The impact of ICT on learning: A review of research

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Since its introduction to the education arena in the 1960s, computers have both intrigued and frustrated teachers and researchers alike. The many promising prospects of computers and its applications did not materialise, and research into their effectiveness in learning has left many unanswered questions. The methods used in educational research of this nature in the past and present have evolved over the years. Quantitative studies such as meta-analyses are still widely used in the United States while recent large-scale research in United Kingdom used a combination of quantitative and qualitative methods. Findings from these research studies have indicated small positive effects and consequently a need for more in-depth and longitudinal studies into the impact of ICT on learning in the future.

INTRODUCTION

With the introduction of computers, the precursor of our modern-day ICT, and the promising potentials of computer-based instruction and learning, many researchers and funding agencies were led to invest much of their resources to investigate the possibility of computers replacing teachers in key instructional roles (Roblyer, Castine and King, 1988). Moreover, the ‘Everest Syndrome’ (cited in Roblyer et al., 1988, p. 5) also resulted in many believing that computers should be brought into the education arena simply ‘because they are there’ and the resultant perpetuation of the myth that students would benefit qualitatively from computers by simply providing them with the software and hardware.

However, this initial enthusiasm and novelty effect began to diminish as the realisation that the fulfilment of the promises and beliefs was not forthcoming, became increasingly evident.

Reynolds (2001) in his keynote presentation on ‘ICT in Education: The Future Research and Policy Agenda’ lamented that

…. we are trapped in a cycle of classic innovation failure – a low quality implementation of a not very powerful new technology of practice produces poor or no improvement in outcomes, which in turn produces low commitment to the innovation and a reluctance to further implement more advanced stages of the innovation…that are more likely to generate the improvement in outcomes that would produce the commitment to ICT utilisation. (Reynolds, 2001, p.2)

SCOPE OF REVIEW

This review seeks to examine and understand the methodology used by researchers to study the impact of ICT on learning. The findings from these research studies will help to evaluate its effectiveness on students’ learning outcomes and implications for education and further research. Most of the studies reviewed are limited to the United States and the United Kingdom, where
research in this field has been more consistent and well documented. Two periods of research have been suggested in this review.

(a) Research findings and their implications from 1960s to 1980s;
(b) Research findings and their implications from 1990s to 2000s, and future research.

METHODS OF ANALYSIS

The Qualitative Approach

In-depth case studies of small groups of learners are usually the norm in qualitative methods of research. Detailed records of ICT-related activities, as well as the learning taking place, are essential as they are necessary for the identification of relationships between them. However, because of the group size being investigated, it is often difficult to generalise any findings from such studies as they are not representative of the whole school population or community.

The Quantitative Approach

The quantitative approach often involves an experimental (or treatment) and a control group. The experimental group is directly involved in the ICT-related learning activities while the control group learns using the traditional method. Both groups are tested before and after the experiment and sometimes, a delayed test may be given to determine the retention rate of the learning. One of the limitations of the quantitative approach is that other factors, such as a novelty effect involving increased enthusiasm of teachers and students, may be unconsciously introduced to confound the results of the experiment.

The Quantitative-Qualitative Approach

In combining both qualitative and quantitative methods, a greater degree of accuracy and validity in the results of studies is obtained, thus strengthening the findings and implications put forward by the researcher. Two methods of this combined study have been advocated. The first method involves the conducting of a large-scale quantitative study, followed by case studies of in-depth investigation (Becta, 2001; Cox, 1993). The second method is a well-established approach known as meta-analysis. In this method, a large number of published case studies of similar characteristics are collected and comparative analysis made to identify relationships between these variables. Since its inception, researchers have consistently used this method to investigate and evaluate data in their research. This method is described in greater detail in the next section.

THE META-ANALYSIS METHOD

The meta-analysis technique was pioneered by Glass (1977) and later adopted by many reviewers (Cohen, 1981; Kulik, Bangert and Williams, 1983; Roblyer, 1988) in their research. Meta-analysts (Kulik et al., 1983) normally used a quantitative approach to their studies incorporating three main tasks:

(a) objective procedures to locate studies;
(b) quantitative or quasi-quantitative techniques to describe study features and outcomes; and
(c) statistical methods to summarise overall findings and to explore relationship between study features and outcomes.

The procedures involved, as used by Kulik and his associates (Kulik, Kulik and Cohen, 1980), are briefly described.
1. A large number of studies that examined the effects of computer-based instructions are collected from different databases.

