IEA International Computer and Information Literacy Study 2018

ASSESSMENT FRAMEWORK

Julian Fraillon
John Ainley
Wolfram Schulz
Daniel Duckworth
Tim Friedman

IEA ICILS
Springer Open

IEA International Computer
and Information Literacy Study 2018
Assessment Framework

Julian Fraillon • John Ainley • Wolfram Schulz
Daniel Duckworth • Tim Friedman

IEA International Computer and Information Literacy Study 2018 Assessment Framework

Springer Open

Julian Fraillon
The Australian Council for Educational Research
Camberwell, Victoria
Australia

Wolfram Schulz
The Australian Council for Educational Research
Camberwell, Victoria
Australia

Tim Friedman
The Australian Council for Educational Research
Camberwell, Victoria
Australia

John Ainley
The Australian Council for Educational Research
Camberwell, Victoria
Australia

Daniel Duckworth
The Australian Council for Educational Research
Camberwell, Victoria
Australia

IEA
Keizersgracht 311
1016 EE Amsterdam
The Netherlands
Telephone: +31 20 625 3625
Fax: + 31 20 420 7136
email: secretariat@iea.nl
Website: www.iea.nl

The International Association for the Evaluation of Educational Achievement (IEA), with headquarters in Amsterdam, is an independent, international cooperative of national research institutions and governmental research agencies. It conducts large-scale comparative studies of educational achievement and other aspects of education, with the aim of gaining in-depth understanding of the effects of policies and practices within and across systems of education.

Design by Becky Bliss Design and Production, Wellington, New Zealand
Cover design by Studio Lakmoes, Arnhem, The Netherlands.

ISBN 978-3-030-19388-1 ISBN 978-3-030-19389-8 (eBook)
https://doi.org/10.1007/978-3-030-19389-8

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

The International Association for the Evaluation of Educational Achievement (IEA) is a nonprofit independent research organization built on a collaborative network of scholars, researchers, policy analysts, and technical experts from national education research centers and government research agencies. More than 100 education systems have participated in IEA's large-scale comparative studies over the last 60 years. These studies have been used to investigate education systems, to assess their relative strengths and weaknesses, and measure trends in an international context, with the aim of fostering improvement in the quality of education around the world. The reports and data resulting from these studies are consequently a rich resource for educational researchers and evidence-based policymaking.

IEA's International Computer and Information Literacy Study (ICILS) 2018 is designed to find out more about the contexts and outcomes of ICT-related education programs, and the role of schools and teachers in supporting students' computer and information literacy achievement. IEA has long been interested in the use of information and communication technology (ICT) in education. The Computers in Education Study (COMPED) was the first IEA study in this field, conducted in 1989 and again in 1992. This was followed by IEA's Second Information Technology in Education Study (SITES) in 1998–1999 (Module 1), 2001 (Module 2), and 2006, which assessed the infrastructure, goals, and practices for ICT education in twenty-six countries.

ICILS investigates students' ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in the community and the educational contexts in which these skills are learned. The first cycle of ICILS was conducted successfully in 2013, and collected data in 21 education systems around the world. It investigated how grade 8 students in these countries developed the computer and information literacy skills that would enable them to participate in an increasingly digital world. It researched the differences between and within participating education systems, and the relationship of achievement to student background and the learning environment.

ICILS 2013 identified a number of interesting and some quite surprising results; these are presented in depth in the ICILS 2013 international report, *Preparing for Life in a Digital Age*. ICILS has led national policymakers and researchers to conclude that further research and the measurement of trends in students' skills was critical to informing policies designed to develop students' skills in computer and information literacy. The ICILS 2013 results also indicated that computational thinking was an area that merited more attention; computational thinking skills have been recognized in many countries as an area of increasing relevance for education in the 21st century.

ICILS 2018 is based on and expands the work of ICILS 2013: it reports on changes in students' computer and information literacy since 2013, and further investigates several areas that provided interesting results in 2013 and highlighted areas of concern for educationalists. ICILS 2018 also offers participating countries an option to assess the computational thinking domain, understood as the process of working out exactly how computers can help people solve problems. The assessment of computational thinking is an innovative and engaging challenge for the students, evaluating not only their ability to analyze and break down the problem into logical steps but also their understanding of how computers might be used to solve the problem.

This publication, the ICILS 2018 assessment framework, describes the background, constructs, and design of the assessment of computer and information literacy and computational thinking skills. The framework is based on the ICILS 2013 framework, but has been adapted and amended to address new challenges for this innovative trend study posed by evolving educational requirements. ICILS, as with all IEA studies, was developed in close cooperation with the international study center, and study representatives from the various participating countries.

I sincerely thank the team of researchers from the international study center located at the Australian Council for Educational Research (ACER), especially research director Julian Fraillon, project coordinator John Ainley, assessment coordinator Wolfram Schulz, and operations coordinator Tim Friedman for their leadership. Special thanks also go to colleagues from the IEA Amsterdam, the Netherlands, and IEA Hamburg, Germany, for their support throughout. I also extend my gratitude to the staff at SoNET Systems, Melbourne, Australia, who were involved in developing the software for the computer-based student assessment, in particular SoNET's Mike Janic and Stephen Birchall. I also gratefully acknowledge the work of Marc Joncas, who served as sampling referee. The IEA Publications and Editorial Committee also contributed to the review of the framework.

ICILS would not be possible without the dedicated commitment of the national research coordinators from participating countries. They play a crucial role in the development and implementation of each IEA study by ensuring that it embodies the interests of the broader community of researchers, policymakers, and practitioners. Together we are researching education to improve learning.

Dirk Hastedt
EXECUTIVE DIRECTOR IEA

Contents

CHAPTER 1

Introduction

1.1 Overview

Over the last four decades, information and communications technologies (ICT) have increasingly affected the ways in which we interact with others and do things in our daily lives and work. These technologies have also changed teaching and learning in schools and the ways in which schools are organized. Education systems, and schools within those systems, have seen these technologies as offering the potential to improve learning in schools, and recognized the importance of developing the capacities of their students to use those technologies in their ongoing lives in order to participate fully in what is often termed the "digital age."

The International Association for the Evaluation of Educational Achievement (IEA) has been researching the impact of ICT on educational processes, as well as factors influencing or impeding the pedagogical use of ICT, since the late-1980s. More recently it has turned its attention to investigating the impact of ICT on educational outcomes. IEA's International Computer and Information Literacy Study (ICILS) is a response to the increasing use of ICT in modern society and the need for citizens to develop relevant capabilities to participate effectively in a digital world. It also addresses the need for policymakers and education systems to gain a better understanding of the contexts and outcomes of ICT-related education programs in their countries. The first cycle of ICILS in 2013 (ICILS 2013) assessed students' computer and information literacy (CIL) with an emphasis on the use of computers as information seeking, management and communication tools. The international recognition of the importance of developing students' abilities to recognize and operationalize real-world problems using computational formulations on computers or other digital devices has prompted the development of an ICILS assessment of computational thinking (CT), which was offered to participating education systems as an international option in 2018.

The second cycle of ICILS, the International Computer and Information Literacy Study 2018 (ICILS 2018), thus investigates students' CIL and CT abilities, and how these relate to school and out-of-school contexts that support learning.

1.2 Purposes of ICILS

The primary purpose of ICILS 2018 is to assess systematically the capacities of students to use ICT productively for a range of different purposes, in ways that go beyond a basic use of ICT. ICILS 2018 includes authentic computer-based assessments that are administered to students in their eighth year of schooling. These generate data reflecting two dimensions of ICT-related capacities:

- First, ICILS 2018 assesses CIL. This was first measured in ICILS 2013, where it was defined as "an individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society" (Fraillon et al. 2013 p. 17). CIL refers to a student's ability to use computer technologies to collect and manage information and to produce and exchange information.
- Second, ICILS 2018 assesses CT, which is the type of thinking used when programming a computer or developing an application for another type of digital device. We define CT to refer to an *individual's ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer*. Yadav et al. (2018, pp. 91–92) articulated the relationships between CT and computer science, defining CT as being focused on the processes of "abstraction, algorithms and automation."

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8_1

ICILS 2018 investigates variations in CIL and CT between and within countries and the relationships between those constructs and student attributes (background characteristics and developed attributes) including their use and experience of computer technologies. ICILS 2018 also investigates how CT is related to CIL.

A secondary purpose of ICILS 2018 is to investigate the use of computers and other digital devices by students and teachers, as well as their attitudes toward the use of computer technologies. Some of these aspects of computer use are directly related to student outcomes, while others may not be directly associated with them but may inform our understanding of the broader context in which computer technologies are used both within and outside school. Further contextual information is provided by schools and education systems about the policies, resources, and pedagogies regarding computer technologies.

1.3 Purpose of the ICILS assessment framework

The ICILS assessment framework articulates the basic structure of the study. It provides a description of the field and the constructs to be measured. It outlines the design and content of the measurement instruments, sets down the rationale for those designs, and describes how measures generated by those instruments relate to the constructs. In addition, it hypothesizes relations between constructs so as to provide the foundation for some of the analyses that follow. Above all, the framework links ICILS to other work in the field so that the contents of this assessment framework combine theory and practice in an explication of "both the 'what' and the 'how'" (Jago 2009, p. 1) of ICILS.

1.4 Background to the study

Schools have been using computers in education and teaching about computing for approximately four decades, and it is a field that remains under active development. One of the important changes in this field has been a shift in the focus on technical usage and programming, including simplified programming using languages such as *Logo* (McDougall et al. 2014), to the widespread use of applications incorporating information management and communications. Punter et al. (2017) argued that the widespread use of the internet, as well as the ready availability of office applications, changed the nature of computer use. Caeli and Bundsgaard (2019) identified four phases of computer use in education in Denmark, beginning with exploring implications of computing for society in combination with aspects of CT, progressing through a phase in the 1990s that emphasized enabling students to use computer applications, and a phase in the early 2000s that focused on the pedagogical use of digital resources, culminating in the most recent phase, which focuses on CT.

ICILS 2013 conceptualized CIL in terms of two strands that framed the skills and knowledge addressed by the instruments (Fraillon et al. 2013, pp. 34–35). Strand 1 focused on the receptive and organizational elements of information processing and management (understanding computer use and accessing, evaluating and managing digital information) and strand 2 was concerned with producing and exchanging information (transforming, creating and sharing computer-based information). The assessment consisted of four 30-minute modules. A module was a set of questions and tasks based on a real-life theme and following a linear narrative structure. Each module had a series of small discrete tasks (skill execution and information management) followed by a large task that required the use of several applications to produce an information product that was scored by trained scorers according to specified scoring rubrics. The results of ICILS 2013 indicated that one dimension, CIL, underpinned the responses to the assessment (Gebhardt and Schulz 2015).

As a result of research and development associated with computing in schools, changes in digital technologies themselves, and changes in conceptions of the meaning of digital capability, there has been an emerging interest in computer science (CS) and computational thinking (CT).

A recent report by the Organisation for Economic Cooperation and Development (OECD) reviewed programs intended to promote digital skills across all age groups. The report referred to "the extent to which ICT skills are included in the curriculum" and focused on both CS and CT (OECD 2016a, p. 18), pointing to cases such as Sweden (with new curricula being introduced to school and teacher education programs) and Spain (where ICT was included in school curricula as part of a broader national digital strategy). The *Computer Science for All* initiative in the United States focuses on providing opportunities for all students to develop computational thinking skills and solve complex problems (OECD 2016a; Yadav et al. 2018) that are implemented through teacher education and the development of instructional materials. Digital Germany 2015 sought to promote ICT studies through national ICT and engineering related competitions, including a national computer science contest for students aged 10 to 16 called Informatik-Biber. In the United Kingdom, the Computing At School (CAS) initiative led to computer science studies being included in senior secondary courses of study. These developments have added the dimension of computer science to computer literacy.

Thus, CIL, CT, and use of digital technologies in learning are the three areas central to the development of ICILS 2018.

1.5 Computer and information literacy

In many developed countries since the late 1970s, there have been increasing efforts to introduce ICT in schools through the provision of personal computers (Tatnall and Davey 2014; Voogt and ten Brummelhuis 2014). Voogt and ten Brummelhuis (2014, pp. 83–84) argued that a "social rationale," which emphasized the need to prepare young citizens for living in a society driven by information technology, was an important element in the introduction of this field in schools in the Netherlands. In many countries there was a consensus that the exchange and transformation of knowledge through information technologies was a feature of modern societies. In addition, it became widely accepted that information technologies would provide the tools for creating, collecting, storing, and using knowledge, as well as for communication and collaboration (Kozma 2003). This view emphasized the importance of enhancing computer literacy as the focus of introducing ICT in schools.

Early definitions of computer literacy typically refer to an individual's capacity to use computers or related devices and computer-based software effectively (see, for example, Haigh 1985). Digital literacy is a similar term that is sometimes used to emphasize the range of digital technologies that may be involved (Lemke 2003). During the early 2000s, the OECD commissioned a study that developed a framework for ICT literacy applicable within cross-national contexts (ETS [Educational Testing Service] 2002). In its definition of ICT literacy, the framework stressed the application of digital technologies to "access, manage, integrate, evaluate, and create information" (ETS 2002, p. 2).

Subsequent evaluation of these early definitions of computer literacy and ICT literacy suggested that: (a) conceptualizations of computer literacy were too restrictive in their focus on operating hardware and software, and (b) conceptualizations of ICT literacy were too restrictive in their focus on information literacy and communication. Later approaches have blended technological expertise with information literacy and communication (Catts and Lau 2008). ICILS 2013 invoked the term computer and information literacy (CIL) to emphasize that having the capacity to use the internet to search for and evaluate information was an important part of the broad capability to use modern technology (Fraillon et al. 2013, 2014).

Binkley et al. (2012) reviewed existing definitions of ICT literacy and argued that they referred to abilities to access, evaluate manage and use information, as well as to the efficient application of technology (e.g., the effective use of applications and devices). As part of its DigComp project, the European Commission set out to identify key components of digital competence, develop descriptors of those components, and establish a framework for the field (Ferrari 2012). The author identified seven competence areas: information management; collaboration; communication and sharing; creation of content and knowledge; ethics and responsibility; evaluation and problem solving; and technical operations. The DigComp framework was further developed and refined, with DigComp 1.0 describing five competence areas: information; communication; content creation; safety; and problem solving (Ferrari 2013). These areas were further revised as part of DigComp 2.0, resulting in the following competence areas: information and data literacy; communication and collaboration; digital content creation; safety; and problem solving (Vuorikari et al. 2016). In 2017, DigComp 2.1 was released to provide additional information about the five competence areas described in DigComp 2.0 by "expanding the initial three proficiency levels to a more fine-grained eight level description as well as providing examples of use for these eight levels. Its aim is to support stakeholders with the further implementation of DigComp" (Carretero et al. 2017, p. 6).

The International Society for Technology in Education (ISTE) established National Educational Technology Standards in the United States context to provide guidelines for what is expected in terms of learning to use technologies (ISTE 2007). These were later renamed to ISTE standards as an international framework for technology in education that referenced students and educators, but which were not specified as national for the United States (ISTE 2018). The updated ISTE standards include references to CT. The US National Education Technology Plan stresses the development of 21st century competencies such as "critical thinking, complex problem solving, collaboration, multimedia communication, and adding multimedia communication into the teaching of traditional academic subjects" (US Department of Education, Office of Educational Technology 2017, p. 10). The ICT sub-area measured in the Technology and Engineering Literacy (TEL) assessment as part of the National Assessment of Educational Progress (NAEP) in the United States includes proficiency with computers and software learning tools, networking systems and protocols, hand-held digital devices, and other technologies for accessing, creating, and communicating information and for facilitating creative expression. It also identifies five sub-areas of competence: construction and exchange of ideas and solutions; information research; investigation of problems; acknowledgement of ideas and information; and selection and use of digital tools (US Department of Education, National Center for Education Statistics 2016).

There have been several approaches to the assessment of computer literacy, including traditional multiple choice and constructed-response items, and performance assessments. Siddiq et al. (2016) noted that many of the assessments focus on lower secondary-school students, and that most of them are computer-based and measure aspects such as searching, retrieving, and evaluating information, as well as technical skills. They also noted that many of these assessments include performance assessments in which students are required to perform tasks on a computer, with those tasks being embedded in a narrative. ICILS 2013, involving grade 8 students in 22 countries, is one example of this approach to the assessment of computer literacy (Fraillon et al. 2014). Other examples of studies using this type of assessment strategy include the national assessments of computer literacy conducted every three years among grade 6 and grade 10 students in Australia since 2005 (ACARA [Australian Curriculum, Assessment and Reporting Authority] 2012, 2015; MCEETYA [Ministerial Council on Education, Employment, Training, and Youth Affairs] 2007; MCEECDYA [Ministerial Council on Education, Early Childhood Development, and Youth Affairs] 2010), the national evaluations of ICT literacy in Chile (Claro et al. 2012), the NAEP TEL assessment of grade 8 students in the United States (NAGB [National Assessment Government Board] 2013), and the ICT literacy assessment of middle school students in Korea (Kim and Lee 2013; Kim et al. 2014). Aesert et al. (2014) also used similar performance measures to assess the ICT competence of primary school students in the Netherlands.

1.6 Computational thinking

A different aspect of learning to use computer technologies focuses on learning foundational principles of computing. This aspect was evident in the early stages of the introduction of computers in classrooms in terms of arguments that saw the links between "programming" and problem solving as important for educational development (Papert 1980). An important element of this in the 1980s was the Logo language, in which commands resulted in movement of a cursor or robot (a turtle) on a screen and line graphics. Many educational approaches closely linked to constructionism and oriented to cognitive development were based on *Logo* (Maddux and Johnson 1997; McDougall et al. 2014; Tatnall and Davey 2014). Since those early developments, visual programming languages (where programs are created by manipulating program elements, or blocks, graphically) for children have emerged in addition to text-based programming languages. *Scratch* and *Python* are examples of visual programming languages in which students use simple blocks of code to develop projects (Ortiz-Colon and Marato Romo 2016). *Scratch* emphasizes its potential role in helping cognitive and meta-cognitive development, as well as the opportunities it provides for introducing principles of computing in a practical and productive way. Within the context of building learning assessments in this area, visual coding approaches are of particular relevance, as they focus on the algorithmic logic underpinning coding across all coding tasks. A visual coding environment is also considered to be accessible to novice users and translatable (code block names could be translated into the target languages) while eliminating the confounding effect of keyboard errors because no typing of code is involved.

Wing (2006) regarded CT as a concept that embraces problem solving and system design, and is based on principles central to computer science. This concept includes the ways of thinking when programming a computer as part of computer literacy (Grover and Pea 2013; Lye and Koh 2014). Computational thinking can be seen as "applying tools and techniques from computer science to understand and reason about both natural and artificial systems and processes" (Royal Society 2012, p. 29). Shute et al. (2017, p. 142) argued that CT is required to solve problems algorithmically (with or without the assistance of computers) by applying solutions that are reusable in different contexts. They elaborated that CT is "a way of thinking and acting, which can be exhibited through the use of particular skills, which then can become the basis for performance-based assessments of CT skills." They suggested that CT involves six elements: decomposition, abstraction, algorithm design, debugging, iteration, and generalization. CT does not necessarily involve developing or implementing a formal computer code (Barr et al. 2011). However, assessments of CT are typically set in computer environments because those facilitate the capturing of the data that reflect the steps in problem solving. These steps usually involve developing or assembling instructions (often including blocks of code) that are necessary to accomplish a task (Brennan and Resnick 2013).

Learning to use and apply computer science is regarded as an important element of school education (Peyton Jones 2011). The UK's Royal Society (2017) advocated for an increased attention to computer science in the British school curricula and emphasized the importance of computational thinking as part of digital literacy. Wing (2006, p. 33) argued that the concept of CT is applicable to all individuals rather than just computer scientists.

Goode and Chapman (2013) developed the curriculum resource *Exploring Computer Science* (ECS) to help elaborate the meaning of CT. This curriculum package includes resources, lesson plans, and professional development for teachers. Its focus is on "conceptual ideas of computing," but it includes consideration of "computational practices of algorithm development, problem solving and programming" (Goode and Chapman 2013, p. 5) in contexts of real-life problems (using the *Scratch* language). ECS is linked to the *Principled Assessment of Computational Thinking* (PACT; see https://pact.sri.com/index.html), which is concerned with the assessment of secondary computer science outcomes (Bienkowski et al. 2015a; Rutstein et al. 2014). This approach involves designing "assessment tasks to measure important knowledge and practices by specifying chains of evidence that can be traced from what students do" (Bienkowski et al. 2015, p. 2; see also

Grover et al. 2015; Grover 2017). PACT is based on design patterns for major CT practices and involves judging the quality of the instructions (or coding steps) that have been assembled.

There have also been other approaches to the assessment of CT. Chen et al. (2017) developed an instrument for primary school students to assess CT that was based on coding in robotics and reasoning of everyday events, and linked to a "robotics curriculum." Zhong et al. (2016) developed a three-dimensional assessment framework based on the concepts of directionality, openness and process. The assessment included three pairs of tasks that were based on a three-dimensional programming language: (1) closed forward tasks and closed reverse tasks, (2) semi-open forward tasks and semi-open reverse tasks, and (3) open tasks with a creative design report and open tasks without a creative design report. Students' codes were assessed by the research team based on sets of rubrics reflecting elements of CT. They concluded that semi-open tasks were more discriminating than others, but that a combination of tasks was needed to assess the various elements of CT. What appear to be common elements in assessments of CT are the capturing of instructions developed by students (almost always using a computer environment) and the judging of the quality of those instructions against a set of criteria reflecting aspects of CT.

1.7 Recent education policy developments related to CIL and CT

Since ICILS 2013 there have been a number of developments in education policy concerned with computer and information literacy. The participating national research centers provided information about these developments, together with examples of research publications connected to these developments. In this section, we focus on those developments that relate to ICILS 2018. Two common themes for developments in educational policy are an enhanced role for CT and an interdisciplinary view of the place of ICT in education.

A review conducted by the European Commission highlighted the development of CT and CS as part of compulsory education (Bocconi et al. 2016), and noted the variations amongst European countries in integrating CT into compulsory education. The review emphasized the need for research on the pedagogies and assessment methods associated with the implementation of CT, as well as research on the results of the implementation. It also identified a need for teacher support through large-scale professional learning opportunities, such as those initiated in England, and the need to develop new assessment tools and methods.

One review characterized the curriculum in Finland as emphasizing seven "transversal" skills that combine knowledge and skills with attitudes across disciplines (Kwon and Schroderus 2017). In the curriculum introduced in 2016, ICT is defined as a transversal skill that crosses subject areas. It concerns operating principles and concepts (including CT), responsible safe use of ICT, application in information management, and creative work and interaction and networking (Finnish National Agency for Education 2016). A country report on ICT in education in Finland included many other aspects, such as the need for teacher education and the development of digital curriculum content (Koskinen 2017). Saari and Säntti (2018) pointed to the priority accorded to digitalization through modernizing infrastructure and expanding teacher education, and how the reform conflicts with traditions of devolved authority. Kaarakainen et al. (2018) reported on performance-based testing of students' and teachers' ICT skills, and argued that assessment data are pivotal to improving the computer literacy of students in Finland.

