Information and Communications Technology in the Science Curriculum: an Australian case study

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ABSTRACT This article describes a case study of the use of information and communications technology (ICT) in a selection of schools in Australia, mainly in the state of Victoria, but also in Western Australia. Although its main focus is on the use of ICT in science, this is placed within the context of the use of ICT within the whole curriculum. A model with three levels is tentatively proposed to describe the influences on the process of implementing ICT in science: the infrastructure for ICT in science, the philosophy for ICT in the school/department, and the external influences on philosophy/practice. The case study approach is justified by the relative dearth of published studies, and the potential relevance of the findings to current developments.

Introduction

This article arises out of a study made of the use of information and communications technology (ICT) in science, in a range of schools in Australia. Most of these schools were in the state of Victoria, but a smaller number were also visited in Western Australia. The purpose of the study was to attempt to identify the factors which might influence the use of ICT in Australian school science. The choice of science as the focus of the study arose originally from the author’s own professional interest, though it rapidly became apparent that the place of ICT in science could not be considered independently of its place in the whole curriculum. The broad similarity between the educational systems in these states and the United Kingdom (UK) was seen to be an advantage in obtaining and interpreting data in what was a small-scale study, of limited duration. However, the fact that the school systems in the two countries, or even in the two states, which are relatively autonomous as far as education is concerned, were unlikely to share entirely the same assumptions provided a useful discipline in the latter processes. Moreover, it was expected that innovations such as the introduction of a ‘laptops for all’ policy (Howell, 1995) would be potentially interesting. Altogether, it was hoped that the study might provide
insights into possible reasons for the relatively slow incorporation of ICT into the school curriculum, particularly when compared with the rapid increase in its use generally in both countries.

**Data from the Study**

The main source of information took the form of interviews, held in early 1997 with teachers in secondary schools, providers of in-service education and training (INSET), and government civil servants. The interviews were loosely structured and usually explored the extent, nature and perceived problems in the use of ICT in science. They subsequently examined the general provision for ICT within the school. However, the precise format of the interviews varied, depending, for instance, on the availability of the interviewees, or on whether the full range of questions was always appropriate for all interviewees.

The sources are listed in Appendix A, as A to L for sources in Victoria, and M to P for sources in Western Australia, but they are not named for reasons of confidentiality. It is not suggested that the sample is representative of all schools in these two states since most of the sources were chosen because of their potential relevance either to ICT in the curriculum generally, or to science in particular. However, some schools were chosen because they were thought to be reasonably typical of most schools. It is anticipated that most of the descriptions in the table will be familiar to readers, with the exception of the terms ‘Science and Technology Centre’, or ‘Navigator School’ whose roles are described in Section e) below.

Since the amount of data obtained from the interviews was characteristically large, it was potentially difficult or repetitious to report. Hence, as an attempt to reduce the amount of data reported, the table in Appendix A, in addition to listing the sources, includes basic descriptions of them, and brief summaries of specific aspects of the interviews. This abbreviated method of reporting the raw data from the study may be justifiable in the interests of brevity, but it may be at the expense of potentially useful detail which could have been lost as a result of the selection process. Patterns were also sought as a means of both understanding and reporting the data. However, the only clearly apparent pattern was that there seemed to be little use of ICT in science, even in schools with substantial provision for ICT. Although this pattern seems to be similar to that in schools in the UK known to the author, and is consistent with other findings (Cuban, 1986) (but not with others [Coleman, 1996]), it would hardly be worth reporting on its own. However, there are a number of factors that might be expected to emerge, even if they did not apply in simple ways to each of the institutions visited. For instance, the availability
of computer hardware and the confidence of teachers in using computers are obvious and well-reported influences on the use of computers in schools (for example, Anderson et al, 1979; Sheingold et al, 1983; Pelgrum & Plomp, 1991). These, and other factors, either from the literature, or arising from an examination of the data, were combined as shown in Figure 1.
Figure 1. Proposed model to describe the influences on the implementation of ICT in science.