2. Guidelines are used to sieve through the studies collected and those that fail to meet the criteria are removed. Each study is counted once even when it is presented in several papers.

3. Variables and categories for describing features of the study are developed; Experimental and control groups are taught during the same period and objective examinations are used as the criterion of student achievement. Attitudes toward computers, subject matter and instruction are based on self-report responses to questionnaire items or scales.

4. To quantify outcomes in each area of study, the **Effect Size (ES)** is used. The effect size is defined as the difference between the means of two groups divided by the standard deviation of the control group.

\[
\text{Effect Size} = \frac{\bar{X} - \bar{C}}{SD_c}
\]

where \( \bar{X} \) is the mean of the experimental group, \( \bar{C} \) the mean of the control group and \( SD_c \) is the standard deviation of the control group.

An extract of the results obtained in the study by Kulik and his colleagues (Kulik et al., 1980, p. 23) is shown in Table 1.

**Table 1. Means and standard errors of achievement effect sizes for different categories of studies**

<table>
<thead>
<tr>
<th>Coding Categories</th>
<th>Number of Studies</th>
<th>Effect Size</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard Error</td>
<td></td>
</tr>
<tr>
<td>Managing</td>
<td>11</td>
<td>0.33</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Tutoring</td>
<td>11</td>
<td>0.36</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td>5</td>
<td>0.49</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Programming</td>
<td>8</td>
<td>0.20</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Drill and Practice</td>
<td>11</td>
<td>0.27</td>
<td>0.11</td>
<td></td>
</tr>
</tbody>
</table>

In order to include the impact of the given effect’s size, Cohen (1977, p.184-185) gives the following guidelines for effect size:

- ES of 0.2 or less = small effect
- ES of 0.5 – 0.8 = medium effect
- ES of 0.8 or more = large effect

5. Finally, the direction and significance of differences in instructional outcomes between the control and experimental groups were also examined and scored using a four-point scale (see Table 2).

**Table 2. The four-point scale**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Difference Outcome</th>
<th>Statistically Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Favoured Conventional Teaching</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Favoured Conventional Teaching</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Favoured Computer-Based Instruction</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Favoured Computer-Based Instruction</td>
<td>Yes</td>
</tr>
</tbody>
</table>

6. As correlation between the effect size and the four-point scores is usually high, regression equations are used for ‘plugging’ effect-size measures for cases with missing data.
RESEARCH (1960s – 1980s)

Many studies were conducted in the past to evaluate the effectiveness of computers in the learning environment. The earliest took place in the 1960s and 1970s when researchers introduced pupils to educational software in a university environment (Cox, 2003). 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. Other studies in the 1970s measured the impact of learning through traditional pre- and post-tests using experimental and control groups. Their performance was usually assessed by the conventional end-of-year examinations.

Box Score Method

In the early years of research, there was no reliable procedure for the reviewing of studies (Roblyer et al., 1988). As such, the so-called box score method was the only available method and it involved the following steps:

- collect all the experimental and evaluation studies;
- examine each study to determine the significant difference between the experimental and control studies;
- count the number of studies which did and did not find such differences.

In the area of instructional computing, the box score method of summarising results was especially problematic where differences in treatment effects were rarely large enough to reject the null hypothesis and most studies tended to show non-significant differences. Edwards et al. (1975) completed a review on computer-assisted instruction using the true box score. They located some 30 studies and coded them for type of CAI, subject area, grade level, supplemental or replacement use, and results. Their findings indicated that CAI was more effective at elementary levels, and for supplemental use. It was also equally effective individual tutoring and programmed instruction, and found to reduce learning time.

Major Studies (1960s – 1980s)

Unlike today, computers were not as widely available in the early days of microcomputers. In spite of this limitation, a few major researches were advanced especially in the area of technology-intensive programs. Some of these studies are highlighted below.

The Los Angeles Unified School District Study

The Los Angeles Unified School District used the Computer Curriculum Corporation (CCC) program for its study in six of its schools in 1976. The CCC curricula used included drill and practice activities in mathematics (Grades 1-6), reading (Grades 3-6) and language arts (Grades 3-6). Pre- and post-tests were used to measure achievements. Of the six schools, four received computer-assisted instruction while two acted as control. Within the CAI schools, alternate groups of students either received CAI or acted as controls (did not receive CAI).

