performance It is also difficult to design specific tests which will measure fairly the learning of the control and experimental learning groups as will be explained later. The limitations of large-scale studies have resulted in many researchers choosing to conduct smaller qualitative studies instead.

2.2 Qualitative methods

Qualitative methods usually involve conducting in-depth case studies of small groups of learners. The method enables detailed records to be kept of all the ICT-related activities, the contributions of the teacher, the other learning experiences of the pupils when using and not using ICT, and the range and extent of the ICT use of each individual learner. The approach enables the researchers to identify the relationships between the learning outcomes and the ICT activities more precisely than other types of research but does not always allow any more generalised findings to emerge (e.g., Watson 1993).

For example, when the findings of case studies are reported there are often many unanswered questions such as, "What is the influence of the whole school environment compared with another school?" and "Would other teachers' pupils have similar learning outcomes?" Other questions include: "Would the ICT activity have the same effect on pupils of a different age?" and "How would the input from parents and friends outside contribute to the pupils learning?" In any investigation, there are factors — teachers' pedagogies, teachers' epistemologies, teachers' attitudes, teachers' practices, learners' attitudes, learners' ICT abilities, the learning context, ICT education resources and ICT developments — which may need to be considered in any investigation.

The limitations of both quantitative and qualitative methods have resulted in two approaches being used to try to improve the validity of the results and the generalisability of the findings. Both approaches involve combining the methods.

2.3 Combining the methods

There are two ways of combining quantitative and qualitative methods. One way is to conduct a large-scale quantitative study, and then conduct case studies of a sub-sample of the cohorts to investigate the range of factors in more depth and to illuminate the large scale data. (e.g., Cox 1993; BECTa 2002). The range of assessment instruments and other techniques need to relate to the nature and types of learning which can be hypothesised for the study, and the relationship between the quantitative and qualitative evidence needs to be justified in terms of the aims of the investigation. The other way is to adopt a well-established approach that is used in many other areas of educational research as well as in other disciplines. Such research involves conducting a meta-analysis of a large number of published case studies and/or quantitative studies from which the results can then be generalised (e.g., Niemiec, et al. 1987).

The main limitations of this approach are the nature of ICT itself and the rapidly changing uses being made in education. The way of minimising the effect is to analyse many studies which have already been conducted within a limited time frame, e.g., during 2001. However, in order to achieve reliable and valid results, we should include evidence reported in many different countries and in many different languages. Even literature reviews in the field of ICT show that the evidence from non-English publications is rarely used to analyse impact results, a practice which is not followed in other disciplines.

Whichever approach is used to investigate the effects of ICT on children's learning, there are strategies that can help researchers achieve reliable results.

3. LEARNING OBJECTIVES

The first considerations which need to be made before investigating the effects of ICT on children's learning is to ask what kinds of learning we are trying to measure, and what we already know about the learning approaches and difficulties. Those considerations can usually be informed by what has already been identified by the relevant research community about the particular learning evidence and theories that might be relevant. For

example, if a project is being set up to measure the effects of using Logo on pupils' understanding of mathematics, then the first stage is to review the literature about pupils' misconceptions and learning difficulties in mathematics. It is not uncommon to read a research paper about investigating the effects of ICT on children's learning of mathematics, language or science that does not first provide the past empirical evidence about children's understanding of the relevant concepts. In order to investigate the impact of ICT on children's learning we need first to identify the learning objectives.

3.1 Identifying learning objectives

During the last thirty years there has been a growing body of research into pupils' learning in many subjects. For example, in science there is extensive evidence about pupils' misconceptions caused by the everyday experiences which pupils have which cause cognitive conflicts with the scientists' views (Gallop 1992), and there are similar widely-known learning difficulties relating to particular theories in modern languages education (Sadeq 2002).

Although the effects of ICT on pupils' learning cannot always be predicted nor confined to traditional learning goals, previous research evidence of pupils' particular misconceptions can provide a reliable basis for identifying the particular learning difficulties which pupils might have. The first stage, however, is to identify what kinds of learning one is trying to measure. We can ask: "Is it an improvement in the understanding of particular concepts, or the acquisition of new skills, or the development of new competencies?" and "What is the expected balance between learning aspects of a subject and learning about the ICT environment itself?" as well as "Are the learning objectives achievable by the ages of pupils being studied?"

For example, a review of pupils' data-handling skills (Cox and Nikolopoulou 1998) showed that pupils' abilities to handle Boolean logic are dependent on their age. Therefore, if we were to research the effects of ICT on children's skills in searching the Internet, we would need to take those cognitive limitations into account when deciding on the tasks, the methods and the analysis. Similarly, if we were to investigate what the effects of using the World Wide Web have on pupils' acquisition of foreign language skills we would firstly need to study the relevant theories and empirical evidence about language acculturation, information searching skills, and the influence of perceptions and representations.

The next stage of determining if ICT is having an impact on children's learning is to identify which methods will most effectively measure impact and are likely to match learning objectives and/or achievements.

