# Pedagogical Adaptation to ICT in Australia

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**Abstract.** Digital computers have developed over the past 70 years or so. Therefore, it is possible to review social adoption and subsequent educational transformation. This paper briefly looks at the generation of new technologies in general, and their subsequent adoption into social understandings. It then looks at the adoption of new technologies into education and asks how quickly they are translated from society to schools. A national survey of Australian schools was undertaken to see how well and how quickly curriculum planners adopted computers, and subsequently how fast these ideas were implemented in classrooms. 307 schools responded to the survey, showing the 'patchy' nature of this innovation dissemination. The time from curriculum awareness to full implementation of the Digital Technologies subject in schools was estimated to be 7-12 years. Since computing technology is advancing rapidly, quantum computing in schools was examined and future curriculum revisions mooted. The paper concludes by asking how best school curricula should adapt to technological developments.

**Keywords:** informatics, computing curricula, implementation time, case study, quantum computing.

## 1 Introduction

### 1.1 Technological Innovations

Historians have labelled technological innovations with descriptions such as 'Stone Age', 'Bronze Age', 'Iron Age', "Agrarian Revolution', 'Industrial Revolution' and 'Information Age'. Each of these pertains to a period of time or a turning point in human thought.

Although many societies and geographic regions passed through these Ages in sequence, they did not all do so at uniform times. Additionally, some societies skipped Ages. For instance, the Bronze Age ended in Africa in 1200 BC, while it lasted until 600 BC in Europe (600 years later). Technological discrepancies can lead to friction between societies (e.g., Iron-Age Spaniards in 1532 used steel weapons to defeat Bronze-Age Incas in Peru). Sometimes these technological differences emanated from physical properties of materials, their abundance and associated processing techniques. Thus, to melt Bronze at 913° C is easier than to melt Iron (1,538 °C) which requires a bloomery or forced-air furnace.

Specific theories have been developed to illustrate the spread of technological innovations. These include Diffusion of innovations (Rogers, 2003), Technology Acceptance Model version 2 (Venkatesh & Davis, 2000) and the Unified Theory of Acceptance and Use of Technology  (Venkatesh et al., 2003). Common to all of these is user perception or expectancy, facilitated by communication, or knowledge of the impact of the technology. In today's world (the Age of the Internet), communication is at close to the speed of light and virtually without cost. Given this convenience, how quickly might we expect innovations to spread?

Further, how quickly are these technological innovations translated from society into school education? Also, in what ways do these innovations transform how and what is taught in schools?

## 1.2 Educational Transformations

Although Einstein is credited with the General theory of Relativity from 1915, it is not yet taught in most Australian Primary/Elementary schools. An exception is the 'Einstein-First project' from 2013 (Kaur, Blair, et al., 2017). Thus, the time between new knowledge generation and educational adoption can be over a century.

One might only speculate how long it was before flint knapping tuition was discontinued as metals began to be smelted. The pace of educational transformation appears to be only loosely connected with the adoption of technological innovations into society more broadly. Some people may argue that education is more about mind-tools like language, mathematics, emotions and culture than specific physical devices. Therefore, there need not be a direct link between technological innovation and schooling. To counter this suggestion, we look at ways in which pedagogical effectiveness has been measured, then link that to technological innovations.

Hattie (2009) and others have found ways to gauge the effectiveness of educational innovations, using effect sizes, effectiveness ratings or improvement indices (What works Clearinghouse, 2020). The Brookings Institute uses a 'leapfrog potential' model, one component of which is the Substitution, Augmentation, Modification, and Redefinition (SAMR) framework for technology (Winthrop, 2018). However, many of these metrics only provide a comparison between a control/traditional learning & teaching process and a new pedagogical approach. When considering the SAMR model, Puentedura shows computers causing small pedagogical effect sizes at the Substitution stage, and having much larger effects when going to the Redefinition stage (2014, p.16).

It could be said that numeracy is a subset of Mathematics, and Literacy is congruent to Literature (but not identical). Technological transformations can lead to curriculum upheaval, and the teaching of new, different content, skills, attitudes. So, it is difficult to find a comparison for efficacy metrication if the educational transformation pertains to Mathematics when the only comparator is a Numeracy skill. Still harder, when the new skill is the use of very advanced Mathematics for the student age-range under consideration (Fluck, et al., 2017) or any other similar technology-mediated educational transformation.

