Report

For The Royal Society

International Comparison of Computing in Schools

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September 2011

Published in September 2011
by the National Foundation for Educational Research,
The Mere, Upton Park, Slough, Berkshire SL1 2DQ
www.nfer.ac.uk

How to cite this publication:
Sturman, L. and Sizmur, J., (2011). *International Comparison of Computing in Schools*. Slough: NFER.

Contents

Summary of headline findings

The outcomes from this small-scale international comparison highlight variability in ICT and Computing education internationally, as well as identifying some areas of common ground. They are not intended to represent an exhaustive survey, but to be useful indicators. They are potentially useful in informing discussions about how to motivate students to pursue their ICT and Computing education. They may also be useful in considering what works or might usefully be developed in our own curricula in the UK. The key findings are as follows:

- A wide range of labels is used internationally to describe the subject areas of ICT and Computing, ranging from Information Technology or Technology Literacy to Informatics and Computer Sciences, Computer Studies or Computer Engineering Technology.
- In the sampled countries'/regions' curriculum documents, the subject labels Information and Communication Technology and Digital Literacy are not used.
- In some educational systems, the subject is not represented in the curriculum. In some it is optional and in others mandatory.
- Approaches to the subject vary. Use of ICT as a tool is generally integrated and cross-curricular at the elementary stage of schooling, even in countries where it is not included in the curriculum. At upper primary and secondary level, the subject areas are usually taught as discrete elements.
- The use of ICT is included in the curriculum more commonly than the technical aspects of Computing, such as programming.
- The age at which the teaching of ICT is expected by the curriculum varies, from introduction at or before age 6 in Ontario and Massachusetts to first introduction at the age of 12 in Singapore and 14 in Italy. There is evidence, however, that many students use ICT earlier than the curriculum implies.
- Younger students are generally expected to use ICT for activities such as producing and presenting text, making presentations and carrying out internet searches. Computers are also used across the curriculum, in subjects as varied as the arts, physical education and mathematics.
- Safe and secure use of ICT tends to be included in the curriculum.
- Massachusetts, unusually, sets out an expectation for keyboarding skills.
- The introduction of more technical Computing skills occurs later, typically from the ages of 12-14 upwards.
- In terms of basic technical Computing skills, students are generally expected to know common terminology, to understand concepts such as 'hardware' and 'software' and to be able to name parts of a computer system, among other elements.
- Programming is covered in most Computing curricula investigated. In some, specific languages are identified, while in others, there is flexibility (e.g. Ontario simply specifies that programming languages should be 'industry standard').
- Only the older students are exposed to the technicalities of networking and systems management, and then not in all countries/regions.
- Curriculum design varies. Most courses are linear, while Ontario offers a menu of Computing courses at the higher levels, from which students can select courses tailored to their different interests and aspirations.

1. Introduction

This report complements the wider Royal Society study of Computing in Schools in the UK and findings from it will be incorporated into the Society's wider report on the subject. This element of the study focused on Information and Communication Technology (ICT) and Computing as a school subject in the 5-19 curriculum in a small number of countries or regions outside the UK. It explored, in particular, the terminology that each country uses for the subject and the ages (if applicable) at which it is taught.

The comparator countries or regions were selected to represent a range of experience, and for their potential relevance and/or interest to policy makers. Most made their key curriculum documents accessible on the internet. Other countries and regions of potential policy interest were considered but not referenced for various reasons, including:

- Pragmatic issues such as national or regional curriculum documents not being available online, or being available only in national languages that could not be accessed and/or translated in the time and resources available for the research (e.g. this applied for Hong Kong, Austria and Russia);
- That the relevant country/region is a member of ALLEA (see below) and therefore would be invited to provide mediated information to the Royal Society directly (e.g. Austria and Russia);
- That some potential contributors face challenges in providing students with access to the relevant ICT infrastructure. For example, India's National Curriculum Framework (see http://oupcomputers.com/curriculum_beyond.php) acknowledged in 2005 that computer access and connectivity were a serious challenge to the country's ability to deliver its curriculum aims; it was deemed unlikely that this could have been addressed to an appropriate level in the intervening six years.

The five selected countries and regions agreed between the NFER and the Royal Society were:

- Finland
- Japan
- USA (Massachusetts)
- Canada (Ontario)
- Singapore.

These are not intended to represent an exhaustive list of the ways in which ICT and Computing are taught around the world but rather to exemplify the range of curriculum experience available to students internationally. They include countries or regions known for ICT innovation and/or considered likely to demonstrate good practice in their ICT and Computing curricula. They also include countries (Finland and Singapore in particular) which tend to perform well in international surveys of achievement such as PISA and TIMSS (http://www.pisa.oecd.org and http://timss.bc.edu) and which are, therefore, frequently referred to by policy makers in England.