3.2 Matching the methods to learning objectives

Goals of early research studies often included what impact ICT had on pupils' learning of well known concepts and skills, and the effects of science simulations on students' understanding of science concepts (Cox 2000), for example. In many of the earlier studies, the methods used to measure the impact of ICT on learning were used to measure the same skills and knowledge acquired through traditional teaching and learning environments. For example, pre- and post-tests would be developed based on problem-solving tasks to measure pupils' abilities to solve problems provided via ICT. But the research findings showed that the kinds of learning which occurred might instead be predicting relationships, or being able to draw graphs of such relationships rather than solving the mathematical relationships which the tests addressed.

In the first ImpacT study (Cox 1993) five different measures were developed to assess the possible mismatch between methods used to measure the learning achievements and the actual achievements which might occur. The first measure was an ICT general paper-based test to assess whether the use of ICT in different subjects had increased their ICT knowledge. Although the test, based on the International Education Association study (Pelgrum and Plomp 1993), was designed to assess many different ICT skills, it could not measure ICT skills which the pupils may have developed such as drafting and redrafting documents or modelling in spreadsheets.

The second type of assessments were pre- and post-tests to measure ICT's contribution to pupils' general reasoning skills, which in turn might have had an effect on their subject-based learning. The third type of assessments were pre- and post-subject-based tests; e.g., in mathematics to measure gains in learning specific mathematical concepts and skills such as angles, division, and problem solving. Finally, there were two types of concept-specific tests: One to measure concepts which the pupils might learn using either ICT or a more traditional method, and the second to measure ICT-specific skills and concepts which could only be learnt *through* the uses of ICT.

The detailed analysis of the first ImpacT project findings showed that for the ICT-related specific skills, the only methods which revealed pupils' achievements were those which were specifically designed to measure ICT-related skills such as data handling (e.g., Cox and Nikolopoulou 1997). However for the largest ImpacT samples (N=2000), the less specific subject-

based assessments revealed statistically significant findings for gains in subject knowledge.

In the very recent ImpaCT2 study (BECTa 2002), as well as using baseline mathematical and English tests to measure gains in achievements, the team also developed an innovative use of concept maps to measure the pupils' perceptions of ICT environments, and the importance of different ICT devices and applications.

In addition to the range of methods which need to be developed or adopted to measure the impact of ICT on pupils' learning there is also the fact that learning can be organised in many different ways, both inside and outside the formal school environment.

4. ORGANISATION OF THE LEARNING

In order to measure the impact of ICT on learning we need to take account of the learning environment, the way in which the activities occur and the way in which the learning is organised. The ways the learner as an individual, group learning or networks of learners, will influence the learning outcomes in different ways and should be considered as part of the learning environment.

4.1 Individual learning

Even though there is an increasing use of the Internet by learners and sometimes it is difficult to know when and if a learner is working on her/his own or collaboratively, there is still extensive use of non-networked learning activities where the learner can be assessed on an individual basis. In the case of large-scale quantitative studies different instruments can be developed to assess the pupils' learning, as indicated above, because other factors, which might also have an impact on learning, are minimised. However, in both large-scale quantitative studies and small case studies we cannot assume that the learning begins or ends with the particular ICT-based activity. There are many other ways in which the learning may be enhanced, not all of which relate specifically to the ICT experience.

Previous research into ICT and learning (e.g., Phillips 1988) and many studies in psychology have shown that after a learner engages in a particular activity he/she continues to reflect on that experience, and assimilation and reorganisation of knowledge can continue to occur. This means that when measuring the impact of ICT on children's learning we should take account of learning continuing some time after the activities have ended. Neglecting this facet of knowledge making is a weakness in some case studies where

learning is only assessed during the activity itself and no account is taken of longer term assimilation or metacognition.

Research has also shown that the impact of an ICT activity on children's learning will be influenced by the ability to work within the medium. In other words, learning achievements may be influenced by the learners' ICT literacy skills. So two other factors need to be taken into consideration: (1) when assessing the impact of ICT on children's learning, we need to find out what kinds of ICT literacy skills are required and in what ways these are related to the actual tasks and activities; (2) we need to consider how the learner's ICT skills and literacies might change over time thereby changing the learning experience and the balance between ICT learning and, for example, subject-based learning. It is usually necessary to measure both types of learning in parallel, factors which apply to pupils who learn in groups as well as to individual learners.

4.2 Learning in Groups

It has been established for many years that pupils learn from each other and from adult guidance (Vygotsky 1978). In many situations, learning with ICT includes collaborative learning (e.g., Crook 1996). So learning can involve small groups of learners working on the same computer-based problem at the same time, *or* two or more learners collaborating asynchronously over the Internet, *or* children collaborating with experts by accessing web pages or e-mailing, *or* whole-class collaborations involving projects and interactive whole class teaching. In designing research projects we need to take account of the effects different types of collaborations may have on the individual learner in the immediate and the longer term by identifying learning experiences within the research's objectives.

5. CONCLUSIONS

The different research methods which have been briefly reviewed and the strategies proposed may ensure that research into the effects of ICT on children's learning will lead to reliable and generalisable results. Many other factors, shown in Figure 1, may also be important influences on learning. One of the most useful strategies for conducting well-substantiated research is to ensure that existing knowledge is considered and used in the planning of any investigation

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BIOGRAPHY

Margaret Cox is Professor of Information Technology at King's College London (University of London) and Honorary President of the Association for ICT in Education. She pioneered the use of Computer Assisted Learning

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