### 1.3 Research objectives

Research on the time for technological innovations to be implemented in school education is sparse. Searches were conducted in three databases in which such studies might reasonably be found: Education Resources Information Center (ERIC), Elton B Stephans Company (EBSCO – international academic search engine provider), and Education and Information Technologies (EAIT - the official journal of the IFIP Technical Committee on Education). The results of these searches are provided in Table 1.

**Table 1**: Number of documents in databases

| **Search string** | ERIC | EBSCO | EAIT |
|---|---|---|---|
| “technological innovation” | 1181 | 730,781 | 633 |
| "technological innovation" AND "school education" | 18 | 583 | 11 |
| "technological innovation" AND "school education" AND "time to implement" | 0 | 0 | 0 |

This provides some evidence of a research gap in determining the time it takes for technological innovations to be implemented in school classrooms. There could be discussion on subsequent changes to pedagogy or learning content. These concepts of technological innovation and educational transformation are now explored in a case study emerging from developments in Australia, with a particular focus on the time taken for implementation to be achieved.

## 2 Australian case study

### 2.1 Background

Within Australia, there is considerable legal autonomy for school curricula, but the Australian Curriculum, initially released in 2014, is used by most institutions. Variations occur by state/territory and school funding arrangements. Approximately 70% of schools are run by government, with the remaining 30% run privately by independent faith communities or charities. Within the Australian Curriculum, computer use in schools is divided into ‘ICT’ (re-labelled as Digital Literacy in 2022), and ‘Digital Technologies’. ICT/Digital Literacy and learning with a computer (student as consumer). ICT/Digital Literacies is taught through all the subjects in the curriculum, and represents the skills needed to enhance learning in all areas, including by elearning. ICT/Digital Literacy therefore represents pedagogical adaptation. Digital Technologies (elsewhere known as Computer Science, Informatics or Computing) involves computational thinking, programming and learning about computers (student as a creator). Digital Technologies thus represents new learning content.

The Australian Curriculum was reviewed in 2021, and a new version released in May of 2022 (ACARA, 2022). The revised specification for the Digital Technologies subject has altered the proportion of learning outcomes related to coding/programming from 14% to 19%. This is now similar to other jurisdictions, ranging from 17% in Singapore to 28% in New Zealand (Fluck & Girgla, 2022).

## 2.2 Australian Computer Society survey of schools

### 2.2.1 Methodology

The survey was developed in two stages. Firstly, the questions were developed by the Australian Computer Society ICT Educators Committee, and were refined over several iterations. Second, ethical permission to distribute the survey by electronic means was sought from each jurisdiction and schools' representative body. Once these permissions were received, sometimes with conditions, the survey was distributed through governmental and teacher associations. As far as possible, every school in the country was invited to participate. Schools were assured of anonymity, and the conditions from some jurisdictions ruled out some comparisons (e.g., between government and private schools).

The survey was conducted in November 2020-April 2021 and received data from 307 schools. These included primary, high school and senior collages (covering students aged from 5-18). Responses came from government schools, independent and Catholic schools. It focused on the Digital Technologies subject in the Australian Curriculum. The data were collected into a single SPSS datafile for analysis using a range of descriptive and statistical methods described below. Zagami provided a full report with recommendations based on the survey (2022).

### 2.2.2 Survey validity

When comparing the number of responding schools with the number of schools in each jurisdiction, the representativeness of the sample differed by state and territory, with $X^2$ (7) = 131.4, $p = .000$. Four states/territories (ACT, NSW, NT & VIC) were under-represented. The other four (QLD, SA, WA and TAS) were over-represented.

There was some confusion about this distinction between ICT (as a general capability) and Digital Technologies (as a discrete subject). One of the survey questions asked:

> *List three software programs/tools (or websites) students use most in their learning of Digital Technologies/IT over the entire year.*

The answers to this question were analysed to determine which tools were strictly relevant to Digital Technologies. Programming tools/sites such as Scratch, Minecraft, Code.org and robotics were clearly relevant. However, literacy learning apps may have been online, but focused on literacy reading/writing/inferencing skills. Therefore, this kind of tool was not classified as strictly relevant to the Digital Technologies subject. Khan Academy was also a popular response, but its popularity for programming/coding videos put it into the 'relevant' category. See Table 2 to see how the accuracy of this understanding was poor in classrooms with younger students, but generally better with teachers of older students.