A brief pro forma was developed in order to collect information on the three key research questions:

1. How concepts relating to the subject areas of ICT and Computing are included in the curriculum in different national or state educational contexts.
2. How these types of learning are usually described in various countries.
3. The ages at which (if applicable) the curriculum expects them to be taught.

An initial web search resulted in a draft version of the pro forma for each of the target countries/regions. This was then sent to a contact in the country for validation. The validated responses form the basis for this report. Validated versions of the pro forma and/or further information were returned by four of the five countries/regions: Finland, Japan, Massachusetts and Ontario. Singapore is included in this report for indicative purposes but the Singaporean ministry (our usual point of contact) was not able to provide a member of staff on this occasion to validate the pro forma.

A similar pro forma (not pre-completed) was also sent to the Royal Society's ALLEA contacts (see http://www.allea.org). Responses were received in time for inclusion from two (in Montenegro and Finland) and an open response was also received from Serbia. These are incorporated in the outcomes reported below, along with a little information from Italy which arrived later.

2. Terminology

Even within the UK, the terms 'ICT', 'Computing', 'IT' and others are used to mean different things in different contexts. In this report, ICT (Information and Communication Technology) is taken to mean the *application* of the technology, including the skills of *using* computer applications, systems and networks. In contrast, Computing is interpreted as the *scientific discipline of computing*, involving technical skills and understanding related to *manipulating* elements of the technology in order to *create* applications, systems and networks. This includes the principles of algorithms, programming, design, problem solving, and so on. In the international context, it is particularly important that each country's terminology is understood, and this is discussed further below.

3. Key findings

3.1 Curriculum and terminology

It is worth bearing in mind that the intended curriculum may not always correspond exactly to the curriculum experienced by students. The curriculum set out for each country/region represents a set of expectations but might be implemented in subtly different ways in different contexts. The findings below focus on the *intended* curriculum rather than the implemented curriculum in each country/region.

The comparator countries/regions vary in how, or indeed, if at all, ICT and Computing are represented in their curricula. In most of them, ICT is integrated with other learning during the earlier years of education, being used as a tool across the curriculum. Where ICT and/or Computing are represented as discrete subjects, this tends to arise at the later stages of schooling, and a wide range of labels is used to describe the subjects. These labels include the following.

For those countries/regions specifying a discrete subject at the elementary phase (which is typically up to age 12 but with some exceptions, see Appendix A):

- Information Technology (elementary and lower secondary, Finland and Japan);
- Technology and Home Economics; Information (Japan);
- Technology Literacy (throughout elementary and lower/upper secondary, Massachusetts);
- Computer and Information Sciences (Serbia);
- Technics and Informatics (Montenegro).

At the upper primary/lower secondary phases (typically ages 12- 15/16, see Appendix A), the labels used in Finland, Japan and Massachusetts match those used at elementary level. For the other countries/regions, additional labels are:

- Computer Applications (Singapore);
- Computer Science (Italy);
- Technological Education - Exploring Technologies; Technological Education - Computer Technology; Introduction to Computer Studies (Ontario);
- Web Presentation and Informatics; Programming Algorithms (Montenegro);
- Technology and Informatics; Informatics and Computer Sciences (Serbia).

At the upper secondary phase (typically ages 15/16 upwards, see Appendix A), the label used in Italy matches that at lower secondary level. For the other countries/regions which identified their courses, additional labels are:

- Computing (Singapore);
- Technology and Society (cross-curricular theme, Finland);
- Computer Studies – Computer Science; Computer Studies – Computer Programming; Technological Education – Computer Technology; Technological Education – Computer Engineering Technology (Ontario);
- Science and Technology/Engineering (Massachusetts);
- Information Technology (Japan);
- Computer Sciences and Informatics (Serbia).

Some of these subject labels suggest a broadly technical emphasis to the curriculum, while others suggest a focus on the application and use of ICT. It is interesting that the term ‘Information Technology’ occurs but ‘Information and Communication Technology’ does not. Another term that might have been expected but does not occur as a subject label is ‘Digital Literacy’, although this might be because such a term would relate to use of computers, which is typically taught in an integrated manner through other subjects, not as a discrete subject.

3.2 The status of ICT and Computing

The comparator countries differ in how they treat the subjects of ICT and Computing. As noted, in some cases (and typically but not exclusively at elementary level), there is no discrete subject and ICT skills are taught through other curriculum areas. In other cases, the subject exists in discrete form. Discrete courses may be compulsory or optional.