Denmark has introduced a lower secondary school subject called technology comprehension, initially optional in 2017 but compulsory from 2018 (Aarhus University 2017). Technology comprehension includes learning to design and program digital products, as well as broader aspects of CT and understanding technology in society. Furthermore, it was observed that teachers did not see technology comprehension as a defined subject, and that teachers needed support to develop engaging interdisciplinary learning activities and professional learning to develop expertise in the field (Tuhkala et al. 2018).

The 16 German federal states developed a national competence framework and strategy for developing digital competences (KMK [Kultusministerkonferenz] 2016). This framework was not limited to CT, but encompassed a range of aspects of digital competence and associated teacher education, school resourcing, and curriculum development. Eickelmann (2018) highlighted the challenges involved in introducing this framework, including a lack of computer equipment and digital content, and slow internet speeds. She argued that new curricula involving digital media, such as those being developed in North Rhine-Westphalia, will be pivotal to these changes.

The United States National Education Technology Plan for 2017 (US Department of Education, Office of Education Technology 2017) focused on transforming learning experiences within greater equity and accessibility. It addressed, among other aspects, the provision of teachers with knowledge and skills to use technology-rich environments (through the *Future Ready Schools* effort; see http://futureready.org) and supporting greater use of technology-enabled assessments. It promotes enhanced infrastructure (including initiatives to help connect schools to broadband internet) and digital education resources (through the #GoOpen intiative), as well as professional learning for teachers. Much of the education technology plan focuses on using educational technology to improve student learning in other curriculum areas. The Every Student Succeeds Act (ESSA) in 2015 provided for expanding science, technology, engineering and mathematics (STEM) education to include computer science (Law Library of the Congress 2015). In finer detail, there has been a burgeoning volume of literature concerned with implementing computational thinking and computer science in classrooms (Lee and Recker 2018; Hacker 2018; Estapa et al. 2018).

Despite Korea's reputation for ICT use, programming was not seen as an important element in the national school curriculum until recent years (Kwon and Schroderus 2017). As part of the 2015 educational reform, software education (which includes programming) has been given greater emphasis in elementary, middle and high schools. Software education was introduced to provide for the development of computational thinking, problem solving processes, algorithms, program development, and coding skills. An informatics course was introduced in 2015 and became a required subject from 2018. This curriculum reform has been accompanied by an extensive program of professional learning for teachers. However, it remains to be seen whether the emphasis will be on learning these skills as part of a general education or developing the foundations for specialist training in information technology.

1.8 Research on the use of digital technologies in learning

The past four decades have seen substantial growth in the availability and use of ICT by young people in school and in their lives outside school. Growth in student use of ICT at home and school has been accompanied by a growing interest in how these technologies are being used. IEA's Second International Technology in Education Study (SITES, Module 2), a major qualitative study of innovative pedagogical practices involving ICT use conducted between 2000 and 2002, considered 174 case studies from across 28 countries (Kozma 2003). The case studies focused primarily on innovative ICT use, covered both primary (one-third of the cases) and secondary schooling (two-thirds of the cases), and encompassed a range of subjects and cross-curricular topics. SITES 2006 explored the use of ICT by grade 8 science and mathematics teachers in 22 countries (Law et al. 2008). The study report highlighted the importance of system and school factors in supporting teachers' pedagogical use of ICT. The report also documented that ICT was used more extensively by science teachers than by mathematics teachers, and suggested considerable variation in the pedagogical use of ICT across education systems.

TIMSS 2015 found that only one-quarter of grade 4 students reported using computers in mathematics lessons or science lessons at least once a month (Martin et al. 2016; Mullis et al. 2016). Only one-fifth of grade 8 students reported working with computers as part of their mathematics lessons at least once a month, while more than two-fifths reported this activity during science lessons (Martin et al. 2016; Mullis et al. 2016). Grade 8 students reported that

ICT use in mathematics was spread evenly across exploring principles and concepts, practicing skills and procedures, looking up ideas and information, and processing and analyzing data, while, in science lessons, ICT was more frequently used for looking up ideas and information. More than half of the grade 8 students surveyed in TIMSS 2015 used the internet to access information and resources, and more than two-thirds used the internet to collaborate with other students (Martin et al. 2016).

The OECD report for the Programme for International Student Assessment (PISA) in 2015 indicated that, across OECD countries in schools with enrolled 15-year-old students, there was an average of 0.8 computers per student, and that almost all of these computers were connected to the internet (OECD 2016b, p. 190). However, less than one-tenth of 15-year-old students in OECD countries reported regular or very frequent use of computers or virtual laboratories to simulate natural or technical processes (OECD 2016b, p. 119). Data from ICILS 2013 have shown that computer and internet access at school varies across and within countries, and is also associated with student background and school contexts (Fraillon et al. 2014).

A survey of ICT in school education commissioned by the European Commission and reported on in 2013 included a survey of students at International Standard Classification of Education (ISCED; see UNESCO [United Nations Education, Scientific and Cultural Organization] 2011) level 2 (grade 8) (European Commission 2013). Eighty percent of the grade 8 students said they had been using computers for more than four years. Students also reported undertaking ICT-based activities more frequently at home than at school. Students surveyed in the European Commission study rarely reported using applications that the research team considered particularly well suited to ICT use during lessons (such as data-logging tools and computer simulations). One-third of the students stated that they used digital textbooks and multimedia resources at least once a week. The report provided evidence of a positive association between the amount of student-centered learning and frequency of ICT use for classroom activities. The European Commission survey also identified three groups of ICT-based activities at home that the report's authors termed "fun" (e.g., streaming or downloading multimedia, music, movies, or videos), "learning" (e.g., online news, information searching, and learning programs), and "games." This classification, however, did not include activities involving the use of computer utilities (software applications) for school-related document preparation.

The report's authors also indicated that students were more confident in their "digital competences when they [had] high access to/use of ICT at home and at school" (European Commission 2013, p. 15). Confident students also tended to be positive about the impact of ICT on their work and leisure. The results from this study suggest that pedagogical use of ICT is not associated with more abundant ICT resourcing; despite enhanced resourcing in the several years before the study, school use of ICT had not increased since 2006.

ICILS 2018 has a specific interest in data concerning computer use by students and teachers because the extents and patterns of ICT use are potentially related to CIL and CT. Multivariate analyses showed that, after controlling for the effect of background variables such as gender or socioeconomic status, student experience of computer use and their frequency of computer use at home were positively associated with CIL scores in most countries (Fraillon et al. 2014). Student access to a home internet connection and the number of computers at home also had statistically significant associations with CIL scores in about half of the participating education systems. Greater interest in and enjoyment of ICT use was associated with higher CIL scores in nine of the 14 countries that met the ICILS sampling requirements. In addition, in several education systems, there was evidence of an association between CIL scores and the extent to which students reported having learned about ICT-related tasks at school.

In ICILS 2013, CIL was also positively associated with *basic ICT skills self-efficacy* (student confidence in undertaking basic ICT-based tasks such as creating or editing documents or searching and finding information on the internet), but not with *advanced ICT self-efficacy* (student confidence to carry out tasks such as building or editing a web page or creating a computer program or macro) (Fraillon et al. 2014; Rohatgi et al. 2016). This finding is congruent with the nature of the CIL construct, which is made up of information literacy and communication skills that are not necessarily related to advanced computer skills such as programming or database management. Even though CIL is computer-based, in the sense that students demonstrate CIL in the context of computer use, the CIL construct itself does not emphasize high-level computer-based technical skills.

Data from ICILS 2013 have also been used in secondary analyses to investigate the ways in which aspects of computer use by teachers and students are related to students' CIL (Bundsgaard and Gerick 2017; Gerick 2018). However, ICILS 2018 is also interested in describing variations in computer use as part of a broader understanding of the roles of information technologies in school education. Secondary analyses of ICILS 2013 suggest that teacher attitudes are associated with the extent and the ways that they use ICT in their teaching (Drossel et al. 2017a; Eickelmann and Vennemann 2017). Similar analyses investigated the influence of professional development on teacher attitudes to, and use of, ICT in school education (Drossel and Eickelmann 2017). In fact, there is evidence that school factors, including teachers' collaborative use of ICT, can shape the pedagogical use of ICT for teaching purposes (Drossel et al. 2017b; Gerick et al. 2017). ICILS 2018 provides updated information on these influences, and extends them to the teaching of CT, based on representative samples of grade 8 students and teachers of grade 8 students across a range of different education systems.

1.9 Research questions

ICILS aims to investigate the extent of CIL and CT among grade 8 students, and the associations of these learning outcomes with student background, developed attributes, experience with using computer technologies, and learning about computer technologies. It also investigates relations between CIL and CT.

1.9.1 Computer and information literacy

The research questions concerned with CIL remain similar to those used in ICILS 2013. The questions are framed around variations in CIL and CT, the relationship of CIL to the characteristics of students, and the contexts in which CIL is developed. The research questions for ICILS 2018 also imply the analyses that could be used to address them, as well as a wide range of more specific research hypotheses.

RQ CIL 1 What variations exist across countries, and within countries, in students' CIL?

RQ CIL 2 What aspects of schools and countries are related to students' CIL?

Following are some of the aspects of schools and education systems that could potentially be related to students' CIL:

(a) General approaches and priorities accorded to computer and information literacy education at system and school level.

(b) School coordination and collaboration regarding the use of ICT in teaching.

(c) School and teaching practices regarding the use of technologies in students' CIL.

(d) Teacher proficiency in, attitudes towards, and experience with using computers.

(e) ICT resources in schools.

(f) Teacher professional development.

RQ CIL 3 What are the relationships between students' levels of access to, familiarity with, and self-reported proficiency in using computers and their CIL?

RQ CIL 4 What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CIL?

1.9.2 Computational thinking

The proposed research questions relating to CT closely reflect those proposed for CIL, but exclude reference to changes from ICILS 2013 and include reference to the relationship between CT and CIL. Analyses will include data from those countries participating in the international option assessing students' CT achievement.

RQ CT 1 What variations exist across countries and within countries, in students' CT?

RQ CT 2 What aspects of schools and countries are related to students' CT?

RQ CT 3 What are the relationships between students' levels of access to, familiarity with, and self-reported proficiency in using computers and their CT?

RQ CT 4 What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CT?

RQ CT 5 What is the association between students' CIL and CT?

1.10 Participants and instruments

1.10.1 Participants and sampling

The ICILS target population comprises students in their eighth year of schooling. In most education systems, this is grade 8, provided that the average age of students in this grade is 13.5 years or above. In education systems where the average age in grade 8 is below 13.5 years old, the adjacent upper grade (9) is defined as the ICILS target population. Schools with students enrolled in the target grade will be selected randomly proportional to size (PPS). Within each sampled school, 20 students are randomly selected from among all students enrolled in the target grade.

The population for the ICILS teacher survey is defined as all teachers teaching regular school subjects at the target grade. It includes only those teachers who are teaching target grade students during the testing period and have been employed at school from the beginning of the school year. Up to 15 teachers are randomly selected from the teacher population at each sampled school.

School-level data are provided by the principal and ICT coordinator from each sampled school. In addition, national centers will provide information about the national contexts for CIL and CT learning by drawing on relevant expertise in each country.

1.10.2 Instruments

The following instruments form part of ICILS.

An *international computer-based student test* consisting of:

- questions and tasks set in authentic contexts designed to measure students' CIL[1]
- questions and tasks set in authentic contexts designed to measure CT[2].

A *student questionnaire* consisting of a computer-based set of items measuring student background, access to, experience and use of, and familiarity with ICT at home and at school. The questionnaire also includes questions designed to gauge students' attitudes toward using ICT.

1 This is the core test instrument completed by students in all participating countries.

2 This test instrument is completed only by students in countries participating in the international option of assessing CT.

A *teacher questionnaire* administered to selected teachers teaching any subject in the target grade. It gathers information about teacher background and their use of ICT. The questionnaire includes items that ask teachers to rate their confidence in using computers in their teaching, to state their actual use of computers, and to express their attitudes toward using computers in teaching and learning.

A *school principal questionnaire*, administered to the principals of sampled schools and designed to capture school characteristics, the application of ICT in teaching and learning, and aspects of the management of ICT at school.

An *ICT coordinator questionnaire* administered to ICT coordinators of sampled schools designed to capture information on resources and support for ICT at schools.

A *national contexts survey* completed by ICILS national research centers drawing on relevant expertise in each country. The survey will gather information on the structure of the education system, the status of CIL-related education in the national curriculum and policies, initiatives and resourcing associated with ICT, and CIL-related education. The online questionnaire also includes questions related to extent in which CT learning is incorporated into the national educational policies (for instance, questions on the extent in which CT processes such as writing or evaluating code, programs or macros are included in the curriculum). The data obtained from this survey should provide a description of the contexts for CIL- and CT-related education in each country and assist with the interpretation of results from the student, school, and teacher questionnaires.

CHAPTER 2

Computer and information literacy framework

2.1 Overview

The ICILS CIL framework was initially developed for ICILS 2013. At the time, it was noted that there was a variety of terms relating to CIL in the research literature (see, for example Virkus 2003) and that the development of context-specific constructs related to CIL had led to a proliferation of frequently overlapping and confusing definitions (Fraillon et al. 2013, p. 15). Since the development of ICILS 2013, the range of concepts associated with students' use of digital technologies has further increased. For example, Siddiq et al. (2016, p. 60) listed nine different names for "concepts for describing what and how students acquire, use, adapt to and learn with technology," ranging from "internet skills" through to "21st century skills"; these include the ICILS 2013 conceptualization of CIL. This evolving breadth of conceptualizations of competencies associated with the use of digital technologies is, in part, a function of the range of local contexts (including local curriculum needs) as countries develop their own approaches to having students both learn how to use digital technologies and use digital technologies to support learning across other domains.

When the CIL construct was first defined and described for use in ICILS 2013, it was necessary to locate CIL within the existing broad suite of constructs related to digital literacy and to clearly articulate the scope of the CIL construct. The reasoning underpinning this process is outlined in detail in the ICILS 2013 assessment framework (Fraillon et al. 2013). The following is a summary of the key decisions in this process with some reflection on their continued relevance for ICILS 2018.

The CIL construct was formulated during a period when there was a tension in the research literature between beliefs in the need to develop new constructs to describe and measure new skills being demonstrated with changes in technology and beliefs that the new skills should be assimilated into existing constructs. This tension is ongoing, and was described by Voogt and Roblin (2012, pp. 301–302) in their comparative analysis of international frameworks for 21st century skills as an "ongoing controversy on whether these terms are actually used to designate new competences, or rather to give greater emphasis to a specific set of long known competences that are considered as especially relevant to the knowledge society."

One of the conceptual challenges for ICILS 2013 was to decide whether the construct of CIL should address a new set of competencies or emphasize its connection to existing ones. The research team, in consultation with external experts, eventually opted for the second approach.

Furthermore, the ICILS conceptualization of CIL needed to take into account two fundamental parameters of ICILS:

- ICILS targets school-aged children (in their eighth year of schooling)
- The assessment is completed using computers and focuses on computer use.

The second of these parameters has necessitated the establishment of a working definition of *computer* for ICILS. In the final decades of the 20th century, the predominant concept of the computer associated with school-aged children was either as a desktop or laptop computer (but not a smartphone or tablet). These devices could be used for a range of educational purposes, including but not limited to: program development, use of productivity tools (such as word processing or spreadsheet tools), tuition applications, art and design tools, data collection, the conduct of simulations, and searching for information (such as from an encyclopedia). As the

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8_2

internet evolved, many learning and information resources became internet delivered rather than residing on personal devices or local networks, and electronic communication was added to the suite of activities associated with computer use in schools. In the early part of the 21st century, the concept of the computer in education has broadened, largely due to the proliferation of portable digital technologies, in particular tablet devices and smartphones, which can access the internet and run applications (see, for example, Hwang and Tsai 2011; Martin and Herzberger 2013). In particular, the ICILS 2018 study team had to determine how best to accommodate the use of tablet devices, which, since the inception of ICILS 2013, have become increasingly prevalent in schools and are now part of the discourse relating to ICT use in schools.

For ICILS, the concept of the computer was developed with reference to the primary use of the device in the context of education rather than with reference to the size and portability of the device. However, in doing this, it was acknowledged that the properties of a device do impact on the purposes for which it can best be used. Haßler et al. (2016), following an extensive literature review of reported use of tablet devices in school, suggested that:

> "Unsurprisingly, certain technologies are more appropriate for particular tasks than others and this is also true when considering uses for tablets: for example, keyboards, larger screens and specialized software (perhaps only available for certain operating systems) may be needed to support specialized tasks such as extensive writing, mathematical constructions and computer programming" (Haßler et al. 2016, p. 148).

The ICILS test of CIL contains tasks that require students to act as both information consumers and producers. While tablet devices are well suited for information consumption, the conclusions of Haßler et al. (2016) suggest that information production tasks are best performed on tablet devices with sufficiently large screens to manage layout. Screen size can be considered in terms of both the physical size of the screen and the available space on the screen. For tablet devices, the latter is maximized by the use of an external keyboard, which consequently prevents an on-screen keyboard from displaying and greatly reducing the visible screen space. For ICILS 2018, the concept of the *computer* was operationally defined as any device able to run the assessment software with a minimum screen size of 29cm and an external keyboard and mouse. This included conventional desktop computers, portable computers and tablet devices with an external keyboard and mouse.

For ICILS 2018, the CIL construct was consequently conceptualized with reference to this concept of computer rather than the broader device contexts implicit (although not always measured in practice) in constructs relating to digital literacy, ICT literacy, and digital competence (Carretero et al. 2017; Janssen and Stoyanov 2012; MCEECDYA 2010; Pangrazio 2016; Wilson et al. 2015).

The CIL construct also embraced information literacy (for a discussion of this in contrast to media literacy see Fraillon et al. 2013, p. 16), which emphasizes the processes of information management including the evaluation of the veracity of information (Catts and Lau 2008; Christ and Potter 1998; Livingstone et al. 2008; Ofcom 2006; Peters 2004).

At the time ICILS 2013 was in its planning and development stage, the concept of 21st century skills was emerging as an umbrella term to account for skills that are broadly regarded as necessary for successful participation in life, work and education in the 21st century. Definitions of and conceptualizations of 21st century skills in the research literature are varied, but largely influenced by six prominent frameworks (Chalkiadaki 2018). Some scholars have attempted to identify the common elements of the broad suite of 21st century skills. For example, van Laar et al. (2017, p. 583) listed core 21st century digital skills as: technical; information management; communication; collaboration; creativity; critical thinking; and problem solving. They further listed contextual 21st century digital skills as: ethical awareness; cultural awareness; flexibility; self-direction; and lifelong learning. Chalkiadaki (2018, p. 6) classified 21st century skills into four sets: personal skills; interpersonal and social skills; knowledge and information management skills; and digital literacy. What is common across the different conceptualizations of 21st century skills is that they comprise a broad range of skills that typically include a sub-set of skills common to CIL as defined in ICILS, but also extending well beyond the reach of what can be assessed in a study such as ICILS. CIL should be regarded as fitting neatly under the broader umbrella of 21st century skills, but with a focus on one of its dimensions.

ICILS was established to investigate the competencies associated with computer and information literacies as the enabling components of digital competence and representing aspects of the broader suite of 21st century skills. The ICILS research team developed the CIL construct independently of specific curriculum goals; the construct focused on what Lampe et al. (2010, p. 62) referred to as technology-mediated educational priorities for middle-school students. These include finding and synthesizing relevant resources, connecting to people and networks, and knowing how to present and express oneself online in general and through online systems in particular.

2.2 Defining computer and information literacy

ICILS defined CIL for use in ICILS 2013 with reference to definitions and constructs associated with information literacy and computer literacy. Information literacy constructs developed first through the fields of librarianship and psychology (Bawden 2001; Church 1999; Homann 2003; Marcum 2002) and are acknowledged as having the following processes in common: identifying information needs, searching for and locating information, and evaluating the quality of information (Catts and Lau 2008; Livingstone et al. 2008; UNESCO 2003). Information literacy constructs evolved to include the ways in which the collected information can be transformed and used to communicate ideas (Catts and Lau 2008; Peters 2004).

Early conceptualizations of *computer literacy* in education typically focused not on the logical reasoning of programming (or the syntax of programming languages) but rather on declarative and procedural knowledge about computer use, familiarity with computers (including their uses), and, in some cases, attitudes toward computers (Richter et al. 2000; Wilkinson 2006). Since that time, the concept of CT has gained increasing prominence across education systems, with perhaps some of the inevitable "definitional confusion" (Grover and Pea 2013, p. 38) that comes with new (or renewed) curriculum areas. While ICILS acknowledges that, conceptually, CT may be included in the broader concept of computer literacy (see, for example, diSessa 2000), ICILS 2018 distinguishes the functional aspects of computer literacy that support the use of digital devices when managing digital information from the problem solving and algorithmic thinking features of computer literacy that are core to CT. The former are part of the CIL construct established in the first ICILS cycle in 2013, while the latter are part of the CT construct developed for ICILS 2018 as an international option.

The assumption that information is received, processed, and transmitted underlies the CIL construct. Computer literacy constructs typically attribute less importance than is attributed by information literacy constructs to the nature and constituent parts of the information processing that happens between reception and transmission. In essence, computer literacy focuses on a more direct path between reception and transmission than information literacy, which emphasizes the processual steps involved as information is evaluated and transformed (Boekhorst 2003; Catts and Lau 2008). Over time, the originally distinct constructs of computer literacy and information literacy converged into a broader dimension reflecting ICT literacy and digital literacy.

Some scholars have emphasized the potential for information literacy and ICT skills to develop independently of each other. Catts and Lau (2008, p. 7) observed that "people can be information literate in the absence of ICT," and Rowlands et al. (2008, p. 295) commented that "the information literacy of young people, has not improved with the widening access to technology: in fact, their apparent facility with computers disguises some worrying problems." The CIL skills measured and reported on in ICILS, however, address computer literacy skills in the context of information literacy as applied to digital information sources. They reflect a combination of skills that, given the pervasiveness of digital information, continue to have a high profile in contemporary frameworks. For example, as mentioned already, the revised DigComp framework (DigComp 2.0) described digital competence in terms of five competences: information and data literacy; communication and collaboration; digital content creation; safety; and problem solving (Vuorikari et al. 2016). The US NAEP TEL framework also described ICT proficiency in terms of five, albeit different, sub-areas: construction and exchange of ideas and solutions; information research; investigation of problems; acknowledgement of ideas and information; and selection and use of digital tools (NAGB 2013).

The definition of CIL established for ICILS 2013 was derived with reference to pre-existing definitions of ICT and digital literacy that illustrated the convergence between information literacy and computer literacy skills in practical real-world applications.

These definitions were:

- "ICT literacy is using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (ETS 2002, p 2).
- "ICT literacy is the ability of individuals to use ICT appropriately to access, manage and evaluate information, develop new understandings, and communicate with others in order to participate effectively in society" (MCEETYA 2007, p. 14).
- Digital literacy is "... the ability to use digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (Lemke 2003, p. 22).