The schools under study had to use the system for drill 10 minutes each school day. Over 2000 students were involved in the study for a three-year period. The final results showed effect sizes of 0.45 for mathematics computational skills, 0.10 for mathematics concepts and applications and 0.15 for reading and language.
Project IMPAC

Four different set-ups were used in this project known as IMPAC (Instructional Microcomputer Project for Arkansas Classrooms) (McDermott, 1985). The set-up was to allow the use of a computer by each student for a certain period of time each day or week. The arrangements were as follows.

- Three types of software were loaded into four microcomputers. Students used the four microcomputers from three to ten days in a ten-day cycle for about 12-20 minutes.
- Eight microcomputers in a network were placed in classrooms where teachers worked with two or three mathematics groups. Two comprehensive mathematics packages were used. The usage by the students was similar to the first group.
- Twenty-four microcomputers were placed in a classroom. Students were brought to the classroom and used the computers for 15-25 minutes each day for eight days out of ten. Students used the same software as that used by the second group.
- Eight computers were networked and a locally-developed software package was used to monitor student progress. Computer-aided instruction was used to supplement the traditional mathematics program. The same time schedule was used as that used by the second group.

Effect sizes of 0.02 to 0.62 were reported for the study, with the most favourable results coming from the last group where traditional instruction was supplemented by computer-aided instruction.

Minnesota Technology Demonstration Program

This was a major two-year study of microcomputer use with Grade 4 to 6 students in Minnesota schools. Over 20 per cent of Minnesota school districts were involved and both microcomputer and video-based technologies were used. The computer to student ratio was very favourable and computer software was selected and used extensively and systematically based on skill needs (Morehouse, 1987).

The final results indicated that the average effect sizes achieved in mathematics, reading and language were –0.09 to –0.31, a rather disappointing finding after much initial enthusiasm and optimism from the participating teachers.

Meta-analysis studies by Kulik

In 1983, Kulik and his colleagues (Kulik et al., 1983) conducted a meta-analysis of 51 independent evaluations of computer-based teaching in Grades 6–12 and found that computer-based teaching raised students’ scores on final examinations by approximately 0.32 standard deviations, or from the 50th to the 63rd percentile. Smaller, positive effects on scores were also evident on follow-up examinations several months after the instructions. In addition, they also discovered that students developed positive attitudes toward the courses that they were taking and learning time was substantially reduced with computer-based instruction.

In an updated analysis of the effectiveness of computer-based instruction, Kulik and Klulik (1991) conducted findings from 254 evaluation studies based on studies prior to 1990. The outcomes measured were:

- student learning;
- performance on a follow-up or retention examination;
- attitude toward computers;
- attitude towards school subjects;
- course completion; and
amount of time needed for instruction.

A total of 248 of the 254 studies reported results from CBI and control groups on examinations given at the end of instruction. In 202 of these studies, the students in the CBI had the higher examination average while 46 of them showed that students in the conventionally taught class had the higher average. The difference in the examination performance of the CBI and control students was reported to be significant in 100 studies.

The average effect size was 0.30 with a standard error of 0.029, again confirming his earlier findings. This means that the performance of the CBI students was 0.30 standard deviations higher than the performance of the control students. In other words, the average student from the CBI class would outperform 62 per cent of the students from the conventional classes.

Past Reviews, Findings and Implications

In their review, Roblyer et al. (1988) made comparison studies before and after 1980 and presented their findings. In the pre-1980 studies, nearly all the estimated 200 studies indicated positive evidence that computer-based treatments offered some benefits over other methods, although a clarification was that there were few clear disagreements among the reviews. A summary of the findings indicated:

- reduction in learning time;
- limited improvement in motivation toward learning;
- computer-based treatments were generally effective in mathematics and reading/language;
- computer-aided learning (CAI) was more effective as a supplement at lower grade level;
- slow learners and under-achievers seemed to gain from computer-based methods more than more able students.
- computer-based methods are generally more effective at lower grade levels. Effectiveness of computer-managed instruction (CMI) seems to increase at higher grade levels while CAI effects seem to decrease at higher levels.

For the post-1980 review (Roblyer et al., 1988), positive effects were for achievements in every analysis of the 85 studies except for ESL, problem-solving CAI, achievement in females and attitudes toward computers as instructional media. The review concentrated on five main areas as shown below.