Massachusetts is an example of the first category, in that there is no national/state curriculum subject focusing solely on ICT and/or Computing. However, students are expected to use technology across the curriculum and to achieve against the Massachusetts Technology Literacy Standards and Expectations. This document specifies the standards students must reach in Grades 3 to 12 (ages 8 to 18), in their use of technology across the curriculum.

Finland is an example of the second category: ICT and Computing are represented in the curriculum only as discrete, optional subjects defined at the local level. Nevertheless, the use of computers as a tool is widespread. A National Plan for Educational Use of Information and Communications Technology (see http://www.edu.fi/download/135308_TVT_opetuskayton_suunnitelma_Eng.pdf) is under development in Finland. This is likely to seek a shared approach to using ICT across the curriculum, learning from existing best practice, rather than aiming to produce a revised curriculum.

Serbia and Montenegro each offer a discrete course comprising some compulsory and some elective modules. In Serbia, for example, students in Upper Primary Grades 5-8 (ages 11-14) are offered elective modules in areas such as programming, interactive graphics and graphic design, as well as the compulsory area of Technology and Informatics. At the post-compulsory secondary level in Serbia (ages 15-18), Computer Sciences and Informatics is a common element of the curriculum across all schools. Similarly, in Montenegro, areas such as using a word processing package are specified in the compulsory subject Technics and Informatics from age 11, while programming skills are covered later in elective modules.

In Grades 7-9 in Japan (ages 12 to 14), students being taught ‘Information’ using Textbook B (one of three available options) are taught more technical applications of ICT than their counterparts following the other textbooks. Thus, the subject is included in the national curriculum but the content differs according to the textbook followed.

The situation is similar in Singapore, where all lower secondary students (ages 12 to 16) have access to the Computer Applications course, but it is compulsory for those following the ‘Technical’ route to their GCE ‘N’ level examinations and elective for those following the ‘Normal’ route.

Finally, in Ontario, students have access to specialist technical courses in Technological Education and Computer Studies from Grade 9 (age 14). While schooling in Ontario is compulsory up to the age of 18, the courses are elective, with the curriculum documents (see Appendix C) stating that: “The goal of Ontario secondary schools is to support high-quality learning while giving individual students the opportunity to choose programs that suit their skills and interests”.

Thus, while the use of ICT appears to be widespread and available to most students, whether or not as a discrete and compulsory subject, access to the more technical aspects of Computing, such as programming, networking and systems management, appears to be more exclusive.

3.3 Curriculum content and ages expected to be taught

3.3.1 Ages at which skills are first introduced

The pro forma used to gather information from the comparator countries specified some sample ICT and Computing skills as indicators of the level of technicality of the skills expected to be taught (see Appendix D). These ranged from using standard software packages (word processing, spreadsheets and presentations) to more technical skills such as identifying and correcting errors in a formula, understanding what a programme is, suggesting and/or implementing improvements to a programme, constructing a network, and learning about systems management.

Wide variation was seen across the comparator countries/regions. As noted earlier, all expected some use of computers although not all expected technical skills to be taught. The earliest ages indicated for the introduction of each of the given aspects is shown in Table 1 below. This shows notable differences in the ages at which ICT skills are first introduced. Even for the basic skills of using software packages, there is wide variation, with some curricula introducing this early in students’ school career (e.g. Ontario, Massachusetts and Serbia) and others delaying till the later years of elementary schooling (e.g. Japan, Montenegro and Singapore). Italy introduces use of ICT to the curriculum in the lower secondary phase, from age 14. Of course, this does not imply that students would not be using computers before these ages. Some will have access to computers outside of school, while others may be in classes where computers are in use, even though not required by the curriculum. Table 1 simply sets out the curriculum expectations.

The introduction of more technical Computing skills also shows a wide range, with some systems beginning to do this from age 12 and others delaying till 15 or 16. Of course, the variation in ages may mask some variation in curriculum content, since these are the ages at which the more technical understanding *begins* to be included. This may be as straightforward as using a formula in a spreadsheet or identifying and correcting an error in a formula (i.e. using basic skills and understanding that will underpin later programming skills). It does not necessarily imply that students will, for example, be programming from age 12.

Table 1: Ages at which the statutory curriculum first expects skills to be introduced

Country/region	**ICT skills (using ICT)** Use of software packages, including: word processing, spreadsheets, presentations	**Computing skills (ICT technical skills)** Introduction of more technical skills, beginning with basic concepts such as using formulae in spreadsheets, understanding what a 'programme' is and suggesting improvements, and, later, adapting and constructing programmes, understanding and/or constructing networks, systems management
Finland †	9	14-16
Italy	14	14
Japan	10-12	12
Massachusetts	6	12
Montenegro	11	14
Ontario	6	14
Serbia	7	15
Singapore	12	16

† Finland has no national curriculum for ICT; these are the ages at which schools might tend to introduce the skills, through their optional courses.