Common to these definitions is the assumption that individuals have the technical skills needed to use the technologies. All three definitions also list very similar sets of information literacy and communication processes. Each also maintains that individuals need to acquire these forms of literacy in order to participate and function effectively in society. Binkley et al. (2012, p. 52) postulated six categories under which ICT literacy knowledge, skills, attitudes, values and ethics can be classified: access and evaluate information and communication technology; analyze media; create media products; use and manage information; apply technology effectively; and apply and employ technology with honesty and integrity.

The definition of CIL established in ICILS 2013 and maintained as the definition in ICILS 2018 is:

> Computer and information literacy refers to an individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace and in society.

This definition relies on, and brings together, technical competence (computer literacy) and intellectual capacity (conventional literacies including information literacy) to achieve a highly context-dependent communicative purpose that presupposes and transcends its constituent elements. This view of CIL is congruent with Audunson and Nordlie's (2003) conceptual model of information literacy and is most closely aligned with the ICT literacy construct evident in the first of the ICT and digital literacy definitions cited above.

2.3 Revising the structure of the computer and information literacy construct

According to the ICILS 2013 assessment framework (Fraillon et al. 2013), CIL was described as comprising two strands each of which was specified in terms of a number of aspects.

Strand 1 collecting and managing information comprises three aspects:

- Aspect 1.1: Knowing about and understanding computer use
- Aspect 1.2: Accessing and evaluating information
- Aspect 1.3: Managing information.

Strand 2 producing and exchanging information comprises four aspects:

- Aspect 2.1: Transforming information
- Aspect 2.2: Creating information
- Aspect 2.3: Sharing information
- Aspect 2.4: Using information safely and securely.

The structure described above did not presuppose an analytic structure although, at the time of its development, the ICILS research team anticipated the possibility that Strands 1 and 2 might lead to separate measurement dimensions. Analyses of the ICILS 2013 main survey data included an investigation of the dimensionality (for details regarding the analytic approach see Gebhardt and Schulz 2015) but the very high latent correlations between the two strands led to the decision to report CIL achievement as a single dimension.

Following ICILS 2013, the project team together with ICILS 2013 national researchers evaluated the CIL construct with reference to its use throughout the full life-cycle of study. While the content of the construct was deemed to be appropriate, they identified potential improvements that could be made to the structure of the CIL construct. Firstly, positioning *knowing about and understanding computer use* (Aspect 1.1) within Strand 1 (the receptive strand) and *using information safely and securely* (Aspect 2.4) within Strand 2 (the productive strand) was problematic because it undermined the stated acknowledgement that each of these aspects was applicable across both the receptive and productive strands. At the time the CIL construct was specified this problem was acknowledged with the caveat that the aspects were included in the strands in which they were deemed to have the greatest applicability. However, on reflection, the ICILS research team decided that it would be better to remove any implication that either aspect was better associated with receptive or productive skills.

Furthermore, in a time of increasing opportunity for young people to act as information creators and publishers, it became apparent that Aspect 2.3 (*sharing information*) should be afforded greater prominence in the structure of the CIL construct.

In response to these concerns, and in consultation with ICILS national researchers, the project team established a revised structure for the CIL construct for ICILS 2018. It is important to note that the restructuring of the CIL construct was undertaken to better communicate the contents and emphases of the construct and to minimize overlap across the aspects of the construct. The change in structure neither means a change in ICILS assessment content nor presupposes a change to the analytic structure of the CIL construct.

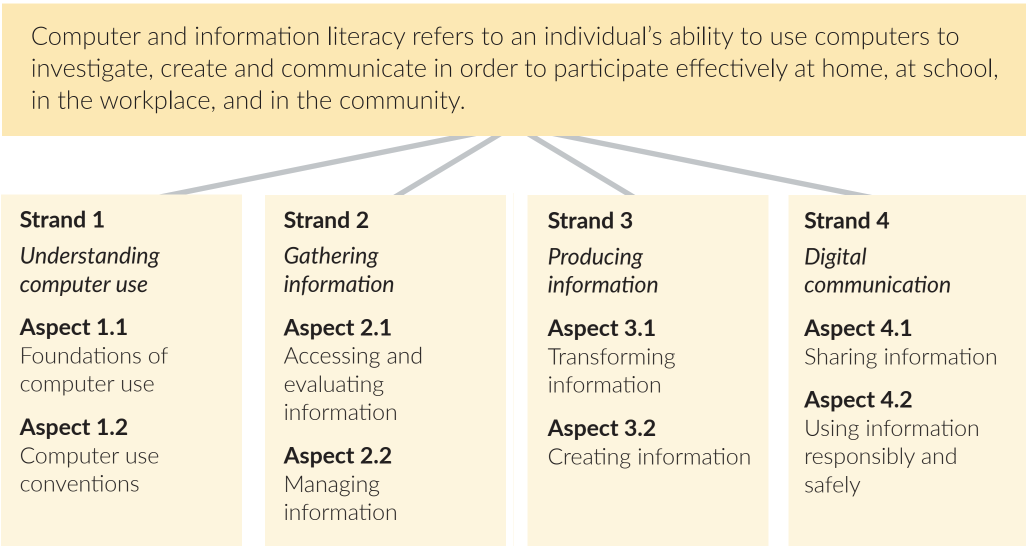
2.4 Structure of the ICILS 2018 computer and information literacy construct

The CIL construct includes the following elements:

- Strand: This refers to the overarching conceptual category for framing the skills and knowledge addressed by the CIL instruments.
- Aspect: This refers to the specific content category within a strand.

The construct comprises four strands, which each contain two aspects (summarized in Figure 2.1 and described in detail in section 2.5). The aspects encompass the set of knowledge, skills, and understandings held in common by the range of definitions of ICT literacy and digital competency discussed previously.

Figure 2.1: ICILS 2018 CIL framework



2.5 Strands and aspects of computer and information literacy

2.5.1 Strand 1: Understanding computer use

Understanding computer use refers to the fundamental technical knowledge and skills that underpin the operational use of computers as tools for working with information. This includes a person's knowledge and understanding of the generic characteristics and functions of computers. Early constructs of ICT and digital literacies typically focused on the receptive and productive elements of information literacy and de-emphasized generic computing technical knowledge and skills (see, for example, ETS 2002). However, it soon was acknowledged that fundamental knowledge and skills when using technology could be blended with information literacy in conceptualizations of ICT literacy (see Catts and Lau 2008), and ICILS 2013 included understanding computer use as an aspect of CIL to reflect the evolution of the domain (Fraillon et al. 2013). The role of basic technological skill in digital literacy continues to be prevalent. The DigComp 2.1 framework included skills associated with solving technical problems and identifying needs and technological responses as part of the problem solving competence area (Carretero et al. 2017). The 2014 US NAEP TEL framework included ICT as a major area of assessment and "understanding technological principles" as a practice. Understanding technological principles "focuses on students' knowledge and understanding of technology and their capability to think and reason with that knowledge" (NAGB 2013, p. 10) and the constituent understanding and reasoning is deemed to be applicable across all areas of TEL.

Understanding computer use comprises two aspects:

- Foundations of computer use
- Computer use conventions.

Aspect 1.1 Foundations of computer use

Foundations of computer use includes the knowledge and understanding of the principles underlying the function of computers rather than the technical detail of exactly how they work. This knowledge and understanding underpins effective and efficient computer use including basic troubleshooting. At a declarative level, a person should know that computers use processors and memory to run programs, or that operating systems, word processors, games, and viruses are examples of programs. They should be able to demonstrate knowledge that computers can be connected and so can "communicate" with one another through networks, and that these can be local or global. They should understand that the internet is a form of computer network that is run through computers and that websites, blogs, wikis, and all forms of computer software are designed to meet specific purposes. They should further be aware that information (such as files) can be stored across a range of locations including locally on a device, on removable devices (such as USB drives, SD cards and portable hard drives), and on local or remote networks (such as in cloud storage), and be aware that the range of storage locations are associated with a range of user benefits, risks and procedures.

The following examples reflect tasks that provide evidence of an individual's knowledge and understanding of the foundations of computer use:

- identifying that computers require physical memory, and that this is finite but may be expanded
- suggesting basic strategies to improve the performance of a computer that is running slowly
- explaining why the content of a completed web-based form might be lost if a user navigates away from the page and then returns to the page
- recognizing strategies to identify the part of a computer network that might be malfunctioning if a network connection has been lost.

Aspect 1.2 Computer use conventions

Computer use conventions include the knowledge and application of the software interface conventions that help computer users make sense of and operate software. This knowledge supports the efficient use of applications, including the use of devices or applications that are unfamiliar to the user. Accordingly, at the procedural level, a person may know how to execute basic, generic file and software functions, such as opening and saving files in given locations, resizing images, copying and pasting text, and identifying file types by their extensions, or modifying settings such as screen resolution or enabling accessibility options. The procedural knowledge included in Aspect 1.2 is thus limited to generic basic commands that are common across software (including operating system) environments.

The following examples reflect tasks that provide evidence of an individual's ability to apply computer use conventions:

- Editing an image using an interface with icons and controls that follow software interface conventions
- Clicking on a hyperlink to navigate to a web-page
- Saving an existing file to a new location with a new name
- Opening a file of a specified type
- Adding users to a collaborative web-based workspace.

2.5.2 Strand 2: Gathering information

Gathering information embraces the receptive and organizational elements of information processing and management. This strand comprises two aspects:

- Accessing and evaluating information
- Managing information.

Aspect 2.1: Accessing and evaluating information

Accessing and evaluating information refers to the investigative processes that enable a person to find, retrieve, and make judgments about the relevance, integrity, and usefulness of computer-based information. The proliferation of information sources that use the internet as a communication medium means that users are required to filter the vast array of information to which they gain access before they can make use of it. However, the process of filtering, in combination with the increasing intuitiveness of computer-based information search programs[3], is producing an ever greater integration of the processes of accessing and evaluating information. For this reason, accessing and evaluating information are regarded as sufficiently integrated to warrant their inclusion as a single aspect, rather than as separate aspects, of the digital information dimension of the CIL construct.

The importance of accessing and evaluating information is also a direct result of the increasing quantity and range of available unfiltered computer-based (and delivered) information. Computer-based information is not only increasing in volume, but also is constantly changing. While accessing and evaluating information are rooted in conventional literacies, the dynamic multimedia and multimodal nature of computer-based information means that the processes of accessing and evaluating that contribute to the CIL construct are different from those that relate only to conventional literacies. The dynamic context of computer-based information therefore necessitates the use of an amalgam of a range of skills (i.e., those typically associated with digital and media literacies) that differ from, and are broader than, the range employed with conventional literacies.

The following examples reflect tasks that provide evidence of an individual's ability to access and evaluate computer-based information:

- Selecting information from within a website or file list that is relevant to a particular topic
- Describing and explaining the functions and parameters of different computer-based information search programs
- Suggesting strategies for searching for information and/or adjusting the parameters of searches to target information better
- Recognizing and explaining characteristics of computer-based information (such as hyperbole and unsubstantiated claims) that detract from its credibility
- Recognizing that published information may serve other purposes than simply the sharing of information
- Suggesting and implementing strategies to verify the veracity of information (such as cross-checking information from multiple sources).

Aspect 2.2: Managing information

Managing information refers to the capacity of individuals to work with computer-based information. This information can be in the form of files that can be stored and opened using applications for later use or data that can be organized within files (such as data within fields in a database). The process of managing information includes ability to adopt and adapt information classification and organization schemes in order to arrange and store information so that it can

3 These include search engines that tailor search results to individual searchers based on location, previous search behavior, and even internet-use behavior of "friends" in a social network.

be used or reused efficiently. Managing information can include applying procedures to make use of alternative file storage locations (such as local, local or remote network or cloud-based locations) to support user access and to back-up information to protect against loss.

The following examples reflect tasks that provide evidence of an individual's ability to manage information:

- Creating a file structure in a directory according to given parameters
- Sorting or filtering information on an internet database
- Explaining the use of tags when storing images in an image library
- Recognizing the most efficient data structure for a given purpose within a simple database.

2.5.3 Strand 3: Producing information

This strand, which focuses on using computers as productive tools for thinking and creating, has two aspects:

- Transforming information
- Creating information.

Aspect 3.1: Transforming information

Transforming information refers to a person's ability to use computers to change how information is presented so that it is clearer for specific audiences and purposes. This process typically involves using the formatting, graphics, and multimedia potential of computers to enhance the communicative effect or efficacy of (frequently text-based or numerical) information.

The following examples reflect tasks that provide evidence of an individual's ability to transform information:

- Reformatting the titles in a document or presentation so as to enhance the flow of information
- Using, modifying, or creating images to supplement or replace text in a document (such as with a flow chart or diagram)
- Creating a chart to represent a table of data
- Transferring data (such as temperature or velocity data) from a data logger and displaying it in ways that illustrate patterns of change
- Creating a short animated sequence of images to illustrate a sequence of events.

Aspect 3.2: Creating information

Creating information refers to a person's ability to use computers to design and generate information products for specified purposes and audiences. These original products may be entirely new or may build upon a given set of information to generate new understandings.

Typically, the quality of information created relates to how the content is structured (whether or not the flow of ideas is logical and easy to understand) and the way in which layout and design features (such as images and formatting) are used to support understanding the resulting information product. Even though information design and layout design are executed together in an information product, they are typically conceptualized and assessed as discrete elements of creating information.

The following examples reflect tasks that provide evidence of an individual's ability to create information:

- Using a simple graphics program to design a birthday card
- Designing and writing a presentation that explains the key elements of an historical event
- Using a given set of information to make recommendations in a report that integrates text, data, and graphics.

2.5.4 Strand 4: Digital communication

Digital communication focuses on the competencies associated with information sharing in social networking (and broader web-based information sharing space) together with the social, legal and ethical responsibilities associated with information sharing. This strand includes responsibilities associated with information production, as well as mechanisms for protection against improper use of information by others. This strand has two aspects:

- Sharing information
- Using information safely and securely.

Aspect 4.1: Sharing information

Sharing information refers to a person's understanding of how computers are and can be used, as well as his or her ability to use computers to communicate and exchange information with others. Sharing information focuses on a person's knowledge and understanding of a range of computer-based communication platforms, such as email, wikis, blogs, instant messaging, sharing media, and social networking websites. Given the rapidly changing nature of this area, Aspect 4.1 focuses on knowledge and understanding of information-based social conventions and, at the higher end of the achievement spectrum, the social impact of sharing information through computer-based communication media.

The following examples reflect tasks that provide evidence of an individual's ability to share information:

- Recognizing some key differences between computer-based communication media
- Using software to disseminate information (such as attaching a file to an email or adding or editing a social media post)
- Evaluating the appropriateness of information for a specified audience
- Evaluating the best communication platform for a particular communicative purpose
- Creating or modifying information products to suit a specified audience and purpose.

Aspect 4.2: Using information responsibly and safely

Using information responsibly and safely refers to a person's understanding of the legal and ethical issues of computer-based communication from the perspectives of both the publisher and the consumer. Internet-based communication platforms increasingly are providing the facility for users to share information. With this facility comes the potential for misuse, particularly when dealing with personal information. Using information safely and securely also includes risk identification and prevention, as well as the parameters of appropriate conduct, including awareness of and prevention of cyberbullying. It furthermore focuses on the responsibility of users to maintain a certain level of technical computer security, such as using strong passwords, keeping virus software up to date, and not submitting private information to unknown publishers.

The following examples reflect content and contexts relating to responsible and safe use:

- Identity theft
- Unauthorized access and impersonation
- Identity concealment
- Phishing
- Malicious software distribution
- Automatic collection of internet usage data
- Social network posts
- Provision and use of personal information
- Attribution and copyright.

The following examples reflect tasks that provide evidence of an individual's ability to use information safely and securely:

- Identifying the characteristics that influence the strength of passwords
- Explaining the consequence(s) of making personal information publicly available
- Describing protocols for appropriate behavior on a social media site
- Suggesting ways to protect private information
- Understanding how internet advertising targets users
- Explaining the techniques used in a phishing email scam.

Check for updates

CHAPTER 3

Computational thinking framework

3.1 Overview

The ICILS CIL construct was established and measured in response to the pervasive belief in the value of CIL-related competencies for participation in the 21st century. At the same time as ICILS 2013 was being developed, there was the beginning of a resurgence of interest from researchers, educators, and policymakers in the importance of CT in education (Voogt et al. 2015). The inclusion of CT as an international option in ICILS 2018 was, in part, a response to a growing belief in the importance of computer science and computational thinking in schooling and efforts across countries to expand students' access to these areas of learning (Yadav et al. 2018).

While CT has been recognized "since the beginning of the computing field in the 1940s" (Denning 2017, p 34), many researchers refer to the work of Papert in the late 20th century (Papert 1980, 1991; Shute et al. 2017; Voogt et al. 2015) as a touchstone for CT research. More recently, Wing's (2006) article on CT has been regarded by researchers as the catalyst, or at least as a common point of reference, for the re-emergence of interest in CT (see, for example, Barr and Stephenson 2011; Bower et al. 2017; Grover and Pea 2013; Shute et al. 2017; Voogt et al. 2015). In this article, Wing characterized CT as "a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (Wing 2006, p. 33). However, despite the high level of interest in CT and the rapid increase in curriculum and educational resources, along with research concerned with CT, there has been confusion about its definition (Denning 2017; Grover and Pea 2013; Selby and Woollard 2013). This confusion is partly attributable the broad range of perspectives on CT that abound. For example, the National Academic Press reported on a 2009 workshop on the nature of CT that cited the following perspectives on CT (National Research Council 2010, pp. 11–12):

- CT is "closely related to, if not the same as…procedural thinking…that includes developing, testing, and debugging procedures"
- CT is about "expanding human mental capacities through abstract tools that help manage complexity and allow for automation of tasks"
- CT is primarily about processes and is a subset of computer science
- CT is "the use of computation-related symbol systems (semiotic systems) to articulate explicit knowledge and to objectify tacit knowledge to manifest such knowledge in concrete computational forms"
- CT is about "rigorous analyses and procedures for accomplishing a defined task"
- CT "is a bridge between science and engineering—a meta-science about studying ways or methods of thinking that are applicable to different disciplines"
- CT is "what humans do as they approach the world [that is, their framing, paradigm, philosophy, or language], considering processes, manipulating digital representations (and [meta] models)," and hence all humans engage in computational thinking to some extent already in their daily lives"
- CT "plays a role in the manipulation of software in support of problem solving"
- "What makes computational thinking especially relevant is that computers can execute our 'computational thoughts'."

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8_3

The range of different perspectives listed above exemplify some of the tensions that exist in approaches to CT. These tensions are associated with identifying where CT should be located on a spectrum of capabilities that, at one end, are characterized by algorithmic procedural thinking associated with computer programming and, at the other end, are described by a broader suite of problem solving capabilities and dispositions (see, for example, Barr et al. 2011; Barr and Stephenson 2011; Voogt et al. 2015). In reflecting on attempts to define CT, Voogt et al. (2015, p. 718) described the tension between "thinking of the 'core' qualities of CT versus certain more 'peripheral' qualities").

For ICILS, the definition and explication of CT, as for CIL, must be considered in the context of the ICILS assessment parameters. In this case the assessment of CT must be:

- Applicable to students in their eighth year of schooling
- Applicable across a broad range of country and curriculum contexts
- Complementary to the ICILS assessment of CIL
- Minimally overlapping with assessment content in other curriculum areas (such as in mathematics or science).

With these parameters in mind, the conceptualization of CT in ICILS is that CT combines the competencies associated with (a) framing solutions to real-world problems in a way that these solutions could be executed by computers; and then (b) implementing and testing solutions using the procedural algorithmic reasoning that underpins programming.

3.2 Defining computational thinking

In a review of CT literature, Selby and Woollard (2013) identified three consistently shared constituent components of CT: (a) a *thought process* (a way of thinking about computing); (b) *abstraction* (describing the common underlying properties and functionality of a set of entities); and (c) *decomposition* (breaking a complex problem into well-defined parts). Voogt et al. (2015, p. 720) suggested that many definitions of CT focus on the "skills, habits and dispositions needed to solve complex problems with the help of computing."

Following is a selection of definitions and descriptions of CT that have been used to inform the development of the definition of CT established for use in ICILS.

(1) "Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (Wing 2011, as cited by Grover and Pea 2013, p. 39).

(2) "We consider computational thinking to be thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms" (Aho 2012, p. 832).

(3) "It [computational thinking] is a cognitive or thought process that reflects:
  - the ability to think in abstractions,
  - the ability to think in terms of decomposition,
  - the ability to think algorithmically,
  - the ability to think in terms of evaluations, and
  - the ability to think in generalizations" (Selby and Woollard 2013, p. 5).

(4) "Computational thinking describes the processes and approaches we draw on when thinking about how a computer can help us to solve complex problems and create systems" (Digital Technologies Hub 2018).

(5) "Computational thinking is the process of recognizing aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes" (Royal Society 2012, p. 29).

(6) "Computational thinking is a problem-solving process that includes:
- Formulating problems in a way that enables us to use a computer and other tools to help solve them
- Logically organizing and analyzing data
- Representing data through abstractions, such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
- Generalizing and transferring this problem-solving process to a wide variety of problems" (Barr et al. 2011, p. 21).

(7) "Computational thinking is a term often used to describe the ability to think with the computer-as-tool" (Berland and Wilensky 2015, p. 630).

Common to these definitions of CT is the idea that CT is regarded as a form of problem solving in which the problems and solutions are conceptualized so that algorithmic, procedural (step-by-step) solutions can be established and implemented using a computer. These characteristics are consistent with the ICILS conceptualization of CT as focusing on problem solving to generate computer-based solutions. While it can reasonably be argued that the core of this conceptualization of CT may be applied to other learning domains, the ICILS test of CT does not include measurement of cross-domain applications of CT.

The definition of CT established within the context of ICILS is:

Computational thinking refers to an individual's ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer.

3.3 Structure of the ICILS 2018 computational thinking construct

The CT construct includes the following elements:

- Strand: This refers to the overarching conceptual category for framing the skills and knowledge addressed by the CT instruments.
- Aspect: This refers to the specific content category within a strand.

The CT construct comprises two strands. One strand contains three aspects and the other comprises two aspects (summarized in Figure 3.1 and described in detail in section 3.4). The aspects encompass the set of knowledge, skills, and understandings held in common across the range of definitions of CT as discussed previously.

Figure 3.1: ICILS 2018 CT framework

Computational thinking refers to an individual's ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer.

Strand 1

Conceptualizing problems

Aspect 1.1
Knowing about and understanding digital systems

Aspect 1.2
Formulating and analyzing problems

Aspect 1.3
Collecting and representing relevant data

Strand 2

Operationalizing solutions

Aspect 2.1
Planning and evaluating solutions

Aspect 2.2
Developing algorithms, programs and interfaces

The structure shown above does not presuppose a sub-dimensional structure of the CT construct. The primary purpose of describing CT using this structure is to organize the CT content in a way that allows readers to clearly see the different related aspects of CT and to support the auditing of the CT instruments against the full breadth of content in the CT construct. We hypothesize that CT will form a single measurement dimension. However, analyses of the dimensionality of the ICILS 2018 CT data will be used to determine whether CT is reported as a single or as multiple dimensions.