Possible Patterns in the Implementation of ICT in Schools

Figure 1 arranges the influences in three main levels, roughly according to the 'distance' of the source of the influence from the original focus of the study, the use of ICT in science, which occupies a fourth level. Since it is proposed to use the diagram to organise this account, the levels are numbered in the order in which they will be considered. Thus, the numbering starts with the use of ICT in science (level 1), and ends with those influences which originate from outside the school (level 4). Level 2 consists of a group of three essentially practical factors, which appear to influence level 1 directly. Level 3 is the philosophy for ICT in either the department or the school, which seems to exert a less direct, but still heavy, influence on the use of ICT within the science department. Since INSET seemed to be involved in each of the levels, it was difficult to incorporate in the diagram. Subsuming it within each level would have been possible, but would have diminished its apparent importance. For this reason, INSET is shown separately, with links to the other levels.

It is hoped that this procedure will not only reduce repetition, but also demonstrate the value of the model in making sense of the data.

(a) The Use of ICT in Science (Level 1)

There seemed to be relatively little use of ICT in science. Given this, the commonest activity was data logging (the use of ICT to monitor the progress of experiments), which was not surprising since this is the ICT activity generally seen as most the characteristic of science. Even in schools where data logging was available, it was usually limited to the use of one machine, often in demonstration mode (A, B, L), rather than the use of data logging on a class basis (P). (Please note that the letter source ‘codes’ are provided as examples, and indicate that definite evidence was obtained about the relevant feature in these cases. However, the absence of a code letter does not imply the absence of the feature in any instance - merely that either the evidence was not obtained, or that schools exhibiting the evidence may not have been chosen as examples on this occasion).
A variety of other ICT activities were observed, but they seemed to result from the interests or enthusiasms of individual teachers, rather than from common departmental practice. Word processing was used for writing up project work (O), or for a whole range of tasks (J) (Tebbutt, 1997). The Internet was used in one school for gathering earthquake data, and a database for cataloguing geological samples (O); simulations were used in schools O and U and mind-mapping software was used in school J.

(b) The Infrastructure for ICT in Science (Level 2)
As Figure 1 shows, this level was more complex in structure than the others. It consists of three perceived influences on the extent to which ICT is used in science. These influences seem to be necessary collectively for the successful implementation of ICT in science, but individually insufficient. Two apparently rather obvious influences will be considered first.

1) The Availability of Hardware. It is clearly difficult to teach ICT, or use it to teach other subjects, if suitable computing hardware is not available. It is also true that most of the schools in the sample that taught ICT centrally had enough computers for this purpose. However, the provision of computing hardware at a sufficient level for ICT to be effectively incorporated into the science curriculum (for example), was seen to be problematic in almost all such schools (A, L, M, and P). A common problem was that the need to maximise the use of expensive facilities apparently led to these schools generally providing only just enough resources for the central teaching of ICT, making it difficult or impossible for other departments to gain access to computer rooms. However, one department (B) was apparently happy to have just the one machine it currently owned, since this allowed the department to use as much ICT as was consistent with their perceived need to maximise their examination results, and as their expertise allowed.

The schools that had chosen to teach ICT across the curriculum (C, D, J, K, and O) met the demand for increased numbers of computers in different ways. Two independent schools (J, K) had a policy requiring pupils to have a laptop computer from an early stage (year 7 or earlier, around 11 years of age, depending on the age range in the school). Such a policy seems an effective way of transferring most of the financial burden to parents, even though the schools still had to provide adequate numbers of mains connections and certain fixed facilities, such as printer stations. There were, however, a number of problems associated with this policy – the physical load on younger pupils of even a laptop computer, with its accessories; the vulnerability of laptops to damage; and the relative difficulty of upgrading laptops. However, not all independent schools had been attracted by the ‘laptops for all’ policy. School O had an equally committed approach to ICT, based on desktop machines located in ‘full-sized’ computer rooms, as well as
‘mini-labs’ with anything from three machines serving one classroom, to six machines which might serve two classrooms. The expectation was clearly that the large-scale or small-scale provision should meet all pupil or staff needs. School O also intended to arrange for pupils to be able to link their home machines to the school system as soon as possible. Most state schools seemed to be currently unable to make the sort of provision described above (J, K, and O). While two (C, D) were apparently able to do so, this seemed to be more a matter of special circumstances than a generally high level of provision, since other schools in the neighbourhood (B, E) were not similarly resourced. However, the State Government of Victoria was intending to increase hardware resources.