**Table 2**: Proportion of teacher-selected tools strictly relevant to Digital Technologies/Information Technology

| Student Year levels | Percentage |
|---|---|
| F - Year 2 | 30% |
| Years 3-4 | 36% |
| Years 5-6 | 60% |
| Years 7-8 | 70% |
| Years 9-10 | 60% |

This failure of teacher-respondents to accurately identify Digital Technologies/Information Technologies tools was worrying. Because it concerned the adoption of new learning content into the curriculum, accurate identification was highly desirable.

### 2.2.3 General survey findings

The average time spent teaching Digital Technologies closely matched the design time in the Australian Curriculum. The time spent per week ranged from 1.1 hours for students aged 4-10 years to 1.9 hours for students aged 13-14 years.

Less than half (46%) of responding schools reported operating a bring-your-own-device policy. Where such policies operated, they tended to focus on tablets for students aged less than 10 years, and laptops for older students.

In half the schools, Digital Technologies was reported as taught in an integrated fashion with other subjects for students in Primary/Elementary schools (aged up to 12). However, it was taught as a separate subject in the majority of Secondary/High schools with older students.

About half the teachers of Digital Technologies in Primary schools were trained in the subject. However, in High schools, 80% were trained for teaching students 15-16 years old. Table 3 illustrates the lack of appropriately trained teachers at each level.

**Table 3**: Proportion of teachers of Digital Technologies working outside their area of expertise (109 to 136 schools responded, according to year-group) (ACS, 2021)

| Student Year | Proportion of schools where more than half the teachers do not have Digital Technologies expertise |
|---|---|
| P/K/F - Year 2 | 56% |
| Years 3-4 | 57% |
| Years 5-6 | 54% |
| Years 7-8 | 31% |
| Years 9-10 | 20% |
| Years 11 -12 | 12% |

A comment from one teacher-respondent read as follows:

> *The Digital Technologies curriculum is very heavy on jargon which makes it really hard for teachers with no formal expertise in that area to teach comfortably – it does in fact almost scare them away from teaching it. It would be good to have a curriculum in plain language (all key terms explained) and have links to places where teachers can find more information before they have to teach something. (ACS, 2021, p. 31)*

This lack of confidence was echoed by many, emphasizing the gap between these ‘new’ schooling requirements and their school education. It is also a comment reflective of the rapid change of the technology from niche to society-wide entitlement over the span of a generation.

The data were interrogated further to see if reporting to parents had any relation to the time spent teaching Digital Technologies (DT), time spent on professional learning and proportion of teachers working outside there are of trained expertise (out of area). There was a weak, but significant, correlation between the mean extent of reporting Digital Technologies from Kindergarten to Year 10 to parents, and the mean time devoted to teaching DT, *r* (198) = .199, *p* = .005. Also, there was a weak and significant correlation between mean reporting of DT K-10 and mean time spent on teacher professional learning for DT, *r* (196) = .225, *p* = .001. However, no significant correlation was found between mean reporting of DT K-10 and mean proportion of teachers out of area, *r* (200) = -.064, *p* = .364.

Therefore, greater professional learning and more time spent teaching Digital Technologies is associated with a greater proportion of schools reporting student achievements in the subject to parents/guardians. That teaching ‘out of area’ made little impact on the proportion of schools reporting student progress, is either a testament to the generic ability of teachers to master any subject, or to their leadership for insisting the subject be taught and reported despite this deficiency in staff training.

## 3 Time from innovation to educational implementation

The survey provided useful data on the implementation of new computer technology into school classrooms, and the barriers to this. We now look at the timescale of the process.

In Australia, the initial Ministerial endorsement of the Digital Technologies curriculum made it available to schools in 2015 (ACARA, 2022). However, by 2021, actual implementation of the subject in schools was patchy. After six years, many schools were not yet delivering the subject. This could be explained by the lack of obligation imposed by government guidelines.

The survey found the proportion of respondent schools reporting student progress with Digital Technologies to parents varied by state/territory within Australia. The survey used this question to identify schools where the subject was taught, assessed and student progress monitored. All of those processes would have to occur for a report on learning to be sent to parents/guardians.

In Western Australia, 95% of schools stated they report student achievements to parents. In New South Wales (the most populous state), only 54% of schools stated this reporting to parents occurred. This could be explained by the variation of the Australian Curriculum used in that state, where the subject is integrated with the Science subject. In Tasmania, reporting to parents was only claimed by 56% of schools. Thus, implementation of the new learning content has been 'patchy'.