3.4 Strands and aspects of computational thinking

3.4.1 Strand 1: Conceptualizing problems

Conceptualizing problems acknowledges that before solutions can be developed, problems must first be understood and framed in a way that allows algorithmic or systems thinking to assist in the process of developing solutions. This strand comprises three aspects:

- Knowing about and understanding digital systems
- Formulating and analyzing problems
- Collecting and representing relevant data.

Aspect 1.1: Knowing about and understanding digital systems

Knowing about and understanding digital systems refers to a person's ability to identify and describe the properties of systems by observing the interaction of the components within a system.

Systems thinking is used when individuals conceptualize the use of computers to solve real-world problems, which is fundamental to computational thinking.

At a declarative level a person can describe rules and constraints that govern a sequence of actions and events, or they are able to provide a prediction for why a procedure is not working correctly by observing the conditions of the error. For example, imagine a student was required to design a game. The student would first need to specify the initial state of the game, the winning condition of the game and the parameters of the permissible actions, and sequence of actions within the game.

At a procedural level, a person can monitor a system in operation, make use of tools that help to describe a system (such as tree diagrams or flow charts), and observe and describe outcomes of a processes operating within a system. These procedural skills are based on a conceptual understanding of fundamental operations such as iteration, looping, and conditional branching, and the outcomes of varying the sequence in which they are executed (control flow). An understanding of these operations can enhance a person's understanding of both the digital world and the physical world; and it can therefore assist in solving problems. With reference to the example of a student designing a game, at the procedural level the student might initiate and adjudicate the game play. The student would need to monitor the players' actions and the consequent outcomes according to the specified rules and conditions of the game. In doing this, the student may observe problems with the game, such as unresolvable or ambiguous situations and be able to modify the game parameters accordingly. It is not always necessary that the game be created as a computer application, as digital systems thinking can also be applied to non-digital systems. In the context of ICILS, digital systems thinking could be applied to describe the actions of a physical system (such as filling a glass with water from a tap) in such a way that these actions could later be controlled by a computer program.

The following examples reflect tasks that provide evidence of an individual's ability to know about and understand digital systems:

- Exploring a system to describe rules about its behavior
- Operating a system to produce relevant data for analysis
- Identifying opportunities for efficiency and automation
- Explaining why simulations help to solve problems.

Aspect 1.2: Formulating and analyzing problems

Formulating problems entails the decomposition of a problem into smaller manageable parts and specifying and systematizing the characteristics of the task so that a computational solution can be developed (possibly with the aid of a computer or other digital device). Analyzing consists of making connections between the properties of, and solutions to, previously experienced and new problems to establish a conceptual framework to underpin the process of breaking down a large problem into a set of smaller, more manageable parts.

The following examples reflect tasks that provide evidence of an individual's ability to formulate and analyze problems:

- Breaking down a complex task into smaller, more manageable parts
- Creating a self-contained sub-task that could potentially be applied more than once
- Exploring the connection between the whole and the parts.

Aspect 1.3: Collecting and representing relevant data

In order to make effective judgements about problem solving within systems it is necessary to collect and make sense of data from the system. The process of collecting and representing data effectively is underpinned by knowledge and understanding of the characteristics of the data and of the mechanisms available to collect, organize, and represent these data for analysis. This could involve creating or using a simulation of a complex system to produce data that may show patterns or characteristics of behavior that are otherwise not clear when viewed from an abstract system level.

The following examples reflect tasks that provide evidence of an individual's ability to collect and represent data:

- Identifying an abstracted representation of map directions
- Using a route simulation tool to store data
- Displaying data to help draw conclusions and inform planning
- Using simulation tool to collect data and evaluate outcomes.

3.4.2 Strand 2: Operationalizing solutions

Operationalizing solutions comprises the processes associated with creating, implementing and evaluating computer-based system responses to real-world problems. It includes the iterative processes of planning for, implementing, testing, and evaluating algorithmic solutions (as the potential bases for programming) to real-world problems. The strand includes an understanding of the needs of users and their likely interaction with the system under development. The strand comprises two aspects:

- Planning and evaluating solutions
- Developing algorithms, programs and interfaces.

Aspect 2.1: Planning and evaluating solutions

Planning solutions refers to the process of establishing the parameters of a system, including the development of functional specifications or requirements relating to the needs of users and desired outcomes and with a view to designing and implementing the key features of a solution. Evaluating solutions refers to the ability to make critical judgements about the quality of computational artefacts (such as algorithms, code, programs, user interface designs, or systems) against criteria based on a given model of standards and efficiency. These two processes are combined in a single aspect because they are iteratively connected to the process of developing algorithms and programs. While the process of developing algorithms may begin with planning and end with evaluation, throughout the process there is a constant iteration between planning, implementation, evaluation, and revised planning (or resolution). Typically, there is a broad array of potential solutions to any given problem and, consequently, it is important to be able to plan and evaluate solutions from a range of perspectives, and to understand the advantages, disadvantages, and effects on stakeholders of alternative solutions.

The following examples reflect tasks that provide evidence of an individual's ability to plan and evaluate computational solutions:

- Identifying the starting point for an algorithmic solution to a problem by reflecting on solutions to similar problems
- Designing components of a solution taking into account the limitations of the system and the needs of users
- Testing a solution method against a known outcome and adjusting it as necessary
- Comparing the relative advantages and disadvantages of a solution against alternative solutions
- Locating a faulty step in an algorithm
- Describing solutions and explaining why they are the best solution among many
- Implementing and managing strategies to test the efficacy of a solution (such as user testing).

Aspect 2.2: Developing algorithms, programs and interfaces

ICILS 2018 does not presuppose that students are familiar with the syntax and features of any particular coding language. This aspect focuses on the logical reasoning that underpins the development of algorithms (and code) to solve problems. It can involve developing or implementing an algorithm (systematically describing the steps or rules required to accomplish a task) and also automating the algorithm, typically using computer code in a way that can be implemented without the need for students to learn the syntax or features of a specific coding language. Creating an interface relates to the intersection between users and the system. This may relate to development of the user interface elements in an application including implementation of specifications for dynamic interfaces that respond to user input.

The following examples reflect tasks that provide evidence of an individual's ability to develop algorithms, programs, and interfaces include the following:

- Modifying an existing algorithm for a new purpose
- Adapting visual directions into instructions for a computer
- Creating visual representations of instructions for a computer
- Creating a simple algorithm
- Using a new statement in a simple algorithm
- Creating an algorithm that combines simple command statements with a repeat or conditional statement
- Correcting a specified step in an algorithm.

CHAPTER 4

Contextual framework

4.1 Overview

This chapter describes the contextual information collected during ICILS 2018 in order to aid understanding of variation in the primary outcome achievement measures of the study: students' computer and information literacy (CIL) and computational thinking (CT). Throughout this chapter, the abbreviation CIL/CT has been used where each of CIL and CT may be considered as an outcome measure potentially influenced by a given set of contextual information. We provide a classification of contextual factors that accords with the multilevel structure inherent in the process of student CIL/CT learning, and consider the relationship of these factors to the learning process (antecedents or processes). We also list the different kinds of variables that will be collected via the different ICILS 2018 contextual instruments and briefly outline prior findings from educational research in order to explain why these variables are included in ICILS 2018.

4.2 Classification of contextual factors

When studying student outcomes related to CIL/CT, it is important to set these in the context of the different factors influencing them. Students acquire competencies in this area through a variety of activities and experiences at the different levels of their education and through different processes in school and out of school. It is also likely, as Ainley et al. (2009) argued, that students' out-of-school experiences of using ICT influence their learning approaches in school. Contextual variables can also be classified according to their measurement characteristics, namely, factual (e.g., age), attitudinal (e.g., enjoyment of computer use), and behavioral (e.g., frequency of computer use).

Different conceptual frameworks for analyzing educational outcomes frequently point out the multilevel structure inherent in the processes that influence student learning (see, for example, Gerick et al. 2017; Hatlevik et al. 2015; Schulz et al. 2016; Vanderlinde et al. 2014). The learning of individual students is set in the overlapping contexts of school learning and out-of-school learning, both of which are embedded in the context of the wider community that comprises local, national, supranational, and international contexts. As for ICILS 2013, the contextual framework of ICILS distinguishes the following levels:

- *Wider community:* This level describes the wider context in which CIL/CT learning takes place. It comprises local community contexts (e.g., remoteness and access to internet facilities), as well as characteristics of the education system and country. Furthermore, it encompasses the global context, a factor widely enhanced by access to the internet.
- *Schools and classrooms:* This context encompasses all school-related factors. Given the cross-curricular nature of CIL/CT learning, it is not useful to distinguish between classroom level and school level.
- *Home environment:* This context relates to the student's background characteristics, especially in terms of the learning processes associated with family, home, and other immediate out-of-school contexts.
- *The individual:* This context includes the characteristics of the student, the processes of learning, and the student's level of CIL/CT.

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8_4

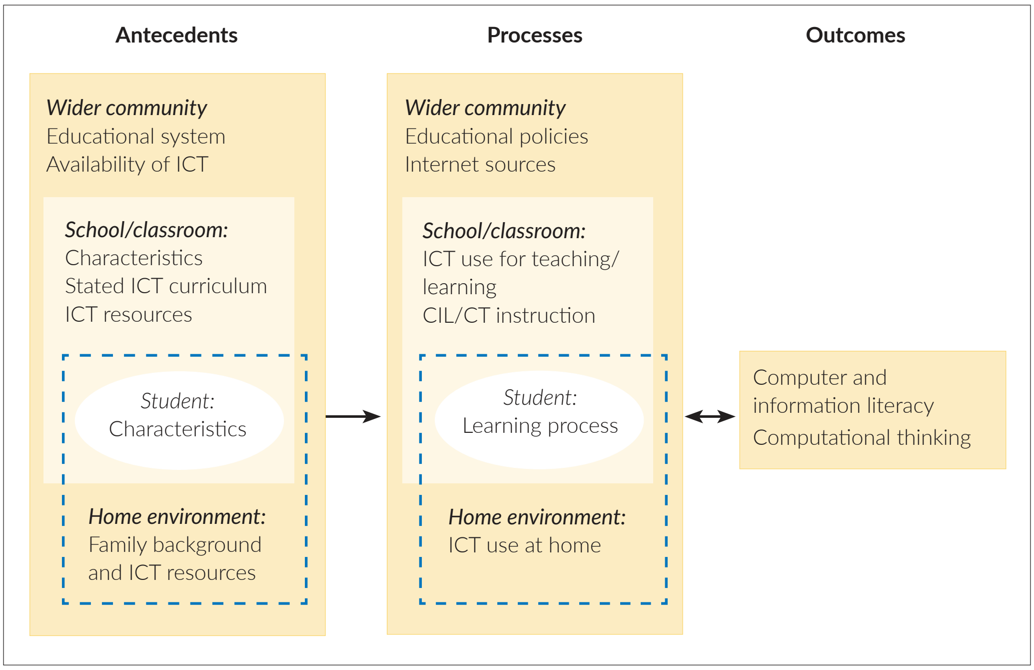
The status of contextual factors within the learning process is also important. Factors can be classified either as antecedents or processes:

- Antecedents are exogenous factors that condition the ways in which CIL/CT learning takes place. They are contextual factors that are not directly influenced by learning-process variables or outcomes. It is important to recognize that antecedent variables are level specific and may be influenced by antecedents and processes found at higher levels, for example, the extent to which schools' ICT resources are likely to be influenced by ICT education policies at the level of the education system.
- Processes are those factors that directly influence CIL/CT learning. They are constrained by antecedent factors and factors found at higher levels. This category contains variables such as opportunities for CIL/CT learning during class, teacher attitudes toward using ICT for study tasks, and students' use of computers at home.

Both antecedents and processes need to be taken into account when explaining variation in CIL learning outcomes. Whereas antecedent factors shape and constrain the development of CIL, process factors can be influenced by the level of (existing) CIL learning. For example, the level and scope of classroom exercises using ICT generally depend on the existing CIL-related proficiency of the students.

In the basic classification of antecedent and process-related contextual factors in their relationship with CIL/CT outcomes located at the different levels, each type of factor at each level is accompanied by examples of variables that have the potential to influence learning processes and outcomes (Figure 4.1). It is important to note that there is a reciprocal association between learning processes and learning outcomes while there is a unidirectional influence between antecedents and processes.

Figure 4.1: Contexts for ICILS 2018 CIL/CT learning outcomes



Notes: The double arrow between process-related factors and outcomes emphasizes the possibility of a reciprocal association between learning processes and learning outcomes. The single-headed arrow between antecedents and processes indicates the assumption within the ICILS contextual framework of a unidirectional influence between these two types of contextual factors.

Reference to this general conceptual framework enables potential contextual factors to be located on a two-by-four grid, where antecedents and processes constitute the columns and the four levels the rows (Table 4.1 shows examples of the contextual variables collected by the ICILS 2018 instruments). The student questionnaire will primarily collect data on contextual factors pertaining to the level of the individual student and his or her home context. The teacher, school principal, and ICT coordinator questionnaires are designed to locate contextual factors associated with the school/classroom level, while the national contexts survey and other available sources (e.g., published statistics) will gather contextual data at the level of the wider community.

Table 4.1: Mapping of variables to contextual framework (examples)

Level of ...	Antecedents	Processes
Wider community	NCS & other sources: Structure of education Accessibilty of ICT	NCS & other sources: Role of ICT in curriculum
School/classroom	PrQ, ICQ, & TQ: School characteristics ICT resources	PrQ, ICQ, TQ and StQ: ICT use in teaching and learning CIL/CT instruction
Student	StQ: Gender Age	StQ: ICT activities Use of ICT CIL/CT
Home environment	StQ: Parent socioeconomic status ICT resources	StQ: Learning about ICT at home

Notes: NCS = national contexts survey; PrQ = principal questionnaire; ICQ = ICT coordinator questionnaire; TQ = teacher questionnaire; StQ = student questionnaire.

4.3 Contextual levels and variables

4.3.1 The wider community context

Levels within the wider community context all have the potential to affect student learning at school or at home. Conceptually, this context has several levels:

- *Local communities*, where remoteness and lack of stable and fast internet connections may affect conditions for ICT use
- *Regional and national contexts*, where communication infrastructure, educational structures, curricula, and general economic/social factors may be of importance
- *Supranational or even international contexts*, where a long-term perspective brings in, for example, factors such as the general advance of ICT on a worldwide scale.

The most important factors potentially explaining variation in CIL/CT are located at the national level (or subnational level in those instances of sub-regions participating in the study). There is evidence of broad differences across countries in terms of access to digital technology across Europe, as well as more broadly across the world (Fraillon et al. 2014; Pew Research Center 2015; World Bank 2016).

Information relating to the contexts of educational systems will primarily be sourced from the ICILS 2018 national contexts survey, and supplemented by information from external databases and other published sources. Typically, these published sources provide information about antecedent country-context variables, while the national contexts survey will deliver data on antecedent and process variables at the education-system level.

More specifically, the national contexts survey is designed to collect systemic data on the following:

- Structure and makeup of the educational system (with specific focus on the target grade)
- Educational policy and practice in CIL/CT education (including curriculum approaches to CIL and CT)
- Policies and practices for developing the CIL/CT expertise of teachers
- Current debates on and reforms to the implementation of digital technology in schools (including approaches to the assessment of CIL/CT and the provision of ICT resources in schools)
- Information about ICT-based learning and administrative management systems.

Antecedent variables at the level of the wider community

International comparative research shows relatively strong associations between the general socioeconomic development of countries and student learning outcomes. ICILS 2018 will therefore select national (and where appropriate possible subnational) indicators related to general human development status as regularly reported by the United Nations Development Programme (UNDP 2016). Examples of these indicators are gross domestic product per person, access to education, and health statistics.

Given ICILS' focus on students' CIL/CT, it is important to take into account the general availability of and infrastructure for ICT. To this end, ICILS 2018 will collect, with the aim of describing the general ICT-related resources at the national level, information relating to variables such as the proportion of the population with access to the internet.

One example of a published source of data regarding national contexts is the ICT Development Index (IDI), developed by the International Telecommunications Union (ITU 2017). The IDI combines 11 indicators into a single measure that can be used as an index of ICT development for 154 countries or used as separate indicators. Another index is the Networked Readiness Index (see, for example, Dutta and Mia 2011).

Data from a range of international surveys show that the provision of ICT resources in schools varies widely across countries (see, for example, Anderson and Ainley 2010; Fraillon et al. 2014; Pelgrum and Doornekamp 2009). In order to obtain information related to the general policies regarding the ICT resourcing of schools, the ICILS 2018 national contexts survey will collect data about approaches to the provision of school-based ICT infrastructure, hardware, and software, as well as policy expectations regarding these provisions.

These system-level data will be complemented by school-level information from the ICT coordinator questionnaire, which will collect information about indicators such as the number of computers per student, software licensing arrangements, and the availability of digital curriculum resources.

The national contexts survey will also gather data about a range of other characteristics of the education systems participating in ICILS 2018. System-level variables related to this aspect include length of schooling, age-grade profiles, and structure of school education (e.g., study programs, public/private management), as well as the degree of autonomy of educational providers.

Process-related variables

The process-related variables on CIL/CT-related education policy that will be collected by the ICILS 2018 national contexts survey include:

- The definition of and the priority that each country gives to CIL education in its educational policy and provision
- Reforms in the use of ICT in education

- The emphasis on CIL/CT learning in the curriculum
- Support by education authorities for teacher professional learning in CIL/CT education
- The influence of different institutions or groups on decisions relating to those goals and aims.

Because the initial ICILS 2013 contextual framework references policies and practices developed as outcomes of earlier large-scale surveys of ICT in education, ICILS 2018 also considers the data relating to students' learning contexts and learning processes that were included in the reports and databases from these studies. These studies include IEA's Second Information Technology in Education Study (SITES) (Plomp et al. 2009), the European Commission's Indicators of ICT in Primary and Secondary Education (Pelgrum and Doornekamp 2009), and the International Experiences with Technology in Education survey, which covered policies and experiences in 21 countries (Bakia et al. 2011).

The information from these studies shows that countries take different approaches to the implementation of CIL/CT education in their curricula. Some education systems include it as a subject within the curriculum, whereas others include it by integrating it into other subjects. The explicitness with which countries describe their CIL/CT curricula and the learning outcomes they want from them also vary across education systems. Some have very explicit curricula regarding CIL education and its expected learning outcomes; others describe CIL/CT education as an "implicit" curriculum that weaves through the curriculum documents for other learning areas.

In order to build on what is already known, the national contexts survey will gather data on the inclusion of CIL/CT education (as a separate subject, integrated into different subjects, or as a cross-curricular approach) in the formal curriculum at different stages of schooling and in different study programs. It will also capture the nomenclature for CIL/CT-related curriculum subjects and whether they are compulsory or optional in each program of study. There will also be specific questions regarding the target grade in terms of curriculum emphasis on CIL/CT education.

Another important process-related variable at the system level is the development of teacher expertise in ICT-related teaching and learning (Charalambos and Glass 2007; Law et al. 2008; Scherer and Siddiq 2015). Teacher education programs often provide aspiring teachers with opportunities to develop ICT-related competencies. To aid assessment of the variety of different approaches to teacher education in the field, the national contexts survey gathers (where applicable) data on ICT-related requirements for becoming a teacher. The survey also seeks out information on the extent to which ICT-related education is part of preservice or initial teacher education, on the availability of in-service or continuing professional development for the use of ICT in education, on the providers of these activities, and on expectations for teachers' ongoing learning about developments in CIL/CT education.

Over the past few decades, many education systems have undertaken reforms involving the expansion in the use of digital technology in education[4]. A key feature of most national plans over the most recent decade is that they aspire to use ICT to transform patterns of learning and teaching, and also to develop capabilities useful within modern economies, rather than simply improve existing practice. However, results from ICILS 2013 suggested that participating countries differ in the extent to which they have introduced, or are introducing, digital technology into school education, including the development of curriculum resources in the form of digital learning objects (Fraillon et al. 2014). Similarly, ICILS 2013 found there was also variation in how education systems assessed ICT-related learning outcomes and in whether they used ICT to assess other disciplines. The ICILS 2018 national contexts survey will therefore gather data about the priorities accorded to these aspects and the nature of corresponding debates about related policies.

4 Two recent examples include the Slovak Republic's program for the "digitalization of the system of education" (Slovak Republic Ministry of Education 2013) and Lithuania's "Strategy on ICT integration into general and vocational education" (2008–2012) (Lithuanian Education and Science Ministry 2011).

4.3.2 School/classroom context

Any study of students' acquisition of CIL/CT must acknowledge the key role that school and classroom contexts play in that acquisition. Use of ICT is increasingly becoming standard practice in education and is therefore an important part of preparing young people for participation in modern society. Factors associated with the school and classroom context will be collected through the teacher, school principal, and ICT coordinator questionnaires. In addition, the student questionnaire includes some questions gauging student perceptions about classroom practices related to ICT. Even though ICILS 2018 will not attempt to investigate the relationship between ICT use in schools or classrooms and achievement in academic learning areas such as language, mathematics, or science, it is of interest to note the evidence of a positive impact of ICT use on classroom achievement in a meta-analysis conducted by Tamin et al. (2011).

Antecedent variables at the school/classroom level

In line with the need to consider basic school characteristics in the analysis of variations in CIL/CT, the school principal questionnaire will collect information on student enrollment, teachers, the range of grades, and the location of each participating school. It will also collect data on school management (public or private). Because, as noted earlier, ICT-related resources at school can be regarded as an important contextual factor to consider when studying students' CIL/CT, the school principal questionnaire will furthermore ask who, in the school, assumes responsibilities for the acquisition of ICT resources.

School-level factors related to ICT resourcing and priorities are known to influence both the way in which teachers use ICT for teaching and learning, and students' ICT-related learning (Fraillon et al. 2014; Gerick et al. 2017). The ICILS questionnaire for each school's ICT coordinator includes questions on the availability of school-owned computing devices at school, their location within the school, how many students have access to them, and the number of years the school has been using ICT. The instrument will also collect data on the support the school provides for ICT use in teaching and learning in terms of personnel and technology or software resources. It additionally includes a question measuring the coordinator's perceptions of the adequacy of the ICT on hand for learning and teaching at school. Analysis of this type of information will support evaluation of the premise that students in those schools with the highest levels of digital resourcing will have greater experience of and access to the use of CIL/CT, and consequently develop higher levels of CIL/CT.

With regard to school-level antecedent variables potentially influencing the development of students' CT skills, school ICT-coordinators are asked whether their school offers a stand-alone computing subject for the target grade, and, if so, to which extent this subject emphasizes a range of activities directly related to CT (e.g., activities such as developing algorithms, or debugging computer code).

The background and experiences of teaching staff potentially influence the acquisition of students' CIL/CT. Teachers' sense of self-efficacy in the use of basic ICT has been reported as linked to greater use of ICT in the classroom (Hatlevik 2016; Law et al. 2008). In ICILS 2013, teacher ICT self-efficacy was the teacher-level variable that showed the strongest association with teachers' reported emphasis on developing students CIL, and "teachers who were confident about their own ICT capability were more likely than their less-confident colleagues to place a greater degree of emphasis on developing their students' ICT-related skills" (Fraillon et al. 2014, p. 217). Furthermore ICILS 2013 reported that "older teachers typically held less positive views than younger teachers about using ICT and expressed lower confidence in their ability to use ICT in their teaching practice" (Fraillon et al. 2014, p. 257).The ICILS 2018 teacher questionnaire will therefore collect information on the background of teaching staff (such as age, gender, subject taught at school) and on their ICT experience (number of years using ICT for teaching purposes, general use of computers at different locations, participation in ICT-related professional development activities, and perceived self-confidence in using ICT for different tasks).