The following sections explore the content of the ICT and Computing curricula.

3.3.2 Curriculum content: ICT

As noted earlier, in most of the comparator countries/regions, ICT is used as a tool across the curriculum during the earlier years of education. However, in several countries, its use is not enshrined in the national curriculum. For example, Finland does not specify particular ICT skills or knowledge, as the national core curriculum allows flexibility for each municipality and school to design its own curriculum for optional studies in ICT. Similarly, while Japanese teachers tend to use ICT as a tool in the early years of elementary schooling, the national curriculum does not set out any specific criteria for ICT education. In contrast, in Massachusetts and Ontario, use of a computer as a tool is specified in subjects such as science, language and mathematics in the elementary grades (ages 6 to 14). This emphasis on ICT as a tool continues into lower secondary education in all comparator countries, with some also expanding their curriculum to include more technical aspects of Computing (see section 3.3.3).

There is some common curriculum content across the countries/regions studied, in terms of the use of ICT as a cross-curricular tool. Students at the earliest ages of using computers at school typically use them for purposes such as producing text or writing reports, making presentations, and carrying out internet searches.

In addition, some countries set out more specific ICT requirements, either as part of a discrete subject or as cross-curricular targets. So, for example, the Grade 1-8 curriculum in Ontario specifies the use of technology for musical notation, composition and recording, suggests the use of software to record choices and activities in Health and Physical Education, and expects students to use mathematical software (e.g. for exploring geometrical properties). Massachusetts' detailed Technology Literacy Standards and Expectations specify the ICT skills and knowledge expected in each of four grade spans (Kindergarten-Grade 2, Grades 3-5, Grades 6-8, and Grades 9-12). These range from basic concepts related to use of hardware and ICT packages at Grade 3 (age 8), to skills such as using pivot tables, linking worksheets and using effective internet search strategies at Grades 9 to 12 (ages 14 to 18). Safe and secure use of ICT also features in the elementary curriculum for both Ontario and Massachusetts.

Beyond ages 11/12, more countries set out specific expectations for the use of ICT as a tool. For example, in Serbia, Montenegro and Singapore, students above these ages would be expected to process and create graphics as well as create presentations with music or other sound effects. Students in Singapore and Massachusetts would be expected to create spreadsheets and/or databases, use peripherals and storage media, and, in Massachusetts, to troubleshoot minor hardware and software issues. Ethical issues also start to appear for more countries at this level. For example, in Singapore, students above this age would be expected to develop an understanding of 'Netiquette'.

Massachusetts is unusual among the comparator countries/regions in specifying keyboarding skills. The Standards for 11-14 year olds indicate that students should be able to type 25-30 words per minute with fewer than 5 errors.

These examples indicate that most ICT content in the countries/regions investigated is skills-based, although knowledge also features for some. For example, students above 14 years old in Massachusetts would be expected to assess the capabilities and limitations of technologies and, in Japan, ICT is textbook based. Textbooks are authorised by the Ministry and decisions about which textbooks to use are made by local education boards. The textbooks include knowledge about computers and also set practical exercises for students to follow, such as showing them how to use software. For example, one of the 'Information' textbooks, used from age 10 upwards, covers the themes of: the information society and the computer; the mechanism of the computer and its function; modelling of problems and the use of computers; storage and management of information and databases; and progress of information technology and impact on society.

3.3.3 Curriculum content: Computing

Curriculum content in Computing tends to include both knowledge and skills for most of the selected countries/regions. Examples of basic Computing skills include using web authoring tools, and installing and uninstalling software (Massachusetts). Examples of knowledge-based concepts include understanding basic terminology, knowing the parts of a computer system, understanding the concepts of hardware and software, knowing what a programme is, recognising the terms ‘server’ and ‘client’, and identifying the components of a network (e.g. Local Area Network and World Area Network - LAN and WAN). These apply variously in Singapore and Montenegro, for example. Additionally, in Massachusetts, students at Grades 9 to 12 (ages 14-18) would be expected to identify properties of devices and understand addressing schemas (e.g. Internet Protocol (IP) addresses, Dynamic Host Configuration Protocol (DHCP) and Domain Name System (DNS)).

The most technical content tends to be covered at the higher grades. For example, although in Japan the subject appears in the national curriculum from Grade 7 (age 12), the more technical aspects tend to be taught later. It was noted earlier that ‘Information’ is taught with one of three textbooks. Similarly, the subject ‘Technology and Home Economics’ is taught through two Grade 7-9 textbooks, including the topic ‘Information and the Computer’ in the latter sections of the Technology textbook. This topic covers basic knowledge of the structure and mechanisms of computers and networks and, being towards the end of the textbook, is more likely to be covered by students in Grade 9 (aged 14) than those in Grade 7.