**Table 4**: Estimated year in which each jurisdiction will achieve full implementation of the 'Digital Technologies' subject.

| State/Territory | Proportion of schools reporting Digital Technologies to parents in 2021 | n | Implementation progress rate (% per year since 2015) | Expected year for 100% implementation |
|---|---|---|---|---|
| Northern Territory | 100% | 3 | 17% | 2022 |
| Western Australia | 95% | 106 | 16% | 2022 |
| Australian Capital Territory | 93% | 15 | 16% | 2022 |
| Queensland | 86% | 205 | 14% | 2022 |
| South Australia | 85% | 142 | 14% | 2023 |
| Victoria | 66% | 99 | 11% | 2025 |
| Tasmania | 56% | 52 | 9% | 2026 |
| New South Wales | 54% | 80 | 9% | 2027 |

We can therefore extrapolate the time for the new learning content relating to computers to enter classrooms (see Table 4). Given that 6 years passed from the release of the Digital Technologies curriculum to the survey date, four states/territories should achieve 100% implementation by the end of 2022. Victoria should achieve full implementation by 2025, Tasmania and New South Wales by 2026 and 2027 respectively. Thus, the time from curriculum specification to full implementation in school classrooms varies from 7 to 12 years.

In Tasmania, government guidelines only mandated reporting for English/Literacy and Mathematics/Numeracy. Full reporting (including Digital Technologies) is expected to begin in 2024 (DoE, 2021, p.3). That will make it nearly 10 years between when the subject was framed, and actual nationwide delivery.

To complicate matters, a substantial review of the subject curriculum became available for schools to use from the start of 2023 (ACARA, 2022). The number of Content Descriptors for Digital Technologies has grown by 70% (from 43 to 73), reflecting some advances in the field. This fragmentation also makes learning outcomes more accessible to teachers, turning complex ones into individual outcomes.

Although the period from publication of the initial curriculum in 2015 to the revision in 2023 is eight years, this is less than the expected implementation period of ten years. The curriculum is being revised at a faster pace than many schools can implement it.

## 4 Future innovations and transformations

### 4.1 Quantum computing

We now look at the future of computers in Australian schools, and the pace required for further adaptation of innovations. In many ways, the Digital Technologies subject is evolving faster than government agencies can revise the guiding curriculum documents. The current curriculum is largely based on digital computers using binary digits (bits) and procedural programming. The rise of Quantum Computing challenges these fundamental concepts.

Australia has nurtured some promising technology innovations in quantum computing. These include room-temperature qubits from nitrogen vacancies in diamond (Hare, 2021; Náfrádi et al., 2016) and work at Michelle Simmons' group at the University of New South Wales with qubits made from Phosphorous atoms in Silicon (Kobayashi, *et al.*, 2021). Therefore, it is relevant to illustrate how some of these technological innovations can become educational transformations.

As a teaching stimulus, students can calculate the storage volume required for a single binary digit (bit) from the dimensions of historical storage devices. In 1951 a mercury delay line measured 110 x 880 x 80 mm and held 12,800 bits (605 $mm^3$ per bit). By 2018, a micro-Secure Digital (SD) card measured 15×11×1 mm and held 64GB bits (2.58 x $10^{-9}$ $mm^3$ per bit). By looking at information storage devices in history, Fig. 1 shows how this plot can be diagrammed and extended.