Teachers will also be asked to give their views on the positive and negative consequences of using ICT for teaching and learning, and to identify any factors that they think impede the use of ICT for teaching and learning at their school. Results from ICILS 2013 indicated that teachers across participating countries tended to recognize positive benefits from using ICT in teaching (Fraillon et al. 2014).

SITES 2006 findings suggested that ICT use by science and mathematics teachers is influenced by the school principal's views about its value, as well as the ICT-related support teachers have at hand (Law et al. 2008). Findings also indicated that ICT-related teaching and learning can be constrained or facilitated by the school's stated curriculum and its policies with regard to ICT. The ICILS school principal questionnaire will therefore collect data on the following factors:

- The extent to which the school has policies and procedures relating to ICT use
- The extent to which the school prioritizes ICT acquisition and resourcing
- Perception of the importance ascribed to ICT use in teaching at the school
- School-level expectations for teachers' knowledge of and skills in using ICT
- The extent to which teachers participate in ICT-related professional development.

Process-related variables at the school/classroom level

The emergence of ICT in school education has, for some time, been seen as having the potential to influence teaching and learning processes by enabling wider access to a range of resources, allowing greater power to analyze and transform information, and providing enhanced capacities to present information in different forms. The evolution of greater interactivity in more recent technologies (sometimes referred to as Web 2.0) has expanded these possibilities considerably (Greenhow et al. 2009). These developments have led to claims by some scholars that it is now possible for students to participate in extended projects that help to develop sophisticated concepts and skills through the use of simulation and visualization tools (Dede 2007). Commentators also argue that students can collaborate in developing learning experiences, generating knowledge, and sharing perspectives on experiences with other students.

The aforementioned large-scale cross-national studies also show that schools and classrooms vary in the extent to which educators use ICT in teaching. Burbules (2007) argued that, although e-learning technologies have the potential to bring transformative effects to classrooms, their implementation has been, for various reasons, surprisingly limited (see also Cuban 2001). The ICILS 2018 teacher questionnaire accordingly asks teachers to consider one of their classes (specified in the questionnaire) and to identify (where applicable) the types of ICT applications used in that class, the type of and extent to which ICT is used as part of teaching practices and for particular learning activities in that class, and the emphasis placed on developing ICT-based student capabilities. Based on research suggesting the benefits of a collaborative teaching approach on teacher self-efficacy and use of ICT for classroom purposes (see, for example, Caspersen and Raaen 2014), the questionnaire also asks teachers about their perceptions of whether and how ICT is used as part of collaborative teaching and learning at their school.

Actual student use of ICT in the learning process is another important factor. A segment of the teacher questionnaire therefore asks teachers to report on student involvement in different learning activities involving ICT use. The student questionnaire also asks students to report on how often they use computers at school, their use of computers for different school-related purposes, and the frequency with which they use ICT in their learning of different subjects. Furthermore, ICILS 2018 asks students about the frequency with which they use different ICT tools (such as tutorial, word processing, or presentation software) in the classroom, and how often activities involving the use of ICT take place during lessons (such as students using digital devices for presentations, or teachers using digital devices to provide feedback to students).

To assess how much students perceive they have learned about ICT use, ICILS 2018 contains a question that is similar to one used in ICILS 2013. This question measures the extent to which students think they have learned at school about different ICT-related tasks (such as providing internet sources or looking for different types of digital information on the internet). In response to the ever-increasing need to educate students about online safety and security issues (Ranguelov 2010; UNESCO 2014), ICILS 2018 also contains a new question on whether students believe they have learned at school about the importance of tasks related to security and privacy when using digital devices (such as checking the origin of emails before opening them, or using social media responsibly).

As part of the CT option, an additional set of questions was included in each of the student and teacher questionnaires to collect data on the degree to which instruction relating to the skills that underpin CT takes place in classrooms. These questions address process-related context factors that may influence the development of CT skills.

4.3.3 Home context

Antecedent variables related to the home environment

The influence of student home background on students' acquisition of knowledge has been shown in many studies, and there is evidence that home background is associated with the learning of ICT skills (ACARA 2015; Nasah et al. 2010; US Department of Education, National Center for Education Statistics 2016). Influences that have been shown to be associated include parental socioeconomic status, language used at home, ethnicity, and whether or not the student and/or his or her parents have an immigrant background.

A large body of literature shows the influence of students' socioeconomic background on student achievement in a variety of learning areas (see, for example, Saha 1997; Sirin 2005; US Department of Education, National Center for Education Statistics 2016; Woessmann 2004). ICILS 2013 results showed that, in participating countries, socioeconomic background consistently explained considerable variation in students' CIL (Fraillon et al. 2014). To assess the socioeconomic status of the students' parents, ICILS 2018 will include questions on the highest educational levels of parents, their occupations, and the number of books at home. This procedure is the same as was used successfully in ICILS 2013.

In the questionnaire, the highest educational levels achieved by the student's mother and father are defined in accordance with ISCED (UNESCO 2011). The occupation of each parent will be recorded through open-ended questions, with occupations classified according to the International Standard Classification of Occupations (ISCO) framework (ILO [International Labour Organisation] 2007) and then scored using the International Socioeconomic Index (SEI) of occupational status (Ganzeboom et al. 1992). Home literacy resources are measured through a question asking students to report the approximate numbers of books at home.

There is evidence from many countries of considerable disparities in students' access to digital resources in homes, and researchers and commentators claim that these disparities affect the opportunities that students have to develop the capabilities required for living in modern societies (Warschauer and Matuchniak 2010). ICILS 2013 provided evidence for these claims in many participating countries, however, in some highly developed countries only small effects were observed (Fraillon et al. 2014). The student questionnaire gathers information about the digital resources in students' homes and uses these data to examine the relationship between resource levels and CIL. In order to take into account changes in technology and use of digital devices, the set of items for measuring digital home resources has been broadened and includes both tablet devices and e-readers.

Many studies have found that the cultural and language background of students can be associated with their educational performance (see, for example, Mullis et al. 2017; OECD 2016c; Schulz et al. 2017). To measure these aspects of student background, the ICILS student questionnaire includes questions about students' and parents' country of birth, as well as about the language which is spoken most frequently at home.

Process-related variables related to the home environment

Home environment factors that potentially influence the learning process include the use of ICT in the home context and learning through interaction with family members. The student questionnaire therefore includes questions about the extent to which students have learned about different aspects of ICT use from family and/or friends, and how often they use ICT at outside of school (including at home).

4.3.4 Individual context

Antecedent variables at the individual level

Antecedent variables at the level of the individual student consist of basic background characteristics that may influence students' CIL-related knowledge and skills. Relevant factors in this category are age, gender, and educational aspirations.

Students' knowledge and skills in different learning areas tend to increase with age. However, cross-national data from grade-based surveys tend to find negative associations between age and achievement within a given grade-level within some countries (see, for example, Schulz et al. 2017, p. 63). Findings from ICILS 2013 (Fraillon et al. 2014) showed a similar negative association which could be due to retention and progression policies where older students in the same grade (grade 8 for ICILS) are also those with lower achievement.

Studies on educational achievement in numerous learning areas have found considerable differences between gender groups. In particular, cross-national research on reading literacy has shown larger gender differences in favor of females (Mullis et al. 2017; OECD 2016c). Males have traditionally tended to be somewhat more proficient in mathematics and science, but there is some evidence of a declining or non-existent gap at present (Martin et al. 2016; Mullis et al. 2016; OECD 2016c). Data reported from Australian and US national assessments of ICT-related skills show significantly higher levels of achievement for female students when compared to male students (ACARA 2015; US Department of Education, National Center for Education Statistics 2016). Cross-national results from ICILS 2013 also indicated that female students tended to have higher levels of CIL than their male counterparts (Fraillon et al. 2014). With regard to CT skills, however, some research suggests that the opposite relationship may be expected (Atmatzidou and Demetriadis 2016).

Individual aspirations with regard to education provide an indication of students' belief in their capacity to succeed in education and should be taken into account during any analysis of variation in students' CIL/CT. ICILS 2013 results showed that students who expected to complete a university degree also had higher levels of CIL (Fraillon et al. 2014). The ICILS 2018 student questionnaire includes the same question as in the previous cycle to gauge students' expected highest level of educational qualification.

Process-related variables at the individual level

Process-related variables at the individual level in this context include attitudinal, as well as behavioral factors. An individual's self-beliefs regarding their own ability with respect to a certain learning area are often viewed as central to the process of learning, and are likely to have a reciprocal association with knowledge and skills (see for example, Schöber et al. 2018; Talsma et al. 2018). Furthermore, it is also important to include student perceptions about responsible and appropriate use of ICT, which can also be seen as intended learning outcomes from teaching CIL and CT. Behavioral variables also relate to using ICT for different purposes and needs, especially in terms of the potential that frequent and varied use of these tools has for facilitating student learning.

The student questionnaire includes items designed to measure the extent to which students express confidence in doing a range of ICT-related tasks. According to Bandura (1993), students' confidence in their ability to carry out specific tasks in an area (self-efficacy) is strongly associated with their performance, as well as perseverance, emotions, and later study or career choices. Moos and Azevedo (2009) concluded from their review of research on computer self-efficacy that this variable plays an integral role in learning in computer-based learning environments. The two authors examined factors related to computer self-efficacy and the relationships between computer self-efficacy, learning outcomes, and learning processes. They found a number of positive associations between behavioral and psychological factors, and computer self-efficacy. A particular finding was that students who experience behavioral modeling also report significantly higher computer self-efficacy than do students who experience more traditional instruction methods.

In ICILS 2013, two dimensions of self-efficacy were identified, one related to student confidence in undertaking basic ICT tasks (such as searching and finding a file on a computer) and another one reflecting confidence in more advanced tasks (such as creating a database, computer program or macro) (Schulz and Friedman 2015). While self-efficacy related to basic tasks tended to be positively correlated with CIL, confidence in undertaking advanced tasks was not consistently associated with students' CIL (Fraillon et al. 2014). The ICILS 2018 includes a modified set of items measuring both student confidence in basic and more advanced ICT tasks that will be analyzed with regard to CIL/CT achievement.

Applying ICT for different purposes on a regular basis has considerable potential to increase knowledge and skills in this area (see, for example, ACARA 2015; Fletcher et al. 2012; US Department of Education, National Center for Education Statistics 2016), and ICILS 2013 showed frequent use of ICT for a wide range of activities (Fraillon et al. 2014). The ICILS 2018 student questionnaire consequently includes questions (modified from the previous cycle) about the frequency of using different ICT applications, using the internet for social communication, and using ICT for recreational (leisure) activities.

Data from other studies suggest a positive association between attitudes towards using ICT and academic achievement (Petko et al. 2016). In ICILS 2018, the student questionnaire includes a series of questions on students' perceptions of the impact on ICT on society and whether they intend to use ICT in the future for work and study purposes.

To gauge the educational context for the acquisition of CT skills, the ICILS 2018 student questionnaire asks students whether they study a CT-related subject (e.g., computing, computer science, information technology, informatics, or similar) in their current school year. This question is part of the international CT option.

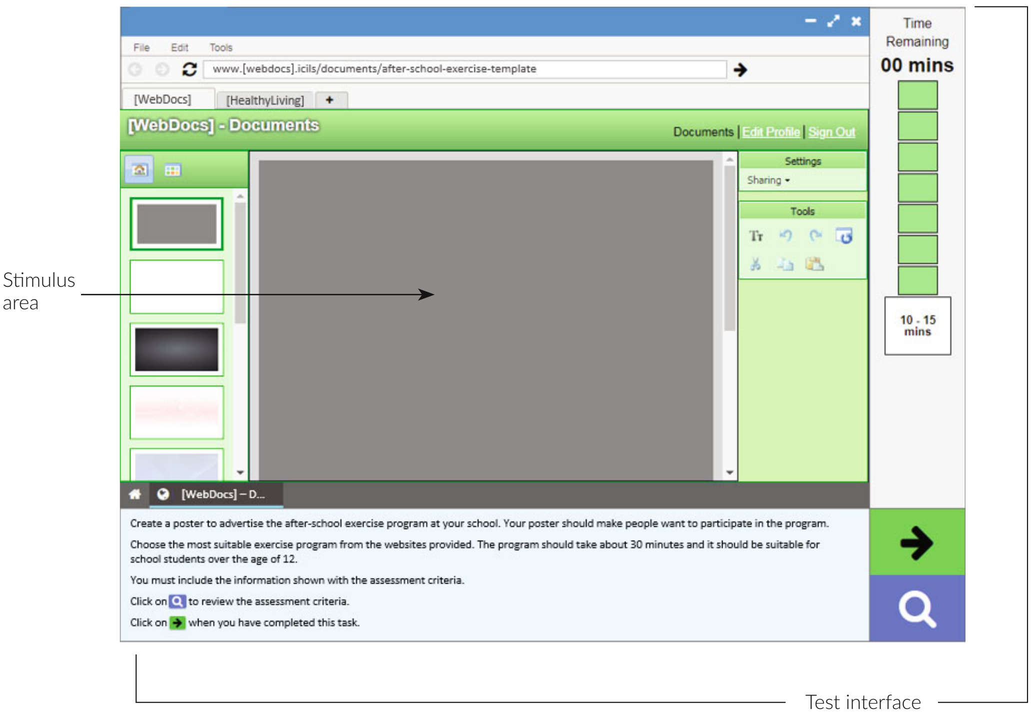
CHAPTER 5

ICILS instruments

5.1 Test instrument overview

The ICILS test is designed to provide students with an authentic computer-based assessment experience, balanced with the necessary contextual and functional restrictions to ensure that the tests are delivered in a uniform and fair way. ICILS uses a customized assessment platform that delivers the assessment content to students off-line (in the majority of schools the assessment is delivered from a USB drive). In order to maximize the authenticity of the assessment experience, the instrument uses purpose-built applications that use standard interface conventions. Students complete a variety of tasks, including multiple-choice and short text response questions, skills-based tasks, and information literacy and communication tasks, using a range of productivity software tools (such as text editors or presentation applications) and web-content. The web-content was developed for exclusive use in ICILS and was the only web-content available to students while they were completing the test. The purpose-built applications are designed to be consistent with the applications that can reasonably be expected to be within the realm of students' typical experience of computer use. Students need to be able to both navigate the mechanics of the test and complete tasks presented to them. In order to support these two purposes, the test environment comprises two functional spaces: the test interface and the stimulus area (Figure 5.1).

Figure 5.1: Test environment comprised of two functional spaces



J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8_5

5.1.1 Test interface

The test interface serves a number of purposes. Firstly, it provides students with information about their progress through the test (such as the number of tasks completed and remaining, and the time remaining). The text for each task is provided at the bottom of the interface. This text may take the form of a question to be answered (in which case the answer space is also included in the section) or an instruction relating to the execution of one or more skills. The test interface includes navigation controls that allow students to move between tasks, and an information button that allows students to access general test-taking information and task-specific information, such as scoring criteria or detailed task instructions. The test interface also houses the stimulus area (see Figure 5.1). The stimulus area is a space that contains either non-interactive content, such as an image of a login screen for a website, or interactive content, such as electronic documents or live software applications. The test interface and stimulus area were similar to that used in ICILS 2013, but their appearance was modernized for ICILS 2018. The position and functionality of the elements in the test interface (such as the navigation button and task progress indicator) were not changed, but the appearance of the elements was modernized to be consistent with 2018 interface design conventions.

5.2 The ICILS test instrument design

The ICILS test instrument consists of two tasks that are each delivered as 30-minute modules. In total, there are five CIL test modules in ICILS 2018. Three modules were developed and used in ICILS 2013, and these were kept secure to enable the establishment of trends in future cycles of ICILS. Two new modules were developed for the ICILS 2018 CIL test instrument. These new modules were designed to address contemporary relevant thematic content and software environments. Data collected from all five modules in ICILS 2018 are used as the basis for reporting ICILS 2018 CIL test results on the ICILS CIL achievement scale established for ICILS 2013. All students complete two of the five available CIL modules in a balanced rotation. The rotated module design for the modules enables the instrument to contain and consequently report on achievement against a larger amount of content (covering the breadth of the CIL framework and a range of difficulties) than any single student could reasonably complete in 60 minutes.

Two 25-minute test modules were developed for the ICILS 2018 CT test. In countries participating in the CT international option, students complete the two CT modules (in randomized order) after completing the international CIL test and ICILS student questionnaire.

5.2.1 CIL test modules

A CIL test module is a sequence of tasks contextualized by a real-world theme and driven by a plausible narrative. Each module has a series of five to eight smaller tasks, each of which typically takes students less than one minute to complete, and each of which contributes to the development of contextual knowledge that underpins work on a single large task. The large tasks typically take 15–20 minutes to complete and involve the development of an information product (such as a presentation, poster, website or social media post) that makes use of information and resources managed by students in the lead-up tasks. The large tasks are specified for students in terms of the software tool and format to be used (and consequently the format of the product), the communicative purpose, and the target audience of the information product. Students are also provided with information about the criteria that will be used to assess each large task.

The module themes are selected to be engaging and relevant to students, and the tasks are developed with a view to preventing prior content knowledge relating to a module theme from advantaging subgroups of students. This is achieved in three main ways: (1) by ensuring that all contextual information students need to manage the tasks is provided to students within the tasks; (2) by confirming that any technical (such as scientific) information used in modules is no more complex than the level of understanding typically expected of students in upper-primary/

elementary school; and (3) by preventing students from returning to earlier tasks in a module, as information in a subsequent task could be used to answer a previous task (see Fraillon 2018 for a detailed explanation of these design features).

The CIL module themes are all contextualized within a school environment, but they do not necessarily relate to conventional academic school work. For example, while modules may relate to communicating information about an aspect of science, social or environmental issues, modules can also relate to planning a class excursion or an online interest club with a community and social focus rather than academic focus.

5.2.2 CT test modules

The CT construct comprises two strands: *conceptualizing problems* and *operationalizing solutions*. Each of the two CT test modules focuses on one of these strands. Each module has a unifying theme and comprises a sequence of tasks that relate to the theme but, unlike the CIL modules, the tasks within the CT modules do not directly relate to the development of a large task. The tasks in the CT module focusing on *conceptualizing problems* related to planning aspects of a program to operate a driverless bus. This includes visual representation of real-world situations in ways that can support the development of computer programs to execute automated solutions. Examples of these are path diagrams, flow charts, and decision trees. Further tasks relate to the use of simulations to collect data and draw conclusions about real-world situations that can inform planning the development of a computer program.

In the module focusing on *operationalizing solutions*, students work within a simple visual coding environment to create, test and debug code (blocks of code that have some specified and some configurable functions) that controls the actions of a drone used in a farming context. In this module, the tasks are incrementally more difficult as the students advance through the module. The difficulties of the tasks relate to the variety of code functions that are available and the complexity of the sequence of actions required by the drone for completion of the task.

5.2.3 Test module rotation

Each student completes two of the five available CIL test modules. These modules are allocated to students in a balanced randomized design. There are 20 possible permutations of the two CIL modules selected from the five available modules. Each student is randomly allocated one module permutation.

In countries participating in the ICILS 2018 CT option, students complete the two CT test modules after having finished both the CIL test and student questionnaire. There are two permutations of the two CT modules and each student is randomly allocated one module permutation.

5.3 Types of assessment task: CIL

The computer-based assessment of CIL contains three types of task that are integrated into a single testing environment. This section contains details of each of these tasks with illustrative example[5]. Some of the example tasks are from the ICILS 2013 module "After-school exercise," where the student's central task was to design a poster to promote an after-school exercise program. Other example tasks are taken from a demonstration module created to illustrate some task formats that are otherwise only part of the secure ICILS assessment materials. This demonstration module is based on the idea of students working with a group of collaborators to plan the design of a new garden area in their school. In this module, students had to prepare an information sheet that explained and engendered support for their garden design, intended to encourage their classmates to vote for their design.

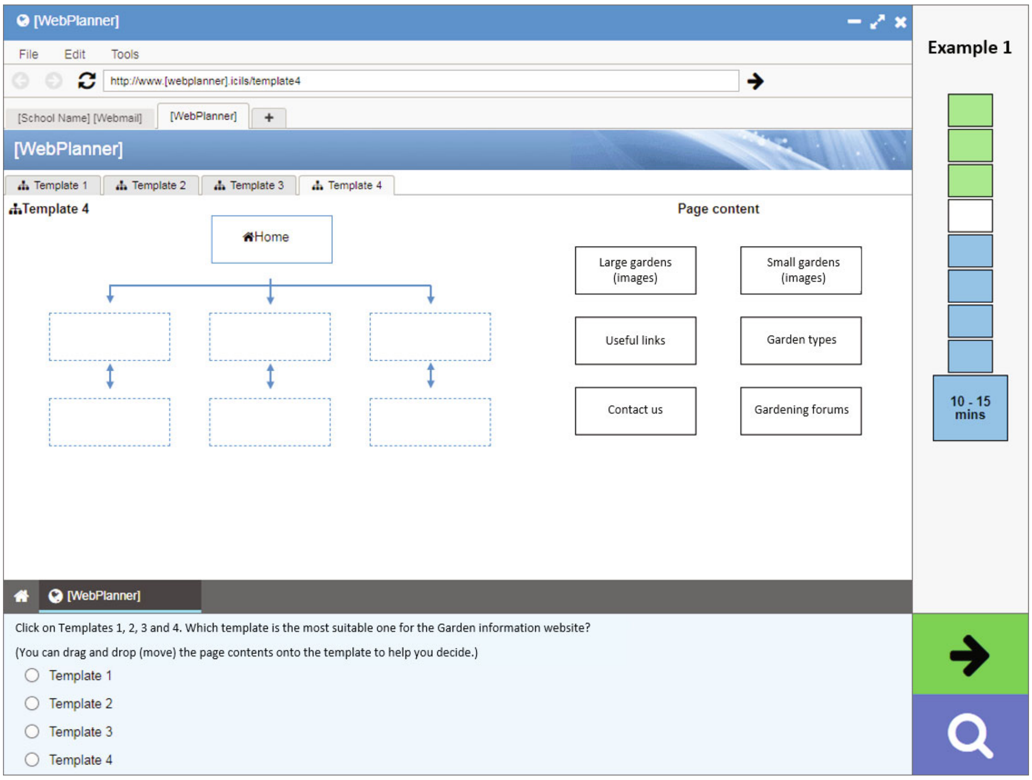
5 At the time of publication of this framework, most ICILS test tasks are secure. Where released modules do not include a particular task type, illustrative examples have been created for use in this framework to accurately represent the types of task formats and content materials used in ICILS.