- **Attitudes** – Only three studies with available data were used in the review and all showed a consistent positive trend towards computers.
- **Content Area** – Computer application was most effective for Science, followed by Mathematics, Cognitive skills and Reading/Language.
- **Application Type** – Analyses were made for Reading and Mathematics due to sufficient numbers of data and both were found to be equally effective.
- **Grade Level** – Of the three levels, effectiveness of CAI was highest for college/adult level (ES = 0.57), while that of the elementary and secondary levels recorded effect sizes of 0.32 and 0.19 respectively.
- **Types of Students** – There was indication of greater effectiveness of computer application with lower-achieving students than with regular, on-grade students though the difference in effects was not significant.
Recognising the need and urgency for research in this field as its priority seemed to be losing grounds, Roblyer et al. (1988) called for a change in the perception about the value of behavioural research in several ways.

- Educational organisations must change their perspectives on research, accept it as a requirement for development and growth, and give it a funding priority along with hardware and software.
- Funding agencies must accept the need for more and better research in instructional computing methods, provide the funds to support it, and solicit ongoing research projects to answer key questions.
- Practitioners must begin to rely on the results of research to indicate the validity of their beliefs and hypotheses, and insist that their organisations provide the data that are needed.

Further research on different areas was also encouraged in the light of the findings. These areas of research are listed as shown:

- application in various skill and content areas;
- computer applications in ESL;
- word processing use;
- creativity and problem-solving with Logo (a programming language) and CAI;
- effects of computer use on attitudes and drop-out rate;
- effects of computer use on achievement of males vs females.

**RESEARCH (1990s – 2000s)**

Much educational research on ICT has been conducted over the past ten years, with more large-scale studies evidently from the United States and the United Kingdom though there are reports of research in different parts of Europe. Literature reviews in this field are important not only to educators but to policy makers who are usually reluctant to fund large-scale longitudinal studies. Yelland (2001) reported the need for such funding in Australia to support a variety of research studies which should include a mixed-method research design (Yelland, 2001, p. 36).

Such research would recognise positive effects and identify any negative influences. In this way we could determine how best to promote effective learning so that outcomes are improved.

**American Studies**

Though American educational research has always been in the forefront, its educational system has been heavily criticised by the American public over the past several decades (Christmann, 2003). Contributing significantly to the criticism of the public schools is the dismal placement of the nation’s mathematics and science students within the global hierarchy, for example The Third International Mathematics and Science Study (TIMSS). In response to the public outcry and criticisms, the schools are incorporating CAI into their curricula in efforts to enhance student achievement.

In order to answer the question, “What differences exist between the academic achievement levels of elementary students who were exposed to computer-assisted instruction, and those who were not exposed to this instruction during consecutive years?”, Christmann (2003) conducted a meta-analysis of 1800 studies for students (in grades K through 6) adopting the following criteria.

1. They were conducted in an educational setting;
They included quantitative results in which academic achievement was the dependent variable and microcomputer-provided CAI was the treatment.

3. They had experimental, quasi-experimental or correlational research designs.

The sample sizes had a combined minimum of 20 students in the experimental and control groups. Only 39 out of the 1800 studies qualified for the final inclusion in the research. A total of 8274 students were involved, with sample sizes ranging from 20 to 930 and an average sample size of 122 students. The result of the test recorded a mean effect size of 0.342, confirming that higher scores were attained by students receiving CAI, though this effect is considered small (Cohen, 1977).

In another meta-analysis study on the effectiveness of CAI on student achievement in secondary and college science education, Byraktar (2001/2002) reviewed 42 studies between 1970 to 1999. In calculating the effect size, she used the formula devised by Hunter and Schmidt (Hunter, 1990) where a pooled standard deviation is used instead of the standard deviation of the control group as developed by Glass (1977).

In the final analysis, only one of the 42 studies showed no difference between CAI and the traditional instruction group (ES = 0). The range of the ES was from –0.69 to 1.295. The mean effect size was 0.273 which can be interpreted as an average student exposed to CAI exceeding the academic achievement of 62 per cent of the students in the traditional classroom.

Waxman and his associates (Waxman, 2003) from the University of Houston synthesised recent research on the effects of teaching and learning with technology on student outcomes. This quantitative study sought to investigate the following questions:

- How extensive is the empirical evidence on the relationship between teaching and learning with technology and student outcomes?
- What is the magnitude and direction of the relationship between teaching and learning with technology and student outcomes?
- Are there certain social contexts or student characteristics that affect the relationship?
- Are there particular methodological characteristics that affect the relationship?
- Are there specific characteristics of the technology that affect its relationship with student outcomes?
- Are there specific characteristics of instructional features that affect technology’s relationship with student outcomes?