While solving the ‘hardware problem’ at the school level also solves it at the subject level for most curriculum subjects, the presence of water, let alone acids, in science experiments means that data logging is an activity which is not usually welcome in computer rooms. For this reason, data logging was only possible in those schools which had a separate provision for science. For science, the word ‘hardware’ involves more than computers and their usual peripherals, since data logging requires interfaces and sensors. This equipment can cost an average of one fifth of the current cost of the necessary computers, even if the equipment is produced in Australia. It can cost substantially more for equipment from the UK (D) or the USA (B, P). This additional cost may explain why only schools D and P seemed to be equipped to make extensive use of data logging.

2) Teacher Capability with Computers and Applications. The need for teachers to be familiar both with computers and the applications that are likely to be used is generally as obvious as the need for suitable hardware. Satisfying this need was not generally a problem in schools with a ‘centralised ICT’ philosophy, since the ‘core’ ICT was usually taught here by a relatively small number of teachers with appropriate expertise. In such schools, the relatively small amount of subject-based ICT tended to be done by enthusiasts who had developed their own expertise (A, B, L, M, and P). However, perhaps because their activities were seen to be peripheral to the mainstream ICT teaching, these enthusiasts could find themselves responsible for substantial amounts of computer, system and software maintenance (M), and hence they followed their interest at some cost.

Lack of computer expertise was a problem, however, for two groups of teachers: a) those who taught in ‘centralised ICT’ schools, who were currently not using ICT in their teaching, but who wished to do so; and b) those who taught in schools which became committed to a ‘devolved ICT’ philosophy. The teachers in the first group were generally left to develop their own expertise with little support in terms of provision of hardware or INSET, and could see themselves rapidly falling further behind where they wanted to be (A). In contrast, some of the teachers in the latter group had been well supported hitherto. Three schools arranged for teachers to be
provided with computers. Two of these schools had a ‘laptops for all’ policy (J, K), and in at least one of them the teachers had the machines a year ahead of the introduction of the policy with pupils (K). A state school (D) had also arranged for teachers to have computers, but subsequent replacements were to be the responsibility of individual staff members, while teachers in the independent schools could expect periodic replacements to be funded by the school. Teachers’ ability to use applications was developed via INSET, provided as a part of the timetable (D), or as a voluntary activity held after school or on Saturday mornings, and complemented by a personal development plan (J).

3) Teachers’ Knowledge of and Skills in the Curriculum Linkage of Applications. This factor is much less obvious than the two above, but it is proposed in order to explain the relatively low use of ICT in science, even in those schools where there is good provision of equipment and teachers are confident in using applications. While this proposal must be tentative since the small number of schools that met the other two conditions in this section limits the quantity of evidence, it is consistent with the findings of Rhodes & Cox (1990, in Grunberg & Summers, 1992).

Some of these schools/departments encouraged staff to use those aspects of computing which appealed to them (J, O). This practice had the advantage of encouraging computer use at an initial stage when otherwise there might have been none, and did result in some very interesting outcomes. However, it can lead to a rather haphazard development of pupils’ skills, though school J countered this by having departments take responsibility for introducing particular applications in a coordinated way. Even this last strategy falls foul of a general problem with this factor, which is to assume that the use of an application in the curriculum is rather obvious. Thus, for example, the apparently obvious use for word processing in science is for writing up experiments (C). Such uses can be disappointing, either because they amount to using a word processor as no more than as a typewriter; or because pupils have not yet developed the skills they need to write freely and correctly. In the absence of more than limited amounts of suitable teaching materials (such as those for spreadsheets, published in Tebbutt & Flavell [1995]), teachers need to develop for themselves materials which can progressively develop skills which cover the range described by Potts (1997) and Howell (1995). However, developing such materials can present intellectual, pedagogical and time demands which can be very stressful for teachers whose own grasp on skills may not yet be secure, and who may be disappointed by their pupils’ initial efforts. This level of stress can be exacerbated when any attempt to enlist help would be interpreted by the school’s management as a criticism of the school’s ICT policy (K).
(c) Philosophy for ICT in School/Department (Level 3)
The departments that were visited had generally a positive stance towards ICT in science, which might be expected given the nature of the sample. Often it seemed to be those schools and departments who had the clearest ideas about what might be done, who were not only making most progress, but were apparently most open to ideas from elsewhere (D, J). Conversely, one department in a Navigator school (C) seemed to display a somewhat closed view, which was surprising given these schools' role in providing INSET for others (see Section e).