5.3.1 Task type 1: Information-based response tasks

Information-based response tasks use a digital interface to deliver pencil-and-paper style questions in a slightly richer format than traditional paper-based methods. The stimulus material is typically a non-interactive representation of a computer-based problem or information source. The response formats for these tasks may be multiple choice, constructed-response, or drag-and-drop ones that use the technology only to display the stimulus material and record student responses. In these tasks, the computer-based environment is used to capture evidence of students' knowledge and understanding of CIL independently of students using anything beyond the most basic skills required to record a response.

As illustrations of an information-based response task format, example task 1 (Figure 5.2) requires students to examine four organizational-structure diagrams for a website and to select the structure that best suits a given set of six pages of content. This relates to Aspect 2.2 (managing information) of the CIL construct. Similarly, example task 2 (Figure 5.3) requires students to examine a non-interactive email (in this case a suspicious phishing email) and to respond using free text in a text entry box in the lower section of the test interface.

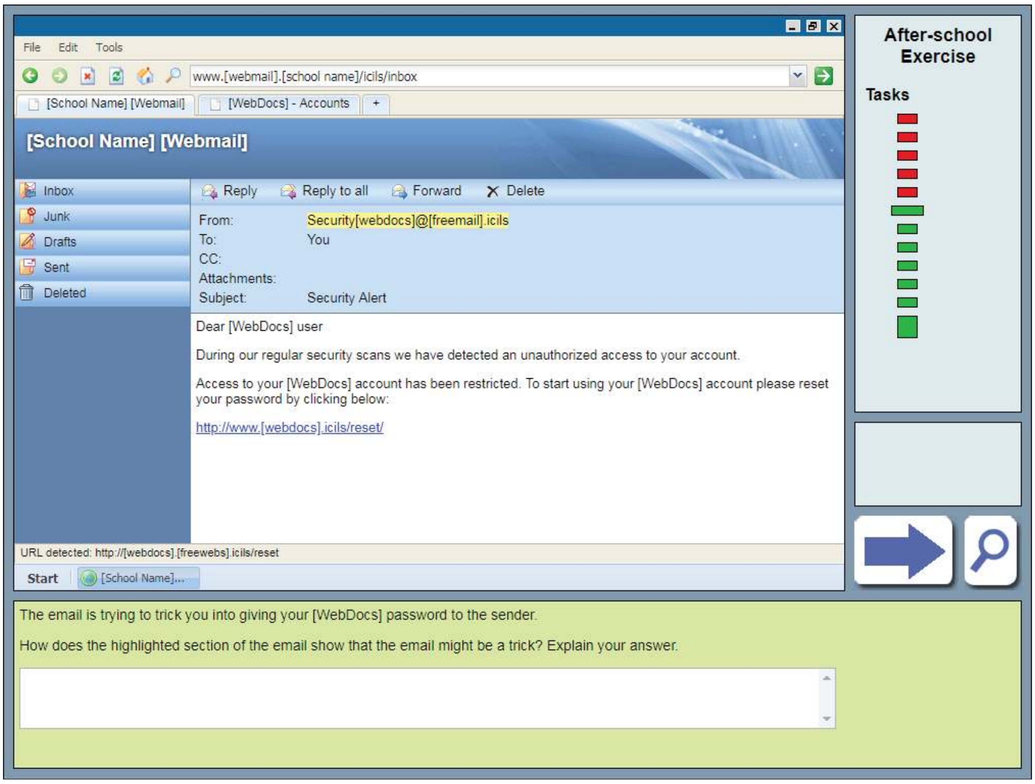
Figure 5.2: Example task 1 (a typical multiple-choice task)



The dynamic computer-based environment in example task 1 (Figure 5.2) enables students to view each of the four website structures in turn. The stimulus could also be presented in a static form (i.e., showing all four diagrams together) in a pencil-and-paper test. The simplest multiple-choice tasks in ICILS could also be presented in an equivalent form on paper.

However, because example task 1 allows students to drag and drop the web page contents into each organizational-structure template and thereby "try out" the different information structures in order to support their choice of the best structure; the computer-based stimulus facet of this task extends beyond what could be made easily available in a pencil-and-paper format. The task then enables students to provide their answer through a conventional multiple-choice format (shown in the lower area of the test interface), with one correct response that can be automatically scored. While the drag-and-drop functionality in example task 1 serves as an aid to determine the correct response, in other ICILS tasks this functionality serves as a method for recording student responses. The ICILS assessment uses the drag-and-drop task format whenever students are required to classify information into groups or to match objects or concepts according to their characteristics.

Figure 5.3: Example task 2 (open-response task from After-school exercise: ICILS 2013 test interface)



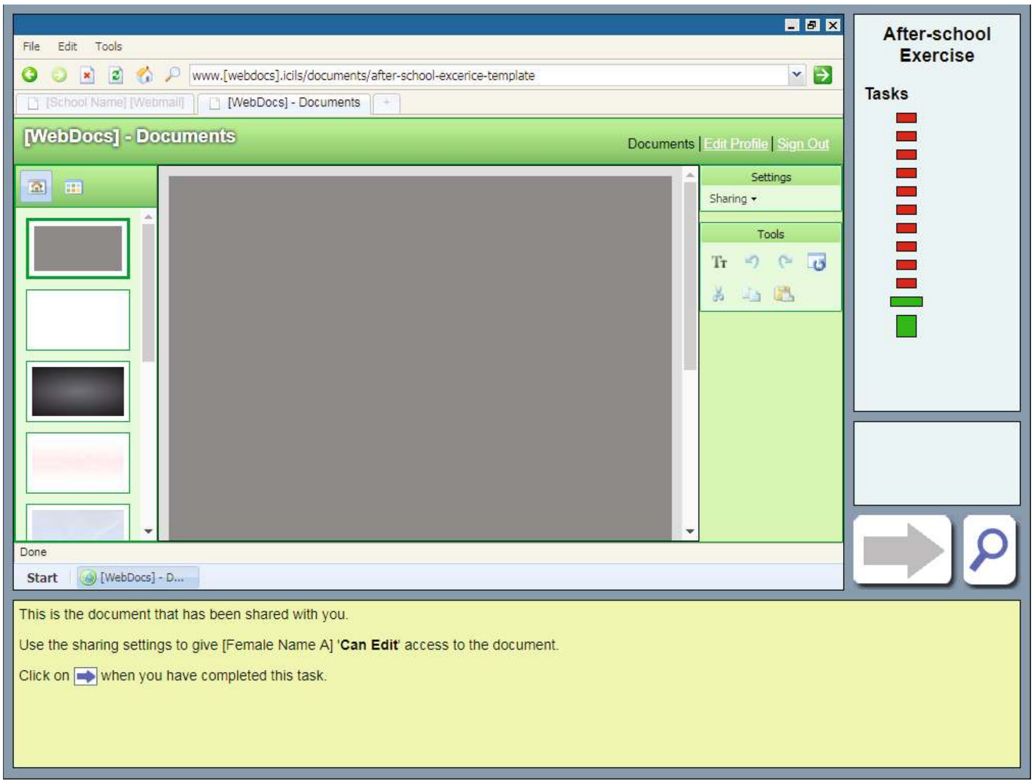
The stimulus material in example task 2 (Figure 5.3) from "After-school exercise" contains a phishing email with some metadata, such as the email address of the sender and the URL associated with the anchor text link. The task is presented to students as an example of an email that is trying to trick the user into clicking the link. Students must identify the discrepancy between the fictionally branded domain name "WebDocs" in the URL at the bottom of the email and the domain name associated with the sender's email address (freemail). Example task 2 relates to Aspect 4.2 (using information responsibly and safely) of the CIL construct. Responses to this task are recorded as text and scored by scorers according to a pre-defined scoring guide.

5.3.2 Task type 2: Skills tasks

Skills tasks require students to use interactive simulations of generic software or universal applications to complete an action. These may be single-action tasks (such as copying, pasting, or selecting a browser tab) or may contain a sequence of steps (such as "Save As" with a specific file name, or navigation through a menu structure). The tasks are designed to allow for all possible "correct" pathways for completing a task (such as using keyboard shortcuts or menu items) and the response data are recorded by the testing software. Some skills tasks only require students to execute given software commands, while others require students to execute commands along with some information processing. Skills tasks are scored automatically.

The ICILS student test contains linear and nonlinear skills tasks. A linear skills task may be as simple as executing a single command (such as opening a file from the desktop), or may require more than one step to complete the task. All appropriate methods of executing a command (e.g., using the mouse, pull-down menus, or keyboard shortcuts) are scored as equivalent and correct. Linear skills tasks that require the execution of more than one command can only be completed correctly if the commands are executed in a necessary prescribed sequence. For example, if students are instructed to copy and paste an image, they would first need to select the image and then execute the copy and paste commands in that order. Responses are automatically detected and scored once participants have reached an "endpoint" to a task.

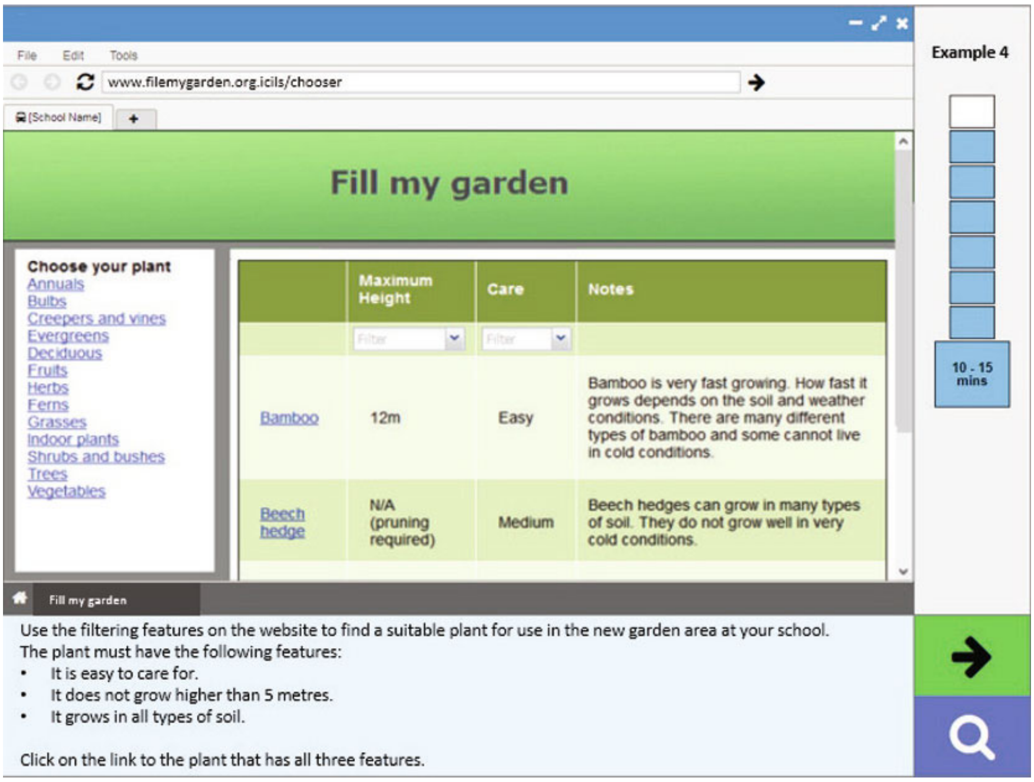
Figure 5.4: Example task 3 (linear skills task from After-school exercise: ICILS 2013 test interface)



Example task 3 (Figure 5.4) provides an example of a linear skills task that requires students to change the settings for a document in a collaborative workspace in order to permit edit access to specified people. Students must first click on the settings/sharing menu link and then enter the specified username into a field. Example task 3 relates to aspect 1.2 (computer use conventions) of the CIL construct.

Nonlinear skills tasks require students to execute a software command (or reach a desired outcome) by executing subcommands in a number of different sequences. Example task 4 is one such nonlinear skills task (Figure 5.5). This task requires students to use the filtering functions of a web-based database and to interpret some simple text in order to locate an object (a plant) that matches a given set of characteristics. The task is thus an example of a nonlinear skills task that requires information-processing skills and relates to Aspect 2.2 (managing information) of the CIL construct. The web-based database contains too many objects for a student to search manually with ease. As such, the automatic scoring gives the highest level of credit to students who make use of the filtering functions (in any order) to support their search. Students who identify the correct task without using the filters receive less credit.

Figure 5.5: Example task 4 (nonlinear skills task)

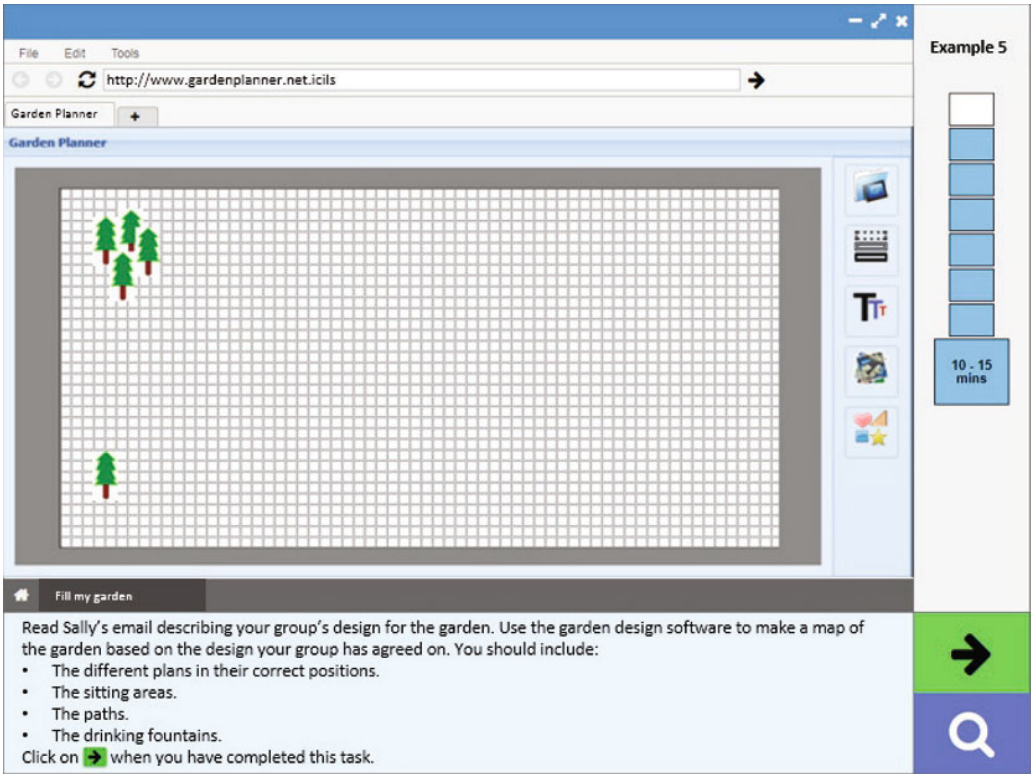


5.3.3 Task type 3: Authoring tasks

Authoring tasks require students to modify and create information products using authentic computer software applications. The applications, purpose-built for ICILS, adhere to software application conventions, such as the use of standard icons, or typical user interface feedback in response to given commands. This approach may require students to use multiple applications concurrently (such as email applications, web pages, spreadsheets, and word processing or multimedia software) as is typically required when using computer software to perform authentic complex tasks. Each student's work is automatically saved as an information product file for subsequent assessment by scorers according to a prescribed set of criteria.

Example task 5 (Figure 5.6) illustrates a simple authoring task, which requires students to use a basic map-drawing application to create a garden design plan that represents the text describing the plan. This relates to Aspect 3.1 (transforming information) of the CIL construct. The task is a simple authoring task because it asks students to use only the instructions and one piece of software (the mapping software) to complete the task. It is also simple because there is a relatively narrow range of "correct" ways in which the student can draw the garden design to match the specifications. The task is manually scored according to the accuracy with which the different specified elements of the garden design are shown in the diagram.

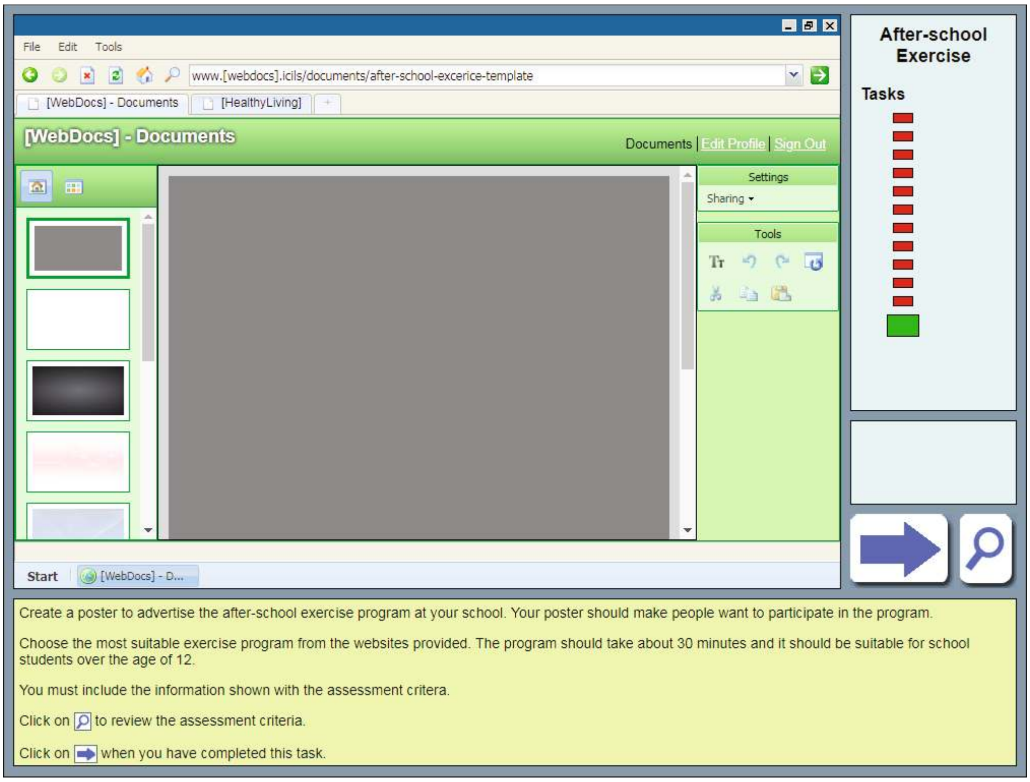
Figure 5.6: Example task 5 (simple authoring task)



Example task 6 is a more complex authoring task (Figure 5.7), requiring students to use information from a website across three sub-pages to create a poster that promotes an after-school exercise program. Students must use information from a range of electronic sources to create an information sheet that explains and promotes their garden design. The stimulus is nonlinear, fully interactive, and behaves intuitively. Students can navigate between browser tabs to switch between the website and the poster design web application. They can copy and paste text from the website to the poster software, and insert elements, such as images and text, on to the canvas of the poster design application. The final information product is saved, stored, and then scored against a set of criteria. The scoring criteria can be categorized as relating to students' use of (1) the software features and (2) the available information.

Criteria relating to students' use of software features can include their ability to use color, text formatting, and general page layout. These criteria typically have an internal hierarchy based on the degree to which the software features are used to support or even enhance the communicative effect of the information product. Criteria relating to students' use of information can also include students' adaptation of information, the relevance (and accuracy) of information selected for and used in the information product, and the appropriateness of selected information for the target audience. Note that the use of information is only assessed with respect to students' use of the information provided to them for use in the module. The highest level of credit is given to student work that demonstrates ability to use the software features to enhance the communicative effect of the information product. The lowest level of credit is given to pieces of work that show no application of the relevant software feature, or uncontrolled use (such as extremely poor color contrast or overlapping text) that inhibits comprehension of the product. The range of criteria available to evaluate example task 6 means that the single task collects evidence of student achievement relating to aspects 3.1 (transforming information) and 3.2 (creating information) of the CIL construct.

Figure 5.7: Example task 6 (complex authoring task from After-school exercise: ICILS 2013 test interface)



5.4 Types of assessment task: CT

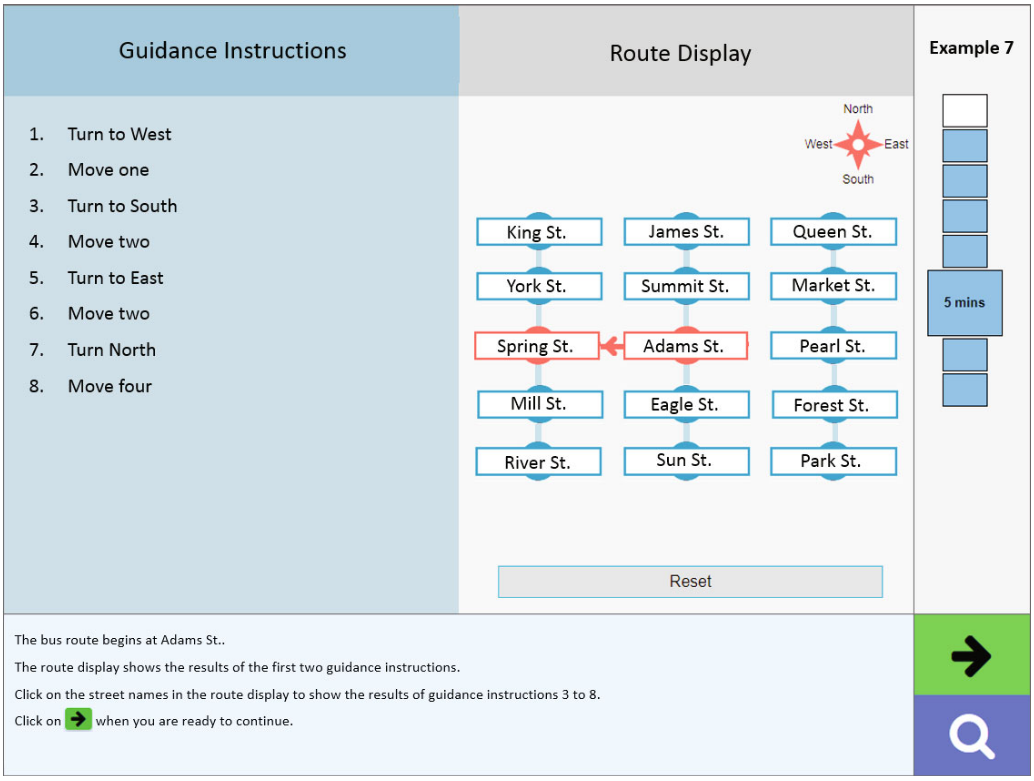
Like the CIL test, the CT assessment also contains information-based response tasks and nonlinear skills tasks (as described in section 5.3). However, in addition to these, the CT assessment instrument includes task types that are unique to the CT assessment. We created illustrative examples of these tasks specifically for inclusion in this framework[6]. These examples are similar to the tasks developed for use in each of the two CT test modules.

5.4.1 Task type 4: Nonlinear systems transfer tasks

Nonlinear systems transfer tasks require students to interpret, transfer and adapt algorithmic information so that the outcomes of the application of algorithmic instructions can be displayed visually. Example task 7 (Figure 5.8) requires students to follow the steps of a simple algorithm (left panel) and to transfer and adapt the steps of the algorithm to a visual display of their application (right panel). In successfully completing this process, students demonstrate both understanding of the visual system (including visual feedback) and the steps of the algorithm. This task relates to aspect 1.3 (collecting and representing relevant data) of the CT construct. These types of tasks are nonlinear because the student can select any node connected by the gray line in the right panel in any order, irrespective of what is described in the left panel.