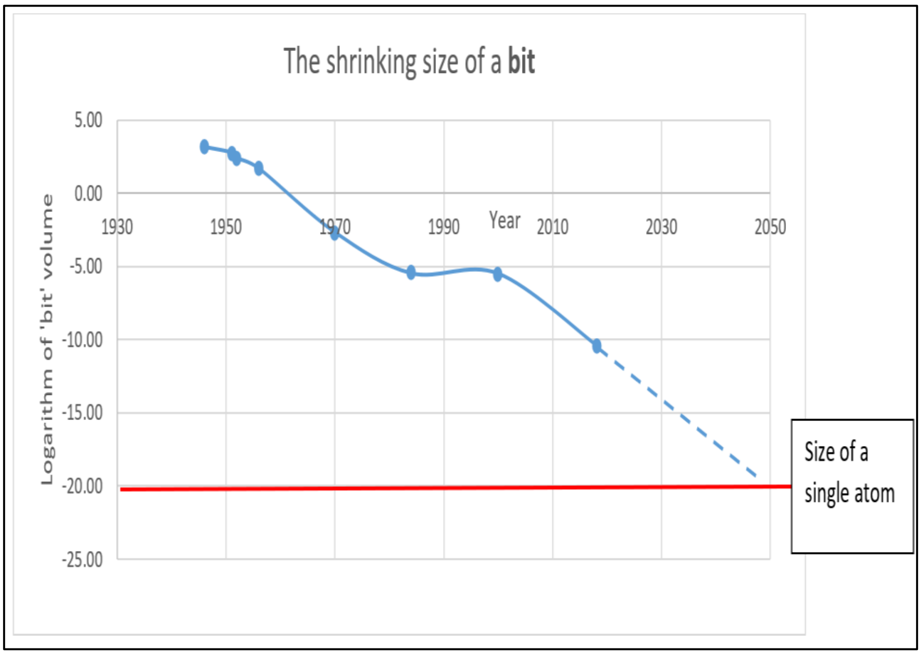

**Fig. 1**: Size v. date plot of computer memory capacity

From this type of information, students can predict when the storage space for a single bit will become smaller than an atom. Faced with this date, they can then be introduced to the probabilistic features of qubits, entanglement and superposition.

Various resources are available for schools to explain this transition from the defined procedural use of bits to the non-deterministic use of qubits. These include:

- Michael Nielsen - Quantum computing for the determined [video lectures] (https://michaelnielsen.org/blog/quantum-computing-for-the-determined)
- IBM - Qiskit Textbook (beta) https://qiskit.org/textbook-beta/; Quantum Composer (https://quantum-computing.ibm.com/composer/files/new)
- Microsoft - Quantum Katas (https://github.com/Microsoft/QuantumKatas); with Brilliant - Quantum Computing (course) (https://brilliant.org/courses/quantum-computing/)
- Jack Ceroni – Quantum Computing resources for high school students (https://unitary.fund/posts/high_school_resources.html)

From (Quantum Computing Report, 2022)

Despite the availability of these educational resource, it remains to be seen how long it will take for Australian curricula to recognize Quantum Computing, revise documents to include them, and subsequently for schools to teach it.

Other jurisdictions are recognizing the importance of being responsive to technological innovations and becoming agile with consequent educational transformations. The

K–12 Computer Science Framework (K12CS, 2016) was designed by some USA states and national stakeholder associations such as the Association for Computing Machinery (ACM). That framework is grounded in algorithmic digital computing. It has great advice for adopters in regard to teacher professional development (which the case study above identified as important). Also, there is good regard for early childhood education. The writers look at future research, and particularly implementation. However, there is no mention of quantum techniques or non-deterministic computing such as machine learning.

There was no such omission from the CC2020 Report (ACM & IEEE-CS, 2020). Aimed at undergraduate programs rather than schools, this curriculum identified quantum computing as an emerging area. One of the contributors, Deloitte, had nominated quantum computers as a ‘macro force’ (p.89).

More recently, Informatics for All (<informaticsforall.org> I4ALL, 2022) is a broader, international coalition aiming to provide a framework for national curricula. It follows on from the Rome declaration (I4ALL, 2019), which called on nations to ensure every child is taught the basics of information technology. The Framework is quite effusive on Artificial Intelligence and Machine Learning, so one might hope this aspect will be adopted Europe-wide and further. However, quantum computing and communications are absent at this stage.

## 5 Future moves

Childe, Bestwick, Yeomans et al. (2019) have filed a UK patent application for a quantum key distribution protocol. This documents a method whereby a commercial enterprise can operate a satellite for quantum communication between two ground points. The commercial enterprise will be unable to intercept the secret messages being passed through the satellite, thus provide unhackable communications as a service. Such technological advances have the potential to have massive impacts on financial, military and social spheres, both beneficial and evil. The question to ask, is how long will it take for the effects to be understood, and then how much longer for school students to be taught about them?

## 6 Conclusion

The imperatives of technological innovation and the implied need for educational transformation encourages us to reflect upon existing school curricula. There will continue to be tension between the old and the new. On one hand, it is valid to want new citizens to think for themselves, be adaptable in many future circumstances, and not rely upon technology to survive. In their younger years, they need to develop key mind-tools such as language, literacy and numeracy. On the other hand, increasing numbers of students acquire pocket-sized devices in their teens that can translate other languages in real time, provide instant global communications and other benefits of computing. We must teach students how to extend their personal capacities with such devices.

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