In some cases, Computing understanding is based on *knowing about* the technical aspects, while in others it is based on *knowing how to* manipulate and manage them. Thus, for example, in Japan, 12-18 year olds studying Information Technology would be expected to understand what a computer network is, as might 7-16 year olds studying the optional Information Technology course in Finland. In contrast, 15-19 year old students of Science and Technology/Engineering in Massachusetts and some 15-18 year olds studying Computer Studies or Technological Education in Ontario would be expected to know how to construct a network.

This more technical content is covered by the national curriculum or standards in all countries/regions except Finland, where courses are discretionary and localised. These optional courses are reportedly popular and range from basic Computing skills to programming. Programming is covered by the curriculum in most of the countries/regions. In Singapore, it is included for students from 16 years old; in Montenegro and Ontario, from 15 years old; in Massachusetts from 14 years; and in Serbia from 13 years. In Japan, it is mentioned for students from 12 years old, although this may refer to the simplest type of programme such as programming a floor turtle. Programming languages mentioned across the comparator countries/regions include: Pascal, Java, HTML, C and C++, LISP, ML, Prolog and visual programming in Delphi. In some countries/regions, however, choice of programming language is left to the school or local area. For example, in Ontario, use of ‘industry-standard’ languages is specified, rather than naming individual languages.

Not all countries or regions include networking and systems management in their Computing curriculum. For example, Japan does not mention networks or systems management and, in Massachusetts, these themes are discretionary at the local level from Grade 10 (age 15) onwards. Countries or regions which do cover these areas in their curriculum do so for the oldest students only. Singapore's post-secondary Higher 2 curriculum for Computing (for students aged 16 upwards) covers five modules: the development of computer solutions; programming concepts; algorithms and design; data management; and computer systems. Elements of practical work are specified but the wording of the curriculum document implies that some aspects of the curriculum will remain theoretical. For example, post-secondary students in Singapore are expected to understand and describe network and systems fundamentals but may not necessarily have worked actively with them. In contrast, students in Ontario, studying Computer Engineering Technology at Grade 11 (age 16 upwards) are expected to design, install, configure, test and troubleshoot networks, while those studying Computer Technology at Grade 11 will have experience of planning, installing and managing a computer network.

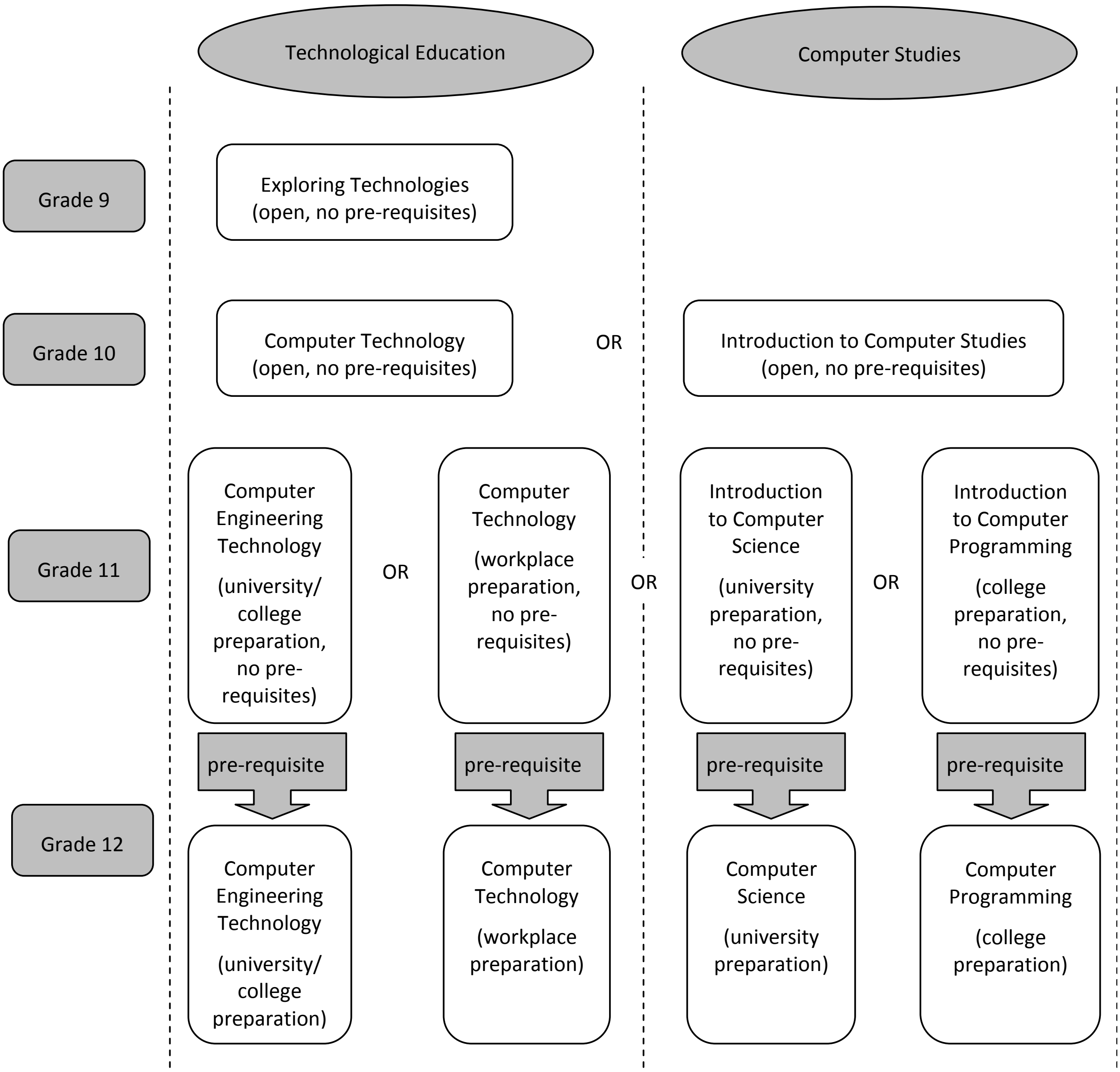
3.3.4 Curriculum design and the model in Ontario