6 At the time of publication of this framework, all ICILS 2018 CT items are secure. Illustrative examples have been created for use in this framework to accurately represent the types of task formats and content materials used in the ICILS computational thinking modules.

Figure 5.8: Example task 7 (nonlinear systems transfer task)



The student does not receive feedback about the correctness of their response but does receive feedback that their choice was registered. When the node selection is made, the color of the node changes from blue to red, and the line between the nodes changes from gray to red with an arrow indicating the direction of the movement between the nodes. These types of tasks are systems transfer tasks because they require the student to decode information presented in one system, deconstruct the rules of a second system, and adapt the information for transfer between the two systems.

5.4.2 Task type 5: Simulation tasks

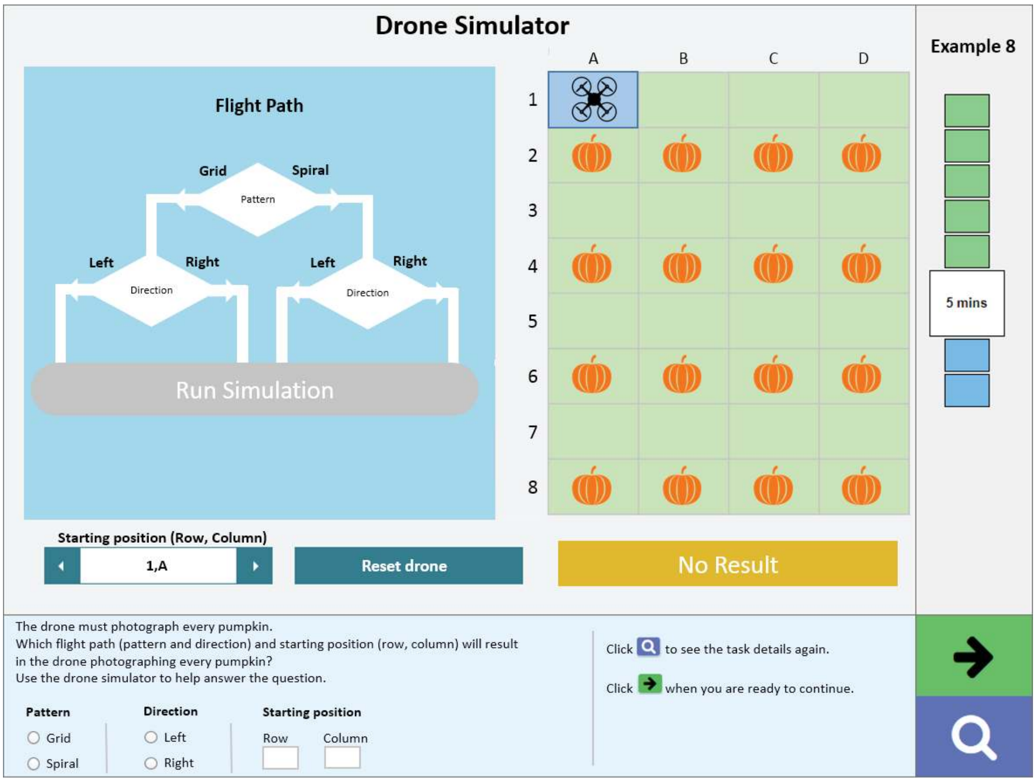
Simulation tasks require students to set parameters, run a simulation to collect data, and interpret the data to answer a research question. Example task 8 (Figure 5.9) requires students to configure the simulation tool and run simulations to identify a drone's optimal flight path over a set of pumpkins.

The decision tree (see left panel of Figure 5.9) is used to configure the flight path of the drone and the starting positon of the drone is also configured by the student. The student can then vary the configuration and run the simulation to identify the optimal parameters for the specified purpose. Simulation tasks such as example task 8 typically relate to aspect 1.3 (collecting and representing relevant data) of the CT construct.

5.4.3 Task type 6: Visual coding tasks

The ICILS 2018 CT test included a set of tasks that made use of a visual coding environment. The task interface and tasks are secure and examples of the interface and tasks cannot be shown without compromising the security of the test. Consequently, in this section, we provide only a description of the properties of the visual coding task interface and the types of visual coding tasks students may complete in the ICILS CT test.

Figure 5.9: Example task 8 (Simulation task)



Visual coding test environment

The visual coding test environment uses the ICILS test interface. However, in the ICILS 2018 visual coding test module, students were permitted to return to previous tasks within the module. This decision was made because, unlike within other ICILS test modules, the visual coding tasks did not follow a sequence where information provided in later tasks could potentially reveal the answer to earlier tasks. Consequently the visual coding test interface included the facility for students to "flag" tasks that they might wish to return to, and a navigation feature that allowed them to navigate freely between tasks they had already viewed.

The overarching objective for the visual coding environment was for students to complete coding tasks relating to the function of a drone used in farming. The visual coding test environment included the following key elements:

- A work space in which code blocks could be placed, ordered and re-ordered, and removed from the work space
- A space containing the code blocks that could be selected and used in the work space. These included code blocks controlling movement of the drone, some simple configurable commands for the drone to execute, simple loops, and conditional statements
- The facility for students to execute the code at any time and to see the consequent behavior of the drone as the code was being executed
- The facility to reset the code in the work space (to the default state of each task) and to reset the starting position of the drone before executing code.

Algorithm construction tasks

Algorithm construction tasks require students to develop their own solution to a problem by iteratively adding code blocks to the work space and executing the algorithm to see the results. These tasks typically allow for a variety of solutions with differing complexity (variety of code blocks) and depth (the number of levels deep nested codes are executed). Student responses are scored with respect to the accuracy with which the code achieves the specified goal, as well as the efficiency of the code, taking into account the number of code blocks used and the students' use of looping and conditional logic the algorithm. These tasks relate to aspect 2.2 (developing algorithms, programs and interfaces) of the ICILS CT framework.

Algorithm debugging tasks

Algorithm debugging tasks require students to modify an existing algorithm (configuration of code blocks in the work space) to solve the problem presented by the task instructions. In these tasks the students are presented with an existing set of code blocks in the work space, a description of the intended outcome of executing the code and an indication that the code is not working and needs to be corrected. Students can freely modify the code and also reset the code blocks in the workspace to the default state of the task (i.e., redisplaying the original incorrect code requiring debugging). Students are assessed on how closely their specified solution matches the ideal solution, including how accurately the code meets the specified goal. These tasks relate to aspect 2.1 (planning and evaluating solutions) of the ICILS CT framework.

5.5 Mapping test items to the CIL and CT frameworks

The test items that comprise the assessment modules are based on the strands and constituent aspects in the assessment framework (see section 2.5). The CIL and CT frameworks are central to the process of instrument development because they provide a theoretical underpinning for the assessment and a way of describing its content. The CIL test items were mapped to the assessment strands and the constituent strands in the CIL framework (Table 5.1) and CT test items were mapped to aspects and levels in CT test (Table 5.2).

In the CIL test, more items and score points per item relate to Strand 2 and Strand 3 than the other strands of the CIL construct (see Table 5.1). The main reason for this is that the large tasks at the end of each module focus on students' creation of an information product and therefore require each of these tasks to be assessed via multiple criteria with multiple score categories. Assessment of the large tasks focuses on Aspects 3.1 and 3.2, and together these contribute the largest number of associated score points across the test modules. The test design of ICILS was not planned to assess equal proportions of all aspects of the CIL construct, but rather to ensure some coverage of all aspects as part of an authentic set of assessment activities in context. The balance of items and score points relating to the different aspects of the CIL construct reflects the balance of time that students are expected to spend completing the different tasks.

While there is a similar number of items assessing each of the two CT strands, the number of score points available for strand 2 (operationalizing solutions) is approximately double those for strand 1 (see Table 5.2). Assessment of the quality of students' operationalized solutions (typically their visual coding solutions to specified problems) are assessed using multiple criteria. The test design of ICILS was not planned to assess equal proportions of all aspects of the CT construct, but rather to ensure some coverage of all aspects as part of an authentic set of assessment activities in context.

Table 5.1: Mapping the CIL test items to the CIL framework

CIL strand/aspect	Total (Items)	Maximum total (score points)*
Strand 1: Understanding computer use		
Aspect 1.1: Foundations of computer use	2	2
Aspect 1.2: Computer use conventions	11	13
Total (strand 1)	13	15
Strand 2: Gathering information		
Aspect 2.1: Accessing and evaluating information	14	16
Aspect 2.2: Managing information	8	8
Total (strand 2)	22	24
Strand 3: Producing information		
Aspect 3.1: Transforming information	15	20
Aspect 3.2: Creating information	21	31
Total (strand 3)	36	51
Strand 4: Digital communication		
Aspect 4.1: Sharing information	7	8
Aspect 4.2: Using information responsibly and safely	3	4
Total (strand 4)	10	12

Table 5.2: Mapping the CT test items to the CT framework

CT strand/aspect	Total (Items)	Maximum total (score points)*
Strand 1: Conceptualizing problems		
Aspect 1.1: Knowing about and understanding digital systems	3	7
Aspect 1.2: Formulating and analyzing problems	2	4
Aspect 1.3: Collecting and representing relevant data	3	5
Total (strand 1)	8	16
Strand 2: Operationalizing solutions		
Aspect 2.1: Planning and evaluating solutions	4	12
Aspect 2.2: Developing algorithms, programs and interfaces	4	11
Total (strand 2)	8	23

5.6 The ICILS student questionnaire and context instruments

5.6.1 Student questionnaire

The student questionnaire is based on the review of previous research discussed as part of the contextual framework (see Chapter 4), and was designed primarily to collect data that address Research Questions 3 and 4 for both CIL and CT:

RQ3 *How do students' levels of access to, familiarity with, and self-reported proficiency in using computers relate to students' CIL and CT?*

RQ4 *What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CIL and CT?*

Data gathered from the student questionnaire are used for two purposes. Firstly, these data are used in analyses that examine the relationships between student-level factors and measured CIL and CT. Secondly, these data are used to provide descriptive information about patterns of computer access and use across and within countries.

The student questionnaire is designed to provide the following indices regarding student and home background:

- Students' age (in years)
- Students' gender
- Students' expected highest level of educational qualifications
- Students' immigrant background
- Students' language use at home (test language or others)
- Students' parents' highest occupational status
- Students' parents' highest level of education
- Student reports on home literacy (number of books at home)
- Student reports on ICT resources at home
- Students' experience with ICT.

The student questionnaire contains questions to generate data reflecting the following aspects of ICT use and attitudes related to ICT:

- Students' experience in using ICT (frequency)
- Students' use of ICT applications (frequency)
- Students' use of ICT for social communication (frequency)
- Students' use of ICT for exchanging information (frequency)
- Students' use of ICT for accessing online content (frequency)
- Students' use of ICT for recreational purposes (frequency)
- Students' use of ICT for school-related purposes (frequency)
- Students' use of ICT in school subject lessons (frequency)
- Students' use of ICT tools in class (frequency)
- Student reports on learning of ICT tasks at school
- Students' ICT self-efficacy
- Student reports on learning about responsible ICT use at school
- Students' perceptions about the impact of ICT for society
- Students' expectations of future ICT use for work and study
- Student reports on the extent of learning about approaches to computational thinking at school.

5.6.2 Teacher questionnaire

The teacher questionnaire is largely concerned with information about teachers' perceptions of ICT in schools and their use of ICT in educational activities in their teaching. Together with questionnaires completed by the school principal and ICT coordinator, the teacher questionnaire is based on the contextual framework (Chapter 4) and designed to collect data that address Research Question 2 for both CIL and CT:

RQ2 *What aspects of schools and countries are related to students' CIL and CT?*

The assumption is that the extent to which ICT is used in schools, and the ways in which ICT is used in schools to teach information literacy, will impact on the development of students' CIL and CT. Information from the teacher questionnaire will also be used to describe the use of ICT in pedagogy among countries and major teaching areas.

It will not be possible to link teacher-based information to individual students. Rather, that information can be used to generate school-level indicators for potential two-level regression analyses in conjunction with student-based data.

The population for the ICILS teacher survey is defined as all teachers teaching regular school subjects to the students in the target grade (generally grade 8) at each sampled school. Fifteen teachers are selected at random from all teachers teaching the target grade at each sampled school to complete the teacher survey[7]. This cluster size is required to produce:

- School-level estimates with sufficient precision to be used in analyses that examine associations with student outcomes
- Population estimates with precision similar to those generated from student data.

The teacher questionnaire consists of questions about teachers' backgrounds, their familiarity with ICT, their use of ICT in teaching a reference class, their perceptions of ICT at school, and their training to use ICT in teaching.

The teacher questionnaire is designed to generate data reflecting the following aspects of teacher perceptions regarding ICT and its use in education:

- Teachers' CIL self-efficacy
- Teachers' use of ICT tools in class
- Teacher reports on student engagement in learning activities with ICT
- Teacher reports on use of ICT in teaching and learning practices
- Teachers' perceptions of the emphasis on ICT skills development in class
- Teachers' positive views regarding the use of ICT in teaching and learning
- Teachers' negative views regarding the use of ICT in teaching and learning
- Teachers' perceptions of adequacy of resources at their school
- Teachers' participation in ICT professional development
- Teachers' perceptions of collaboration for ICT use
- Teachers' emphases on teaching approaches to computational thinking in class.

7 In small schools this means all teachers of grade 8 students.

5.6.3 School questionnaires

There are two complementary school questionnaires: a principal questionnaire and an ICT coordinator questionnaire. The principal questionnaire focuses on characteristics of the school and broad policies, procedures and priorities for ICT in the school. The coordinator questionnaire focuses on ICT resources in the school and the policies and practices that make use of those resources to support learning. While these two questionnaires should ideally be completed by different people, ICILS 2018 makes provision for the possibility that both may be completed by the same person in a small school where there is no identifiable ICT coordinator.

Principal questionnaire

The principal questionnaire is designed primarily to collect data that address Research Question 2 for both CIL and CT:

RQ2 *What aspects of schools and countries are related to students' CIL and CT?*

The assumption underlying Research Question 2 is that the extent to which, and manner in which ICT is used in schools will impact on the development of students' CIL and CT. The ICILS framework assumes that the school principal can provide important perspectives on school practices and policies regarding the pedagogical use of ICT.

The principal questionnaire also collects data that will provide further context on variation in the use of ICT in pedagogy across education systems.

The ICILS principal questionnaire covers the following areas: characteristics of the principal (including their use of ICT), school characteristics (number of enrollments, range of grades taught, characteristics of the school location, ratio of female to male enrollments), management of ICT in the school, encouragement to use ICT in teaching and learning, schools' pedagogical orientations, and provision for professional development in the use of ICT.

The principal questionnaire includes questions designed to collect data about the following contextual aspects at the school level:

- School principals' use of computers for school-related purposes (frequency)
- School size (student enrollment)
- Student-teacher ratio
- School structure and management
- Economic background of students
- School principals' perceptions of the importance of ICT use at school
- School principal reports on their expectations of teachers' ICT skills
- School principal reports on ICT policies and procedures
- School principal reports on teachers' professional development for ICT use
- School principal reports on school priorities for ICT use in teaching and learning.

ICT coordinator questionnaire

The ICT coordinator questionnaire will be designed primarily to collect data that address Research Question 2 for both CIL and CT:

RQ2 *What aspects of schools and countries are related to students' CIL and CT?*

The assumption underlying Research Question 2 is that the extent to which, and manner in which ICT is used in schools will impact on the development of students' CIL and CT. The ICILS framework assumes that the ICT coordinator can provide important perspectives on school practices and policies regarding the pedagogical use of ICT. The ICT coordinator questionnaire will also collect data that provide further context on variation in the use of ICT in pedagogy across education systems.

The ICT coordinator questionnaire collects data on ICT resources (numbers of computers of different types, availability of computers for student use, availability of other ICT devices, availability of digital learning resources, networking and internet connectivity), ICT use in the school (provision for specialist teaching of ICT, emphases in curriculum areas, learning management systems, school administration), ICT technical support (maintenance provision, support for managing resources), and provision for professional development in ICT at school.

The ICT coordinator questionnaire includes questions designed to generate data reflecting the following ICT-related aspects:

- School experience in using ICT
- School policies towards the use of ICT at school
- The computer-student ratio at school
- The quality of ICT resources at school
- Perceptions of hindrances to the use of ICT in teaching and learning at school
- Perceptions of school emphasis on teaching activities to develop students' CT skills.

5.6.4 National contexts survey

The national contexts survey is intended to collect data that primarily addresses Research Question 2 for both CIL and CT:

RQ2 *What aspects of schools and countries are related to students' CIL and CT?*

The assumption underlying Research Question 2 is that the opportunities to use ICT impact on opportunity to learn about CIL and CT and therefore on the development of student outcomes in these domains.

Data from the national contexts survey will be used to compare profiles of CIL and CT education in participating education systems. In addition, the data will provide information about contextual factors concerned with structure of the education system and other aspects of education policy for the analysis of differences in approaches to ICT-related learning across education systems. Data from the national context questionnaire will be used for two broad purposes:

- To provide systematic descriptions of policy and practice in the use of information and communication technologies in school education across participating ICILS countries
- To provide systematic data that can be used as a basis for interpreting differences among education systems in ICT-related learning outcomes as well as patterns of relationships among factors that are related to ICT-related learning outcomes.

References

Aarhus University. (2017). *Computational thinking and design to become a mandatory part of curriculum in Danish primary school*. Center for Computational Thinking and Design, Aarhus University, Denmark. Retrieved from http://cctd.au.dk/currently/news/show/artikel/computational-thinking-and-design-to-become-a-mandatory-part-of-curriculum-in-danish-primary-school/.

ACARA. (2012). *National Assessment Program – ICT literacy years 6 and 10 report 2011*. Sydney, Australia: Australian Curriculum, Assessment and Reporting Authority.

ACARA. (2015). *National Assessment Program – ICT literacy years 6 & 10 2014 report*. Sydney, Australia: Australian Curriculum and Reporting Authority (ACARA). Retrieved from: http://www.nap.edu.au/_resources/D15_8761__NAP-ICT_2014_Public_Report_Final.pdf.

Aesaert, K., van Braak, J., van Nijlen, D., & Vanderlinde, R. (2015). Primary school pupils ICT competences: Extensive model and scale development. *Computers & Education*, *81*, 326–344. Retrieved from https://doi.org/10.1016/j.compedu.2014.10.021.

Aesaert, K., van Nijlen, D., Vanderlinde, R., & van Braak, J. (2014). Direct measures of digital information processing and communication skills in primary education: Using item response theory for the development and validation of an ICT competence scale. *Computers & Education*, *76*, 168–181: Retrieved from https://doi.org/10.1016/j.compedu.2014.03.013.

Aho, A. (2012). Computation and computational thinking. *The Computer Journal*, *55*(7), 832–835.

Ainley, J., Enger, L., & Searle, D. (2009). Students in a digital age: Implications for teaching and learning. In J. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education* (pp. 63–80). Heidelberg, Germany: Springer.

Anderson, R., & Ainley, J. (2010). Technology and learning: Access in schools around the world. In B. McGaw, E. Baker, & P. Peterson (Eds.), *International encyclopedia of education* (3rd ed., pp. 21–33). Amsterdam, the Netherlands: Elsevier.

Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences, *Robotics and Autonomous Systems*, 75, 661–670.

Audunson, R., & Nordlie, R. (2003). Information literacy: The case or non-case of Norway? *Library Review*, *52*(7), 319–325.

Bakia, M., Murphy, R., Anderson, K., & Trinidad, G. E. (2011). *International experiences with technology in education: Final report*. Washington, DC: US Department of Education.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, *28*(2), 117–148.

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. *Learning and Leading with Technology*, *38*(6), 20–23.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads*, 2, 48e54. Retrieved from https://dx.doi.org/10.1145/1929887.1929905.

Bawden, D. (2001). Information and digital literacies: A review of concepts. *Journal of Documentation*, *57*(2), 218–259.

Berland, M., & Wilensky, M. (2015). Comparing virtual and physical robotics environments for supporting complex systems and computational thinking. *Journal of Science Education and Technology*, *24*, 628–647.

Bienkowski, M., Rutstein, D., & Snow, E. (2015a). *Computer science concepts in the next generation science standards*. Paper presented at the 2015 annual meeting of the American Educational Research Association (AERA), Chicago, IL. Retrieved from https://www.aera.net/Publications/Online-Paper-Repository/AERA-Online-Paper-Repository.

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8

Bienkowski, M., Snow, E., Rutstein, D. W., & Grover, S. (2015b). *Assessment design patterns for computational thinking practices in secondary computer science: A first look* (SRI technical report). Menlo Park, CA: SRI International. Retrieved from http://pact.sri.com/resources.html.

Binkley, M., Erstad, E., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining 21st century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17–66), Dordrecht, The Netherlands: Springer.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). *Developing computational thinking in compulsory education. Implications for policy and practice*. Joint Research Centre Report EUR 28295 EN. Luxembourg: Publications Office of the European Union. Retrieved from https://doi.org/10.2791/792158.

Boekhorst, A. K. (2003). Becoming information literate in the Netherlands. *Library Review*, *52*(7), 298–309.

Bower, M., Wood, L., Lai, J. W. M., Howe, C., & Lister, R. (2017). Improving the computational thinking pedagogical capabilities of school teachers. *Australian Journal of Teacher Education*, *42*(3). 53–72. Retrieved from http://dx.doi.org/10.14221/ajte.2017v42n3.4

Brennan, K., & Resnick, M. (2013). Imagining, creating, playing, sharing, reflecting: How online community supports young people as designers of interactive media. In C. Moza & N. Lavigne (Eds.), *Emerging technologies for the classroom: A learning sciences perspective* (pp. 253–268). New York, NY: Springer. Retrieved from https://doi.org/10.1007/978-1-4614-4696-5.

Bundsgaard, J., & Gerick, J. (2017). Patterns of students' computer use and relations to their computer and information literacy: Results of a latent class analysis and implications for teaching and learning. *Large-scale Assessments in Education*, *5*(17), 1–15. Retrieved from https://largescaleassessmentsineducation.springeropen.com/articles/10.1186/s40536-017-0052-8.

Burbules, N. (2007). E-lessons learned. *National Society for the Study of Education 2007 Yearbook*, *106*(2), 207–216.

Caeli, E. N., & Bundsgaard, J. (2019). Datalogisk tænkning og teknologiforståelse i folkeskolen tur-retur. Manuscript submitted for publication.

Carretero, S., Vuorikari, R., & Punie, Y. (2017). *DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use*. Joint Research Centre Report EUR 28558 EN. Luxembourg: Publication Office of the European Union. Retrieved from https://doi.org/10.2760/38842.

Caspersen, J., & Raaen, F. D. (2014). Novice teachers and how they cope. *Teachers and Teaching: Theory and Practice*, *20*, 189–211.

Catts, R., & Lau, J. (2008). Towards information literacy indicators. Paris, France: UNESCO.

Chalkiadaki, A. (2018). A systematic literature review of 21st century skills and competencies in primary education. *International Journal of Instruction*. *11*(3), 1-16.