The synthesis included quantitative, experimental and quasi-experimental research and evaluation studies during a six-year period (1997-2003). The study also focused on studies that have teaching and learning with technology in K-12 classroom contexts where students and their teachers interact primarily face-to-face, compare a technology group to a non-technology comparison group and have reported statistical data that allowed the calculation of effect sizes. Using these criteria, the study was trimmed down from an initial size of 200 to 42. The final study contained a combined sample of about 7,000 students with a mean sample number of 184. The mean of the study-weighted effect sizes across all outcomes was 0.410 (p<0.01), with a confidence interval of 0.175 to 0.644. This result indicated that teaching and learning with technology had a small, positive, significant effect on student outcomes when compared to traditional instruction.

**British Studies**

In Britain, the National Council for Educational Technology (NCET) and its successor organisation, British Educational Communications and Technology Agency (Becta) have taken
large and bold steps in such educational research. During the mid-1990s, the United Kingdom government invested in a large-scale evaluation of integrated systems (Cox et al., 2003). The first report released by NCET was positive and found that children had made learning gains in mathematics, although not in reading. A second report identified the transferability of learning gains. The final report made an important reservation that the gains did not appear to be automatically transferable. The researchers also reported that the software used was mainly seen by pupils and teachers as being successful in teaching core mathematical and English skills but not all such successes were measurable through the subsequent tests or examinations (Wood, 1999). Effects on motivation and behaviour were marked but there was no evidence that they transferred to other context.

Two more large-scale projects by Becta, ImpacT and ImpaCT2 were initiated to examine the impact on ICT and attainment by students.

**ImpacT Project**

This United Kingdom project developed a range of assessment methods based on those used by previous large-scale projects, as well as new ones which were specifically designed to measure attainment in conceptual understanding and intellectual processes (Watson, 1993). These included:

- different subject- and topic-based tests, conducted over two years, testing pupils’ subject knowledge at the beginning and end of the period;
- a series of linked case studies to investigate the effects of teachers’ pedagogies on pupils’ use of ICT and the consequent learning outcomes; and
- a study of the uptake and use of ICT by all the teachers and pupils in the study, which involved new data-collection instruments, including pupils’ record sheets (collecting data on the types of ICT use and where this occurred).

In this study, there was evidence of a positive contribution to attainment in English, with a statistically significant effect of using word processing for pupils aged 8-10 years but only a partial non-significant effect for pupils aged 12-14 years. The pupils’ English was assessed through various essay-writing tasks, which were graded by two independent English teachers. The quality of the essays was also assessed through measuring the rates of cohesion and coherence in the pupils’ texts and the errors in spelling. The main finding from the study of primary pupils was that the frequency of use of ICT in their English lessons affected their achievements in English. There was a positive contribution from the use of word processing in the ‘high IT’ primary classes. When pupils composed directly with word-processing facilities, they were more prone to summarise and remove redundant information. At the secondary school level, the results were less conclusive, partly because of poor returns on the English essays and because of the limited use of ICT in English lessons.

In mathematics, pupils aged 8-10 years and 14-16 years in classes which were using Logo (a programming language) and subject-based mathematics software achieved statistically higher scores in tests than those pupils who were taught similar concepts through traditional methods. The results provided significant evidence of a positive impact of ICT on pupils’ learning in mathematics where ICT were being integrated into the mathematics curriculum. The project’s mini-studies provided additional evidence of positive effects of ICT on attainment in mathematical reasoning using Logo and boolean logic skills using databases.
ImpaCT2 Project

ImpaCT2 was one of the most comprehensive investigations into the impact of ICT on attainment conducted in the United Kingdom (Harrison, 2001). This large-scale evaluation study, was funded by the Department of Education and Skills and managed by Becta. The study extended over three years (1999-2002) and its purpose was to make an independent evaluation of the impact of ICT on children’s achievement in a representative sample of schools in England.

ImpaCT2 was a longitudinal study involving 60 schools in England and its aims were to:

- identify the impact of networked technologies on the school and out-of-school environment;
- determine whether or not this impact affects the educational attainment of pupils aged 8-16 years;
- provide information that would assist in the formation of national, local and school policies on the deployment of ICT;
- devise methods of assessing pupils’ attainment; and
- devise a framework for measuring the ICT environment.