Most of the comparator countries/regions have a 'linear' curriculum model, if they include ICT/Computing in their curriculum. In other words, they tend to offer a single basic course at elementary school, which is followed by a more in-depth course or set of modules at secondary level. Where ICT is integrated with other curriculum subjects, this typically results in a parallel curriculum design, with ICT mentioned in the curriculum document for more than one subject, but with parallel skills expected within each separate subject.

One obvious exception to the linear model is Ontario, which provides a menu of Computing courses at the higher grades. Some of these courses enable students to develop broad, transferable skills, while others provide a sound foundation in software development and programming, as well as developing students' awareness of professional and ethical responsibility. Thus, from Grade 9 (age 14 onwards), students can choose from a number of courses, depending on their interests and aspirations. At Grade 9, there is a single option. At Grade 10, there are two options and from Grade 11, four options per grade. Diagram 1 summarises these options. Where more than one course is available, students may earn credit for any one course within each grade. The Computing courses fall into two strands: Technological Education and Computer Studies. The Technological Education strand encompasses broad-based courses enabling students to develop transferable skills for the changing workplace landscape, whereas the Computer Studies strand gives students a solid foundation in software development, algorithms and data structures, programme correctness and efficiency, and professional and ethical responsibility.

Ontario's model is described in more detail below, for information and simply because it is so different from the model in other countries/regions investigated. At Grade 9, the single Technological Education option (Exploring Technologies) is described as an 'Open' course and demands no pre-requisite knowledge. It explores a range of technologies, including Computer Technology. This introduces students to fundamental concepts and skills in computer technology, considers related environmental and societal issues, and explores pathways to careers in the field. It bridges the gap between the elementary school science and technology curriculum and the later Grade 10 course options (though it is not a pre-requisite for them).

Diagram 1: Summary of the options available in the Ontario model



The two options at Grade 10 are Computer Technology and Introduction to Computer Studies (both Open courses with no pre-requisites). Computer Technology, in the Technological Education strand, introduces students to computer systems, networking and interfacing, and includes assembling, repairing and configuring computers with various types of operating systems and application software. Students write computer programmes to control peripheral devices. They also learn about related environmental and societal issues and career opportunities. Introduction to Computer Studies, in the Computer Studies strand, introduces students to programming. Students plan and write simple programmes and create relevant internal documentation. They study hardware configurations, software selection, operating system functions, networking, and safe computing practices. They also investigate the social impact of computer technologies, and develop an understanding of environmental and ethical issues related to the use of computers.