Evidence from the sample (A, B, L, and M) and from teachers at conferences suggested that ICT was most commonly taught as a subject. This policy seemed to be as much a consequence of the history of its development as a deliberate decision, but since this teaching usually took place in a centralised facility, the teachers teaching other subjects of the curriculum generally had little opportunity to use the computer room(s).

In contrast, the few schools whose policy was to teach ICT across the curriculum were usually much more explicit about the nature of, and reasons for, the policy. This account sometimes took the form of a written internal document specifying the aims, and a detailed action plan (D); or published descriptions (J) of what had been done, and why (Howell, 1995; Potts, 1997). However, some schools, particularly independent ones who perceived themselves to be in competition with neighbours, seemed to be unwilling to publicise what they were doing (O). In spite of this, the description of the policy and its implementation were no less clear in interviews.

Explicit policies for ICT in science, whether spoken or written, were generally notable by their apparent absence. The exception to this pattern was where a strong school policy for ICT across the curriculum devolved particular responsibility to individual departments (e.g. in school J, mathematics and science departments have responsibility for introducing the use of spreadsheets for all pupils on behalf of the school).

Conversely, any kind of substantial presence of ICT in the science departments of schools with centralised ICT teaching suggests considerable commitment to ICT, either reflecting an explicit or implicit policy not otherwise identified. For example, school P was using hand-held graphics calculators for data logging, with additional equipment.

(d) External Influences on Philosophy/Practice (Level 4)
This collection of influences is complex and fluid, and the individual influences themselves could seem esoteric. It might, therefore, be expected that data would be difficult to gather and interpret. It is perhaps surprising that, in fact, the data on this group of influences seems to be quite clear.

Government Initiatives. One possible reason for governments not to specify requirements, such as the substantial use of computers, might be a
reluctance to specify ends when they are unable (or unwilling) to provide the means. However, the situation in Victoria was apparently almost the opposite of this, with the State Government being prepared to specify both the ends and the means, and to do so with apparent enthusiasm. Their essential policy was to introduce 'Learning Technologies' (ICT) across the curriculum in all state schools (H). School principals’ responsibility for implementing this whole-school approach and individual teachers’ responsibility to change were to be written into the appropriate personal development plans.

Complementing this apparently ‘stick’ approach to development, were a number of ‘carrot’ strategies, which will be outlined here and detailed later, as appropriate. Key amongst these perhaps was a teacher professional development programme, for which $14 million per annum had been allocated over 4 years. An obvious component of this programme was INSET, which is described below. In addition, schools which were connected to the Internet could access a substantial array of resource material, via hotlinks to useful web sites (hence facilitating access to useful material, without precluding normal ‘surfing’), INSET courses on-line, research material and examples of exemplary student work (Victoria Department of Education, 1997). Those who were not yet connected to the Internet could use a specially prepared virtual Internet system on CD-ROM to develop and practise Internet skills in preparation for full-scale operation, without incurring on-line costs.

Curriculum Frameworks. In recent years, governments have increasingly been using curriculum frameworks, national curricula or examination syllabuses to encourage curriculum change. Given the Victorian Government’s commitment to increasing the use of ICT described above, it is surprising that the appropriate curriculum framework specified the use of computing within science, only for students in year 10 (around 15 years of age) and beyond (Board of Studies, 1995). Even so, this limited requirement was still greater than that specified in Western Australia, where ICT seemed not to be featured at all (Education Department of Western Australia [EDWA], 1994; EDWA, 1996). Paradoxically, the popularity of ICT as a subject within the post-compulsory examinations (years 11 and 12; 16- and 17-year-old students) in Australia was leading to further pressure on the computing facilities in schools, even where the schools might have wished to give greater emphasis to work both with younger pupils, and across the curriculum (P).