This study combined both traditional and new research methods on a very large sample of more than 2000 pupils. Two preliminary studies were carried out in 1999 to determine the appropriate methods for measuring the impact of ICT.

The sample studied was 2,179 pupils in 60 schools, of which 30 were primary, 25 secondary and five were special schools. The selected schools represented pupils from different socio-economic groups in the urban, suburban and rural areas of England. The schools were divided into two groups: one group having a high quality of ICT provision and the second group having an average ICT provision. In each school, teachers selected 25 pupils from each key stage (KS) as a representative sample of the children in their schools in terms of ability, gender, ethnicity and socio-economic status. Data were collected on 25 pupils from each key stage:

- KS2 (Year 5 in 1999/2000);
- KS3 (Year 8 in 1999/2000);

Three strands of analysis were incorporated into the study:

- Strand 1: analysis and interpretation of national test data in relation to school rating for ICT;
- Strand 2: development and use of innovative research methods to reveal how pupils use ICT out of school; and
- Strand 3: independent Triangulated Case Studies.

In Strand 1, historical test data for individual pupils was extrapolated to indicate predicted performance. Actual performance was then compared with the predicted test results. The purpose of this analysis was to measure whether effective use of ICT by a school could enhance pupils’ attainment. In Strand 2, teacher researchers, pupil researchers and link (professional) researchers gathered data on ICT activities outside the school. In addition, a pupil questionnaire and a concept mapping task were used to gather information and data from the pupils involved in the project. In Strand 3, an independent team of researchers from the University of Leicester carried out 15 case studies of a representative sample of primary, secondary and special schools. The techniques involved the use of video diaries and electronic journals of ICT practice created by pupils and teachers.
The study reported mixed results for the effects of ICT on pupils’ attainment in English. At the primary level, there was a statistically significant impact of ICT on the KS2 English tests but not at KS3 or KS4 (Harrison, 2002). Case studies also showed the predominant use of ICT in English was for word processing (Comber, 2002).

Evidence from the study showed that ICT had a positive relationship to pupils’ learning of mathematical skills and the results varied according to the amount and type of use of ICT in the mathematics curriculum. High users of ICT at KS3 outperformed, on average, low users of ICT in mathematics, but differences at KS4 were slight. However, this aspect of the research was designed to establish whether correlation existed between ICT use and attainment and not to establish causal relationships.

The relationship between ICT use and attainment in KS2 was least marked in science, failing to reach statistical significance. However, findings at both KS3 and 4 indicated statistically significant positive associations between the level of ICT use and pupils’ attainment and showed an enhanced performance.

**Findings and Implications**

Meta-analysis studies of America schools generally showed a positive trend in the achievement of students when ICT is employed (e.g., Christmann, 2003, Bayraktar, 2001/2002, Waxman, 2003). In her studies, Bayraktar (2001/2002) found that computers were more effective when used in simulation or tutorial modes and CAI was more effective when computers were used individually by students. She suggested that tutorial and simulation CAI programs could be used in science classrooms to enhance student learning and classrooms should have sufficient computers for students to work individually. Furthermore, the studies showed that CAI was more effective when used as a supplement to traditional instruction rather than as a substitute. Therefore, the use of ICT in conjunction with other teaching strategies could be more beneficial for student learning. Another important finding revealed that teacher-developed programs were more effective than commercial software programs. Consequently, more attention should be devoted to specific educational objectives and curriculum goals when designing software for higher levels of effectiveness.

In ImpaCT2, the findings (Harrison, 2002) indicated that a diversity of pupils were learning with ICT. There was evidence that some pupils were gaining benefit at all the key stages investigated. Evidence from the qualitative strands of the research strongly suggested that impact on the curriculum was greatest when pupils’ use of ICT was fully integrated across the curriculum as a whole through both classroom and home-based activities. Although the findings from the study covered many areas, only aspects relating to the learning and ICT are listed as shown.

- Positive effects on school achievement for higher usage levels of ICT (based on pupil estimates of ICT activity) were found both at the level of the individual pupil and at the level of the school, although these were not large.
- The relationship between levels of ICT usage and effectiveness was not consistent across all key stages and subject areas at the school level.
- In none of the 13 comparisons was greater use of ICT associated with poorer outcomes, whether in terms of relative gains or in terms of examination results.
- Pupils are engaging in innovative uses of technology often outside the school context and are acquiring a complex range of skills and literacies in networked ICT, including a range of online social and communication skills.
• Many pupils have developed a complex understanding of the role of computers in the world today including a wide range of equipment and locations in which such technologies are used.