At Grade 11, none of the four choices across the two strands demand pre-requisite courses but are designed for different potential destinations. In the Technological Education strand, students can choose from Computer Engineering Technology or Computer Technology, while in the Computer Studies strand, they have a choice of Introduction to Computer Science or Introduction to Computer Programming. All of these courses teach students about related environmental and societal issues, and raise students' awareness either of college/university programmes leading to careers in computer technology, or of potential apprenticeships and other employment opportunities in the field of computer technology. The broad outline of these courses is as follows:

- The Computer Engineering Technology course (a university or college preparation course) examines computer systems and control of external devices. Students assemble computers and small networks and build systems that use computer programmes and interfaces to control and/or respond to external devices.
- The Computer Technology course (a workplace preparation course) enables students to develop knowledge and skills related to computer hardware, networks, operating systems, and other software. Students use utility and application software, and learn procedures for installing, maintaining, and troubleshooting computer systems and networks.
- Introduction to Computer Science (a university preparation course) gives students opportunities to design software independently and as part of a team, use industry-standard programming tools and apply the software development life-cycle model. They write and use sub-programmes and develop solutions for various types of problem. They explore environmental and ergonomic issues and emerging research in computer science.
- Finally, Introduction to Computer Programming (a college preparation course) allows students to write and test computer programmes, using various problem-solving strategies. They learn the fundamentals of programme design through a software development project. They learn about computer environments and systems, and explore safe computing practices and emerging technologies.

The Grade 12 curriculum in Ontario also offers four options but, at this grade, the Grade 11 equivalently-named courses are pre-requisites. In the Technological Education strand, the two courses are, once again, Computer Engineering Technology or Computer Technology. In the Computer Studies strand, students have a choice of Computer Science or Computer Programming. Again, these courses teach students about related environmental and societal issues, and explore future pathways. The broad outline of these courses is as follows:

- The Computer Engineering Technology course (a university or college preparation course) and the Computer Technology course (a workplace preparation course) extend the skills developed in their pre-requisite Grade 11 courses.
- In Computer Science (a university preparation course), students use modular design principles to create complex and fully documented programmes, according to industry standards. Student teams manage a large software development project, from planning through to project review stage and they analyse algorithms for effectiveness.
- In Computer Programming (a college preparation course), students learn object-oriented programming concepts, create object-oriented software solutions, and design graphical user interfaces. Student teams plan and carry out a software development project using industry-standard programming tools and appropriate project management techniques.

This menu of courses is initially complex to understand but presents students with more Computing choices, designed for different purposes and outcomes, than seen in the other comparator countries/regions. This may be deemed an advantage for students who are clear about their career and/or academic path, but may be potentially confusing for students who are less clear about their direction.

3.4 Conclusion

Despite being drawn from such a small number of countries or regions, the outcomes above provide a clear indication of the variability in curriculum practice in ICT and Computing internationally. There is wide variation in the terminology used to describe the subject(s) in the curriculum, as well as variation in the ages at which different concepts are introduced, if at all. Use of ICT as a tool is more widespread than the teaching of more technical Computing skills and, even where these technical aspects are taught, there is variable practice in terms of the concepts taught and the potential balance of hands-on practical work and theoretical understanding.

It should be remembered, however, that this is a small-scale comparative study. It is not intended to provide an exhaustive survey of ICT and Computing curricula, either within or between countries. Neither can it comment on how the implemented curriculum in a country or region might vary from that which is prescribed or how teachers' qualifications and their teaching approaches might impact on attainment. Even so, as an indicative survey, it can highlight possible ways of approaching the subjects and can, therefore, suggest areas for further consideration and/or investigation in terms of our own curriculum development in the UK.

Appendix A: Schooling in each country/region sampled

Country/region	Elementary schooling	Secondary schooling	Compulsory to age…	Comments
Finland	Basic education (ages 7-16)	Upper secondary (ages 16-19)	16	Compulsory to 16 but most students attend till 19 in practice
Italy	First cycle – Primary (ages 6-11)	Second cycle - Lower Secondary (ages 11-14) and then EITHER: Upper Secondary (ages 14-19) in licei, technical institutions and vocational institutes OR initial Vocational Training (ages 14-17)	16	
Japan	Elementary (ages 6-12)	Junior high school (ages 12-14) and senior high school (ages 15-18)	15	
Massachusetts	Elementary (ages 6-14)	High school (ages 14-18)	16	
Montenegro	Elementary (ages 6-15)	Gimnazija (ages 15-18)	15	
Ontario	Elementary Grades 1-8 (ages 6-14)	Secondary/High school Grades 9–12 (ages 14-18)	18	
Serbia	Lower primary (ages 7-11) Upper primary (ages 11-15)	Secondary (ages 15-18)	14	
Singapore	Primary (ages 6-12)	Lower secondary (ages 12-16/17) and post-secondary (ages 16/17 to 18/19/20)	12	The four years of lower secondary are not compulsory but are universal. Secondary and post-secondary ages depend on the courses selected.