Marketing. One striking feature that is reflected in the data was the number of schools with a ‘laptops for all’ policy, predominantly independent schools in Victoria. Since some schools (J) gave clear educational arguments for such a policy (see level 2 above), it might be unfair to suggest that the only motive was marketing. However, such motives have been identified (Plomp et al, 1990), and it was clear that independent schools in Melbourne without
such a policy were increasingly seen to be ‘behind the times’ and were therefore under pressure to adopt this policy. School O was also clearly aware of the marketing value of computing, though this school had not followed the laptops approach – perhaps being under less pressure to do so because it was geographically well separated from schools who were seen to have successfully implemented a laptops policy.

Parents’ perception that computers reflect well on a school also influenced the ICT policy of non-independent schools. Thus, one school in Victoria, which was not visited, was reported as encouraging parents to provide laptops for their children if they could afford to do so, and was apparently proposing to introduce differentiation in the teaching to accommodate them. A further example of the effect of parents’ views was that the science department in school A perceived the school’s need to ‘show off’ its computer facilities as a strong reason for maintaining their central position close to the entrance area. Moreover, this reason was seen to be stronger than any counter-arguments for devolving computing, and introducing ICT across the curriculum.

(e) INSET

The prominence of INSET in Figure 1 partly reflects its central place in the Government’s strategy for increasing the use of ICT in schools, and its consequent linkage with many of the levels in the diagram. A key part of this strategy seemed to be the designation of educational institutions (usually, but not always, schools) either as Science and Technology Centres (F and I), or, more recently at the time of the study, Navigator schools (or for some, both [C and D]). Both organisations were expected to act as models of good practice in the use of ICT to improve student learning, and to provide teachers with INSET. The Navigator schools’ contribution to this INSET was mainly through the use of ‘practicums’, in which principals and subject teachers spent quite a short time at the Navigator schools and were then charged with cascading the innovations they had seen in their own schools. The stage of development of the Navigator schools themselves seemed to be variable. Usually, the management structures seemed to be well advanced and were often impressive. For example, in school D senior staff, answering directly to the principal, were responsible for each of the technical, INSET and curricular aspects of ICT. Some of the developments ‘on the ground’ were also impressive (technology at C); and where this was perhaps not yet so (science at D), a determination to develop ICT in the subject was evident and would be likely to lead to effective INSET being provided on a mutual self-help basis. This variation was not surprising, given that the study was made early in the life of such schools, which had presumably been chosen on the basis of some elements of good practice, but without the opportunity to select staff for their new role.
Regional Centres (G) were a further source of the kind of INSET which was once familiar in the UK but which is now rare. They provided a very large range of daytime and twilight courses about both software packages and their application in the curriculum.

**Conclusion**

The process of implementing ICT in schools is difficult to monitor due to uncertainties in determining what the situation is at any one time, how this data should be interpreted, and what procedures might affect the situation. Large-scale studies (e.g. Stevenson, 1997; McKinsey & Company, 1997) focusing mainly on ‘technological factors of high visibility’ (Grunberg & Summers, 1992, p. 255) are one monitoring mechanism. Although many case studies are conducted, they tend not to be in the public domain, either because their small scale makes them individually difficult to generalise from, or because their sponsors have a vested interest in the information that they reveal. The small scale of the study reported here, and the fact that the sample is therefore almost inevitably unrepresentative, means that its findings must be interpreted with caution. However, the casestudy methodology does have advantages. For instance, it allows insights into ‘the teacher in the context of the social organisation of the school’ ... ‘a complex system of variables that interact’ (Grunberg & Summers, 1992, p. 272). It might also be argued that the unreliability of individual case studies could be countered by using the results of later studies to reinforce or refute those from earlier studies.

Although many of the findings are unsurprising, even these provide a useful reinforcement function – for instance, the importance of adequate numbers of computers for the effective use of ICT in the curriculum. But there are also indications of less well-known factors, such as the amount of effort, organisation, and length of time required to ensure effective implementation of ICT; or the fact that, even when teachers have the ability to use applications, this is not sufficient to ensure their use in the curriculum.

The relevance of studies such as the one described here, is that developments in the use of ICT in schools are not limited to Australia, and are taking place in many countries, not least the UK. What remains to be seen is whether these developments will make more effective use of the information available in the literature; whether case studies will find a place in this literature; and whether current developments will be more successful than many developments hitherto.
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