In view of these findings, some issues are being considered in the school context (Harrison, 2002).

• The acceptance that networked technologies in schools are inevitable and beneficial is almost universal among teachers. However, many of them are as yet unsure as to the impact of ICT on attainment, although they acknowledge other benefits such as increased motivation and improved behaviour. ICT is perceived to be particularly beneficial for pupils with special educational needs.

• Schools should concentrate their attention on using ICT in the teaching of curriculum subjects as an aid to improve attainment.

• Strategies for effective use of ICT resources, particularly searching on the Internet and use of ICT to support homework are still in development.

FUTURE RESEARCH

There is clear evidence from the present findings that ICT has a positive, although small effect on the learning of students. Most researchers appear optimistic about the roles that ICT will play in the school environment in the future though some have their reservations. In his concluding remarks, Christmann (2003) wrote:

… more research is needed to test the lofty expectations that many have CAI as the basis for educational achievement. Otherwise, CAI may become another misunderstood, overbought, under-used, and, eventually, a large discarded tool.

Indeed, with their updated knowledge and acquired experience on ICT, researchers are even keener to investigate thoroughly its effectiveness on learning, acknowledging that its continuing existence in schools is inevitable. Increasingly, there appears to be an underlying call for large-scale and longitudinal study of ICT and its impact on learning worldwide.

Based on evidence gathered from published research studies, especially in the context of ImpaCT2 findings, Cox (2003) in her report to the Department for Education and Skills, Becta, recommended five key areas of priorities for future research.

1. A need for more long-scale studies in order to:
   • measure attainment which is sustained over a long period (at least two to three years);
   • find out what specific uses of ICT have on the learning of concepts and skills in specific topics and subjects;
   • monitor and assess the whole learning process;
   • compare the effects of different uses of ICT on the learning of the same subject;
   • measure the effects of the use of ICT on the curriculum, and consequently on the learning of the pupils; and
   • identify appropriate methods for measuring the effects of specific use of ICT to take account of new ways of learning and new knowledge.

2. Research needs to be conducted to measure how informal learning experiences contribute to the whole learning process and thereby affect learners’ achievements.

3. New methods of measuring attainment need to be developed.

4. More research needs to be conducted into the effects of specific uses of ICT on pupils’ approaches to learning generally, on their meta-cognitive skills and on their long-term learning strategies.
5. A more extensive review of the literature would provide more substantial evidence of the effects of specific uses of ICT on pupils’ learning.

**Australian Research Perspective**

Over recent years, there were various Australian initiatives and research in the area of ICT, generally qualitative in nature. In 1999, a commissioned study (Downes, 2001) was conducted on the educational use of the internet with children eight years and under. The data for the study were obtained through literature review, a one-day workshop, telephone discussions, two observation/discussion sessions with children, a focus group of parents and telephone and/or email discussions. Findings indicated the need for sound pedagogical framework in the use of digital resources so as to ensure their effective use with young children.

In addition, Netdays Australia 2000 (Carr, 2002) was a case study involving 60 teachers and 342 schools around Australia and 15 classes in overseas countries. Its aim was to examine the teacher’s role in an online curriculum project. The data provided by the teachers were gathered through three surveys and a detailed report from 14 teachers who successfully implemented the online project. The main learning outcome for students was to recognise, promote and celebrate cultural diversity. However, there were no guidelines in assessing students in the online projects and teachers had to develop their own criteria for the evaluation of their students’ work. Six pedagogical traits were identified from the study.

- Teachers saw themselves as learners with their students and managers of their students’ learning.
- The technology matched the needs of the students and the project.
- The teachers structured the activities so that support was provided in different areas as the project grew.
- The teachers were totally committed to the project.
- The teachers had in place common management strategies.
- The students felt ownership of the project.

In a joint investigation by the Deakin Centre for Education and Change, The Institute of Koorie Education and the Institute of Disability Studies at Deakin University, Blackmore and her colleagues (Blackmore et al., 2003) reported that there was a lack of evaluation of effective practice using ICT in schools. Although ‘no research was undertaken in schools’ (Blackmore et al., 2003, p. i), their report was developed through:

- workshops with a reference group that developed the conceptual framework and identified key words,
- focused discussions between researchers in specific areas,
- contact with teacher networks,
- contact with ICT policy personnel in state educational systems,
- reference list of 1000 items, and
- 200 websites.