Appendix B: Validating organisations

We are grateful to the NFER's international contacts who helped us by providing information and/or validating draft versions of the information for their country/region. Thanks are due to the following:

- Finland – Information validated by Ilkka Karryla, Eurydice Unit, Finland
- Japan - Information validated by Ryo Watanabe, Director, Department for International Research and Cooperation, National Institute for Educational Policy Research (NIER), Ministry of Education, Culture, Sports, Science and Technology (MEXXT), Japan.
- Massachusetts - Information provided by Connie Louie, Instructional Technology Director, Massachusetts Department of Elementary and Secondary Education, USA
- Ontario - Information validated by Ministry of Education staff, Ontario.

Appendix C: Key curriculum documents

Finland

Basic curriculum:
http://www.oph.fi/english/publications/2009/national_core_curricula_for_basic_education
Secondary curriculum:
http://www.oph.fi/english/publications/2003/National_Core_Curriculum_for_Upper_Secondary_Schools_2003

Japan

Courses of study: http://www.mext.go.jp/english/elsec/1303755.htm
Educational vision: http://www.mext.go.jp/english/lawandplan/1303463.htm

Massachusetts

Massachusetts Technology Literacy Standards and Expectations:
http://www.doe.mass.edu/edtech/standards/itstand.pdf

Ontario

Grades 1-8 curriculum:
http://www.edu.gov.on.ca/eng/curriculum/elementary/subjects.html
Science and technology (Elementary):
http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf
Technological Education Grades 9-10:
http://www.edu.gov.on.ca/eng/curriculum/secondary/teched910curr09.pdf
Technological Education Grades 11-12:
http://www.edu.gov.on.ca/eng/curriculum/secondary/2009teched1112curr.pdf
Computer Studies Grades 10-12:
http://www.edu.gov.on.ca/eng/curriculum/secondary/computer10to12_2008.pdf

Singapore

Curriculum Maps - primary: http://www.moe.gov.sg/education/primary/curriculum
Curriculum Maps - N level: http://www.moe.gov.sg/education/secondary/normal
Curriculum Maps - A level: http://www.moe.gov.sg/education/pre-u/curriculum
Computer Applications Syllabus (lower secondary):
http://www.moe.gov.sg/education/syllabuses/sciences/files/computer-applications-lower-secondary.pdf
Computing Higher 2: http://www.seab.gov.sg/aLevel/2011Syllabus/9754_2011.pdf

Appendix D: The research pro forma

International Comparison of Computing in Schools

Dear colleagues

The NFER, on behalf of the Royal Society, the UK's national academy of sciences, is carrying out a study looking at the way that the subjects 'Information and Communications Technology' (ICT) and 'Computing' are taught in schools and colleges internationally. This is part of a wider study that involves teachers, academics and other members of the computing community in the UK coming together to address growing concerns that the design and delivery of the ICT and computing curricula in schools is putting young people off studying the subjects further. For more details about the wider study see: http://royalsociety.org/education/policy/computing-in-schools/.

In this international comparison, we aim to find out:

1. How concepts relating to the subject areas of 'Information and Communications Technology' (ICT) and 'Computing' are included in the curriculum in different national or state educational contexts.
2. How these types of learning are usually described in various countries.
3. The ages at which (if applicable) the curriculum expects them to be taught.

We have reviewed your curriculum documents online and begun drafting answers to these questions for your country/region. We would greatly appreciate if you would assist our study by validating our answers to the questions below or by adding further information as necessary.

The Royal Society is planning to produce a final report of the study by the end of this year and would be more than happy to provide you with a copy, by way of thanks. Please advise us if you do not wish to receive it.

Kind regards

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When does your country's primary/secondary curriculum specify that each of the following aspects of ICT/Computing should be taught?	Ages expected to be taught OR not in the curriculum			What is the name of the curriculum subject(s) under which each aspect is taught?
	From age …	To age …	Not in the curriculum	
Using a word processing software package				
Using a spreadsheet software package				
Using a presentations software package				
Using formulae in a spreadsheet package (e.g. knowing what a 'formula' is, identifying or correcting an error in a formula)				
Understanding what a 'programme' is (i.e. that a programme is a logical sequence of instructions)				
Suggesting desirable improvements to a programme (e.g. indicating that it would be useful for a programme to do X in addition to Y)				
Adapting a programme in order to improve it.				
Constructing a programme (e.g. developing a sequence of instructions for a floor turtle to follow, or developing a simple new programme)				
Understanding what a computer network is				
Constructing a computer network				
Systems management				

Are there other ICT or Computing skills taught in your country's school curriculum?	What is the name of the subject(s) under which these other skills are taught? e.g. 'Science', 'Technology', 'Engineering', 'Informatics', 'Business' etc	Links to web pages giving curriculum documents for these subject(s) and the above highlighted aspects
Yes ☐ No ☐		

If you wish, please give examples of the type of activity in the curriculum	
at the youngest ages	at the oldest ages

Providing independent evidence to improve education and learning.

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