The report also suggested that “there is still little evidence about how it (ICT) impacts on cognitive learning outcomes” (Blackmore et al., p. 209/210).
Paris’ (2004) latest work involved 52 Year 10 students from South Australia. The study was to examine students’ attitudes towards online web assisted learning (OWAL). Using data collected through questionnaires, one of the findings was that students showed a strong positive tendency towards OWAL compared to paper assisted learning, that is the use of text.

However, these Australian studies do not seem to address the basic question, “How can we measure the effectiveness of ICT on students’ learning outcome?” Consequently, there would appear to be a major need for an approach to the studies of ICT in Australia that emphasise both the quantitative and qualitative aspects. The findings would then lead to more effective teaching and learning for students, which is the chief aim of education.

Yelland (2001) stressed the need for an Australian research on the impact of ICT on learning, especially with regard to literacy and numeracy outcomes and the concept of multi-literacies that incorporate the use of ICT. This need arises from the fact that the majority of influential studies relating to ICT originate from the United States and more recently the United Kingdom. She felt that a quality Australian-based research study would inform educational practice and improve outcomes for all students in Australian schools. Furthermore, there must be a search for ways to improve learning and educational outcomes that include the use of appropriate technologies as an integral part of learning, not as an add-on to existing practices that were in place before ICT was invented. In addition, a longitudinal study to complement research in literacy and numeracy research would be beneficial. This study would document the effective use and integration of ICT and link them to a variety of outcome measures.

**Further Research**

Recently, there has been an increased interest in neural network and learning. The brain, which is the centre of learning, memory and recall, plays an important part in the whole learning process. It is therefore important that further research should also be focussed on these areas:

(a) interdisciplinary research on how the brain learns and how ICT can be used effectively in the learning process;

(b) the use of ICT to stimulate the memory process, leading to effective learning;

(c) innovative computer softwares or programs and other ICT tools that help students to think creatively and critically.

It is interesting to note that many students are attracted to simulation and video games, and they tend to spend hours playing them in arcades and at home. What are the features of these games that make them so irresistible to students? In fact, the game developers are way ahead in terms of the technology used compared to that which is available in schools. It is no wonder that students find the software used in schools boring and uninteresting! Research into this area may include:

(a) a study on the features of video games that make them attractive to the players and how some of these features may be incorporated into educational softwares;

(b) an extended study on the effectiveness of these new educational programs on learning;

Many research studies, especially meta-analyses, have made findings that showed that ICT has small effects on learning outcomes and sometimes negative effects have been found. Qualitative research on how to improve the effective use of ICT through innovative methods, possibly incorporating a variety of ICT tools should be investigated as pilot studies. Such studies should be ongoing such that feedback can be obtained and methods modified to refine the teaching and learning process.
CONCLUSIONS

Using the analogy of an ecosystem the school can be considered as a place where “dynamic interactions of species adapt to one another within the system” (Zhao, 2003). Zhao further emphasised the fact that any invading species may need to adapt to the ecosystem it enters but it can change the ecosystem and its native species.

The introduction of ICT in schools can be likened to that of the invading species to the ecosystem. There will be a time of adjustment and adaptation by the principals, teachers and students as each seeks to find its place in the new learning environment and interacts with the new technology. In fact, the ICT development in schools generally passes through four phases, namely the emerging, applying, and transforming phases (UNESCO, 2002). The emerging phase is characterised by the purchase of computer equipment and software with teachers and administrators exploring the use of ICT in the school. In the applying phase, ICT is used to replace existing tasks. In the infusing phase, schools would have acquired a range of ICT and teachers begin to explore new ways of using ICT for their personal and professional practice. Finally, the last phase is realised when ICT becomes an integral part of the school system. Thus, the impact of ICT will be felt as it permeates throughout the whole school system, changing the methodology of teaching, the physical setting and the learning process.

Therefore it is pertinent that ICT contributes positively to the learning in schools and for it to be effective, it requires the conscious effort of all the species in the school ecosystem, that is the principal, teachers, parents and students to make it work.

REFERENCES


Yelland, N. (2001). Teaching and Learning with Information and Communication Technologies (ICT) for Numeracy in Early Childhood and Primary Years of Schooling. Canberra: DETYA.