Charalambos, V., & Glass, G. (2007). Teacher professional development and ICT: Strategies and models. *National Society for the Study of Education 2007 Yearbook*, *106*(2), 87–102.

Chen, G., Shen, J., Barth-Cohen, L., Jiang, S., Huang, X., & Eltoukhy, M. (2017). Assessing elementary students' computational thinking in everyday reasoning and robotics programming. *Computers & Education*, *109*, 162–175. Retrieved from https://doi.org/10.1016/j.compedu.2017.03.001.

Christ, W. G., & Potter, W. J. (1998). Media literacy: Symposium. *Journal of Communication*, *48*(1), 5–15.

Claro, M., Preiss, D., San Martín, E., Jara, J., Hinostroza, E., Valenzuela, S., Cortes, F., & Nussbaum, M. (2012). Assessment of 21st century ICT skills in Chile: Test design and results from high school level students. *Computers & Education*, *59*, 1042–1053. Retrieved from https://doi.org/10.1016/j.compedu.2012.04.004.

Church, A. (1999). The human–computer interface and information literacy: Some basics and beyond. *Information Technology and Libraries*, *18*(1), 3–21.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.

Dede, C. (2007). Reinventing the role of information and communications technologies in education. *National Society for the Study of Education 2007 Yearbook*, *106*(2), 11–38.

Denning, P. J. (2017). Remaining trouble spots with computational thinking. *Communications of the ACM*. *60*(6), 33–39. Retrieved from https://cacm.acm.org/magazines/2017/6/217742-remaining-trouble-spots-with-computational-thinking/abstract.

Digital Technologies Hub. (2018). *Computational thinking*. Melbourne, Australia: Digital Technologies Hub, Education Services Australia Ltd. Retrieved from http://www.digitaltechnologieshub.edu.au/teachers/topics/computational-thinking.

diSessa, A. A. (2000). *Changing minds: Computers, learning, and literacy*. Cambridge, MA: MIT Press.

Drossel, K., & Eickelmann, B. (2017). Teachers' participation in professional development concerning the implementation of new technologies in class: a latent class analysis of teachers and the relationship with the use of computers, ICT self-efficacy and emphasis on teaching ICT skills. *Large-scale Assessments in Education*, *5*(19), 1–13. Retrieved from https://doi.org/10.1186/s40536-017-0053-7.

Drossel, K., Eickelmann, B., & Gerick, J. (2017a). Predictors of teachers' use of ICT in school: the relevance of school characteristics, teachers' attitudes and teacher collaboration. *Education and Information Technologies*, *22*(2), 551–573. Retrieved from https://doi.org/10.1007/s10639-016-9476-y.

Drossel, K., Eickelmann, B., & Schulz-Zander R. (2017b). Determinants of teachers´ collaborative use of ICT for teaching and learning. *European Educational Research Journa*l, *(16)*6, 781–799. Retrieved from https://doi.org/10.1177/1474904116655811.

Dutta, S., & Mia, I. (Eds.). (2011). *The global information technology report 2010:2011 transformations 2.0*. Geneva, Switzerland: World Economic Forum.

Eickelmann, B. (2018). Digitalisierung an Schulen. Eine Bestandsaufnahme. [Digitization in schools. An inventory]. *SchulVerwaltung Spezial*, *20*(4), 152-155.

Eickelmann, B., & Vennemann, M. (2017). Teachers' attitudes and beliefs towards ICT in teaching and learning in European countries. *European Educational Research Journal*, *16*(6), 1–29. Retrieved from https://doi.org/10.1177/1474904117725899.

Estapa, A., Hutchison, A., & Nadolny, L. (2018). Recommendations to support computational thinking in the elementary classroom. *Technology and Engineering Teacher*, *77*(4), 25–29.

ETS (2002). *Digital transformation: A framework for ICT literacy*. Princeton, NJ: Educational Testing Service. Retrieved from http://www.ets.org/Media/Tests/Information_and_Communication_Technology_Literacy/ictreport.pdf.

European Commission. (2013). *Survey of schools: ICT in education. Benchmarking access, use and attitudes to technology in Europe's schools* (final report). Brussels, Belgium: Author. Retrieved from https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/KK-31-13-401-EN-N.pdf.

Ferrari, A. (2012). *Digital competence in practice: An analysis of frameworks*. Seville, Spain: Institute for Prospective Technological Studies, European Commission. Retrieved from http://www.ifap.ru/library/book522.pdf.

Ferrari, A. (2013). *DigComp: A framework for developing and understanding digital competence in Europe*. Joint Research Centre Report EUR 26035 EN. Luxembourg: Publication Office of the European Union. Retrieved from https://doi.org/10.2788/52966.

Finnish National Agency for Education. (2016). *New national core curriculum for basic education*. Helsinki, Finland: Author.

Fletcher, G., Schaffhauser, D., & Levin, D. (2012). *Out of print: Reimagining the K–12 textbook in a digital age*. Washington, DC: State Educational Technology Directors Association (SETDA).

Fraillon, J. (2018) International large-scale computer-based studies on information technology literacy in education. In J. Voog, G. Knezek, R. Christensen, & K.W. Lai (Eds.), *Second handbook of information technology in primary and secondary education*. Cham, Switzerland: Springer. Retrieved from https://doi.org/10.1007/978-3-319-53803-7_80-1.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). *Preparing for Life in a Digital Age: the IEA International Computer and Information Literacy Study International Report*. Cham, Switzerland: Springer. Retrieved from https://www.springer.com/gp/book/9783319142210.

Fraillon, J., Schulz, W., & Ainley, J., (2013). *International Computer and Information Literacy Study: Assessment Framework*. Amsterdam, the Netherlands: International Association for the Evaluation of Educational Achievement. Retrieved from http://pub.iea.nl/fileadmin/user_upload/Publications/Electronic_versions/ICILS_2013_Framework.pdf.

Ganzeboom, H. B. G., de Graaf, P. M., & Treiman, D. J. (1992). A standard international socioeconomic index of occupational status. *Social Science Research*, *21*(1), 1–56.

Gebhardt, E., & Schulz, W. (2015). Scaling procedures for ICILS test items. In J. Fraillon, W. Schulz, T. Friedman, J. Ainley, & E. Gebhardt (Eds.), *ICILS 2013 technical report* (pp. 155–176), Amsterdam, The Netherlands: International Association for the Evaluation of Educational Achievement (IEA). Retrieved from http://www.iea.nl/fileadmin/user_upload/Publications/Electronic_versions/ICILS_2013_Technical_Report.pdf.

Gerick, J. (2018). School level characteristics and students' CIL in Europe: A latent class analysis approach. *Computers & Education*, *120*, 160–171.

Gerick, J., Eickelmann, B., & Bos, W. (2017). School-level predictors for the use of ICT in schools and students' CIL in international comparison. *Large-scale Assessments in Education*, *5*(1), 1–13. Retrieved from https://doi.org/10.1186/s40536-017-0037-7.

Goode, J., & Chapman, G. (2013). *Exploring computer science.* Stanford Research International (SRI).

Greenhow, C., Robelia, B., & Hughes, J. (2009). Learning, teaching, and scholarship in a digital age: Web 2.0 and classroom research. What path should we take now? *Educational Researcher*, *38*, 246–259.

Grover, S. (2017). Assessing algorithmic and computational thinking in K-12: Lessons from a middle school classroom. In J. Rich and B. Hodges (Eds.) *Emerging research, practice, and policy on computational thinking* (pp. 269–288). Cham, Springer. Retrieved from https://doi.org/10.1007/978-3-319-52691-1.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field, *Educational Researcher*, 42(1), 38–43.

Grover, S., Pea, R., & Cooper, S. (2015). Designing for deeper learning in a blended computer science course for middle school students, *Computer Science Education*. 25(2), 199–237. Retrieved from https://doi.org/10.1080/08993408.2015.1033142.

Haigh, R. W. (1985) Planning for computer literacy. *The Journal of Higher Education*, *56*(2), 161–17. Retrieved from https://doi.org/10.1080/00221546.1985.11777083.

Hacker, M. (2018). Integrating computational thinking into technology and engineering education. *Technology and Engineering Teacher*, *77*(4), 8–14.

Hatlevik, O.E. (2016). Examining the relationship between teacher's self-efficacy, their digital competence, strategies to evaluate information, and use of ICT at school. *Scandinavian Journal of Educational Research*, *61*(5), 555–567.

Hatlevik, O., Ottestad, G., & Throndsen, I. (2015). Predictors of digital competence in 7th grade: a multilevel analysis. *Journal of Computer Assisted Learning Archive*, *31*(3), 220–231. Retrieved from https://doi.org/10.1111/jcal.12065.

Haßler, B., Major, L., & Hennessy, S. (2016). Tablet use in schools: A critical review of the evidence for learning outcomes. *Journal of Computer Assisted Learning*, *32*(2), 139–156.

Homann, B. (2003). German libraries at the starting line for the new task of teaching information literacy. *Library Review*, *52*(7), 310–318.

Hwang, G.-J., & Tsai, C.-C. (2011). Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, *42*(4), E65–E70.

ILO. (2007). *International Standard Classification of Occupations: ISCO-2008*. Geneva, Switzerland: International Labour Organisation.

ISTE. (2007). *National educational technology standards for students* (2nd ed.). Eugene, OR: International Society for Technology in Education.

ISTE. (2018). *ISTE standards*. Retrieved from https://www.iste.org/standards.

ITU. (2017). *2017 global ICT development index*. Retrieved from https://www.itu.int/net4/ITU-D/idi/2017/.

Jago, C. (2009). *A history of NAEP assessment frameworks*. Washington, DC: National Assessment Governing Board (ERIC Document Reproduction Service No. ED509382). Retrieved from http://www.nagb.org/content/nagb/assets/documents/who-we-are/20-anniversary/jagoframeworks-formatted.pdf.

Janssen, J., & Stoyanov, S. (2012). *Online consultation on experts' views on digital competence*. Joint Research Centre Institute for Prospective Technological Studies Report, Seville, Spain. Retrieved from http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=5339.

Kaarakainen, M., Kivinen, O., & Vainio, T. (2018). Performance-based testing for ICT skills assessing: a case study of students and teachers' ICT skills in Finnish schools. *Universal Access in the Information Society*, *17*(2), 349–360.

Kim, H. S., Kil, H. J., & Shin, A. (2014). An analysis of variables affecting the ICT literacy level of Korean elementary school students. *Computers & Education*, *77*, 29–38. Retrieved from https://doi.org/10.1016/j.compedu.2014.04.009.

Kim, J., & Lee, W. (2013). Meanings of criteria and norms: Analyses and comparisons of ICT literacy competencies of middle school students. *Computers & Education*, *64*, 81–94. Retrieved from https://doi.org/10.1016/j.compedu.2012.12.018.

KMK. (2016). *Bildung in der digitalen Welt. Strategie der Kultusministerkonferenz* [Education in a digital world. Strategy of the Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany]. Berlin, Germany: Kultusministerkonferenz.

Koskinen, K. (2017). *Finland: Country report on ICT in education*. Brussels, Belgium: European Schoolnet. Retrieved from http://www.eun.org/documents/411753/839549/Country+Report+Finland+2017.pdf.

Kozma, R. (Ed.). (2003). *Technology, innovation, and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education.

Kwon, S., & Schroderus, K. (2017). *Coding in schools: Comparing integration of programming into basic education curricula of Finland and South Korea*. Helsinki, Finland: Finnish Society on Media Education.

Lampe, C., Resnick, P., Forte, A., Yardi, S., Rotman, D., Marshall, T., & Lutters, W. (2010). Educational priorities for technology-mediated social participation. *IEEE Computer*, *43*(11), 60–67.

Law Library of Congress. (2015). *Public Law No. 114-95, S.1177, Every Student Succeeds Act. 114th US Congress*. Retrieved from https://www.congress.gov/bill/114th-congress/senate-bill/1177.

Law, N., Pelgrum, W., & Plomp, T. (2008). *Pedagogy and ICT use in schools around the world: Findings from the IEA SITES 2006 study*. Dordrecht, The Netherlands: Springer. Retrieved from https://www.springer.com/gb/book/9781402089275.

Lee, V.R., & Recker, M. (2018). Paper circuits: A tangible, low threshold, low cost entry to computational thinking. *TechTrends: Linking Research and Practice to Improve Learning*, *62*(2), 197–203.

Lemke, C. (2003). Standards for a modern world: Preparing students for their future. *Learning and Leading with Technology*, *31*(1), 6–9.

Lithuanian Education and Science Ministry (2011). *Strategy on ICT integration into general and vocational education (2008–2012)*. Retrieved from http://www.itc.smm.lt/wp-content/uploads/2009/11/IKT_strategija.zip.

Livingstone, S., Van Couvering, E., & Thumim, N. (2008). Converging traditions of research on media and information literacies. In J. Corio, M. Knobel, C. Lankshear, & D. Leu (Eds.), *Handbook of research on new literacies* (pp. 103–132). New York, NY: Lawrence Erlbaum Associates.

Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*, *41*, 51–61. Retrieved from https://doi.org/10.1016/j.chb.2014.09.012.

Maddux, C. D., & Johnson, D. L. (1997). *Logo: A retrospective*. Computers in the Schools Monographs/Separates, Vol. 14, Numbers 1–2. New York, NY: CRC Press.

Marcum, J. (2002). Rethinking information literacy. *Library Quarterly*, *72*(1), 1–26.

Martin, F., & Ertzberger, J. (2013). Here and now mobile learning: An experimental study on the use of mobile technology. *Computers & Education*, *68*, 76–85.

Martin, M.O., Mullis, I.V.S., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in science*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College. Retrieved from http://timssandpirls.bc.edu/timss2015/international-results/.

McDougall, A., Murnane, J., & Wills, S. (2014). The education programming language Logo: Its nature and its use in Australia. In A. Tatnall & B. Davey (Eds.), *Reflections on the history of computers in education: Early use of computers and teaching about computing in schools*. IFIP Advances in Information and Communication Technology Vol. 424. Berlin, Heidelberg: Springer.

MCEETYA. (2007). *National assessment program: ICT literacy Years 6 and 10 report 2005*. Ministerial Council on Education, Employment, Training and Youth Affairs. Carlton South, VIC, Australia: Curriculum Corporation. Retrieved from http://www.nap.edu.au/verve/_resources/2005_ICTL_Public_Report_ file_main.pdf.

MCEECDYA. (2010). *National assessment program: ICT literacy Years 6 and 10 report 2008*. Ministerial Council for Education, Early Childhood Development, and Youth Affairs (ERIC Document ED534805). Carlton South, VIC, Australia: Curriculum Corporation.

Moos, D., & Azevedo, R. (2009). Learning with computer-based learning environments: A literature review of computer self-efficacy. *Review of Educational Research*, *79*(2), 576–600.

Mullis, I.V.S., Martin, M.O., Robitaille, D. F., & Foy, P. (2009). *TIMSS Advanced 2008 international report: Findings from IEA's study of achievement in advanced mathematics and physics in the final year of secondary school*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College. Retrieved from http://timssandpirls.bc.edu/timss2015/international-results/.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2017). *PIRLS 2016 international results in reading*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College. Retrieved from http://timssandpirls.bc.edu/pirls2016/international-results/.

Nasah, A., DaCosta, B., Kinsell, C., & Seok, S. (2010). The digital literacy debate: An investigation of digital propensity and information and communication technology. *Educational Technology Research and Development*, *58*(5), 531–555.

NAGB. (2013). *2014 Abridged Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress*. Washington, DC: National Assessment Governing Board.

National Research Council. (2010). *Committee for the Workshops on Computational Thinking: Report of a workshop on the scope and nature of computational thinking*. Washington, DC: National Academies Press.

OECD. (2013) *PISA 2012 Results: What students know and can do. Student performance in mathematics, reading and science* (Volume I). Paris, France: OECD Publishing. Retrieved from https://dx.doi.org/10.1787/9789264208780-en.

OECD. (2016a). *Working Party on measurement and analysis of the digital economy. Skills for a digital world. Background Paper for Ministerial Panel 4.2. DSTI/ICCP/IIS(2015)10/FINAL*. Paris, France: OECD. Retrieved from http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/IIS(2015)10/FINAL&docLanguage=En.

OECD. (2016b). *PISA 2015 results (Volume 2): Policies and practices for successful schools*. Paris, France: OECD Publishing. Retrieved from https://dx.doi.org/10.1787/9789264266490-en.

OECD. (2016c). *PISA 2015 results (Volume 1): Excellence and equity in education*. Paris, France: OECD Publishing. Retrieved from https://doi.org/10.1787/9789264266490-en.

Ofcom. (2006). *Media literacy audit: Report on media literacy amongst children*. London, UK: Ofcom.

Ortiz-Colon, A. M., & Marato Romo, J. L. (2016). Teaching with Scratch in compulsory secondary education. *International Journal of Emerging Technologies in Learning*, *11*(2), 67–70. Retrieved from https://doi.org/10.3991/ijet.v11i02.5094.

Papert, S. (1980) *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), *Constructionism* (pp. 1–11). Norwood, NJ: Ablex.

Pangrazio, L. (2016). Reconceptualising critical digital literacy. *Discourse: Studies in the Cultural Politics of Education*, *37*(2), 163–174. Retrieved from https://doi.org/10.1080/01596306.2014.942836.

Pelgrum, W. J., & Doornekamp, B. D. (2009). *Indicators on ICT in primary and secondary education*. Report IIPSE: EACEA-2007-3278/001-001. Brussels, Belgium: European Commission, Directorate General Education and Culture.

Peters, J. (2004). *Learning outcomes and information literacy*. London, UK: Society of College, National and University Libraries.

Petko, D., Cantieni, A., & Prasse, D. (2016). Perceived quality of educational technology matters: A secondary analysis of students' ICT use, ICT-related attitudes, and PISA 2012 test scores. *Journal of Educational Computing Research*, *54*(8), 1070–1091.

Pew Research Center. (2015). *Internet seen as positive influence on education but negative influence on morality in emerging and developing nations*. Washington, DC: Pew Research Center. Retrieved from http://assets.pewresearch.org/wp-content/uploads/sites/2/2015/03/Pew-Research-Center-Technology-Report-FINAL-March-19-20151.pdf.

Peyton Jones, S. (2011). *Computing at school: International comparisons*. London, UK: Microsoft Research.

Plomp, T., Anderson, R. E., Law, N., & Quale, A. (Eds.). (2009). *Cross national policies and practices on information and communication technology in education* (2nd ed.). Greenwich, CT: Information Age Publishing.

Punter, R., Meelissen, M., & Glas, C. (2017). Gender differences in computer and information literacy: An exploration of the performances of girls and boys in ICILS 2013. *European Educational Research Journal*, *16*(6), 762–780. Retrieved from https://doi.org/10.1177/1474904116672468.

Ranguelov, S. (2010). Summary report. Education on online safety in schools in Europe. *New Horizons in Education*, *58*(3), 149–163.

Richter, T., Naumann, J., & Groeben, N. (2000). The computer literacy inventory (INCOBI): An instrument for the assessment of computer literacy and attitudes toward the computer in university students of the humanities and the social sciences. *Psychologie in Erziehung und Unterricht*, *48*(1), 1–13.

Rohatgi, A., Scherer, R., & Hatlevik, O. (2016). The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Computers & Education*, *102*, 103–116.

Rowlands, I., Nicholas, D., Williams, P., Huntington, P., Fieldhouse, M., Gunter B., Withey, R., Jamali, R. J., Dobrowolski, T., & Tenopir, C. (2008) The Google generation: the information behaviour of the researcher of the future. *Aslib Proceedings*, *60*(4), 290–310. Retrieved from https://doi.org/10.1108/00012530810887953.

Royal Society. (2012). *Shutdown or restart: The way forward for computing in UK schools*. London, UK: The Royal Society.

Royal Society. (2017). *After the reboot: computing education in UK schools*. London, UK: The Royal Society.

Rutstein, D. W., Snow, E. B., & Bienkowski, M. (2014). *Computational thinking practices: Analyzing and modeling a critical domain in computer science education*. Paper presented at the annual meeting of the American Educational Research Association, Philadelphia, PA. Retrieved from https://www.aera.net/Publications/Online-Paper-Repository/AERA-Online-Paper-Repository.

Saari, A., & Säntti, J. (2018). The rhetoric of the 'digital leap' in Finnish educational policy documents. *European Educational Research Journal*, *17*(3), 442–457. Retrieved from https://doi.org/10.1177/1474904117721373.

Saha, L. J. (1997). Introduction: The centrality of the family in educational processes. In L. J. Saha (Ed.), *International encyclopedia of the sociology of education* (pp. 587–588). Oxford/New York/Tokyo: Elsevier.

Scherer, R., & Siddiq, F. (2015). Revisiting teachers' computer self-efficacy: A differentiated view on gender differences. *Computers in Human Behavior*, *53*, 48–57.

Schöber, C., Schütte, K., Köller, O., McElvany, N., & Gebauer, M. M. (2018). Reciprocal effects between self-efficacy and achievement in mathematics and reading, *Learning and Individual Differences*, *63*, 1–11.

Schulz, W., Ainley, J., Fraillon, J., Losito, B., & Agrusti, G. (2016). *IEA International Civic and Citizenship Education Study 2016: Assessment framework*. Cham, Switzerland: Springer. Retrieved from https://www.springer.com/gb/book/9783319393568.

Schulz, W., Ainley, J., Fraillon, J., Losito, B., Agrusti, G, & Friedman, T. (2017). *Becoming citizens in a changing world: IEA International Civic and Citizenship Education Study 2016 international report*. Cham, Switzerland: Springer. Retrieved from https://www.springer.com/gb/book/9783319739625.

Schulz, W., & Friedman, T. (2015). Scaling procedures for ICILS questionnaire items. In J. Fraillon, W. Schulz, T. Friedman, J. Ainley, & E. Gebhardt (Eds.), *ICILS 2013 technical report* (pp. 177–220). Amsterdam, the Netherlands: The International Association for the Evaluation of Educational Achievement. Retrieved from https://www.iea.nl/fileadmin/user_upload/Publications/Electronic_versions/ICILS_2013_Technical_Report.pdf.

Selby, C. C., & Woollard, J. (2013). *Computational thinking: the developing definition*. Southampton, UK: University of Southampton. Retrieved from https://eprints.soton.ac.uk/id/eprint/356481.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review 22*, 142–158. Retrieved from https://doi.org/10.1016/j.edurev.2017.09.003.

Siddiq, F., Hatlevik, O. E., Olsen, R. V., Throndsen, I., & Scherer, R. (2016). Taking a future perspective by learning from the past: A systematic review of assessment instruments that aim to measure primary and secondary school students' ICT literacy. *Educational Research Review*, *19*, 58–84.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, 75(3), 417–453.

Slovak Republic Ministry of Education. (2013). *Koncepcia informatizácie rezortu školstva s výhľadom do roku 2020: DIGIPEDIA 2020* [The concept of digitalization of the system of education with a view till the year 2020: DIGIPEDIA 2020]. Bratislava: Slovak Republik Ministry of Education. Retrieved from https://www.minedu.sk/data/att/4796.pdf.

Tamin, R., Bernard, R., Borokhovski, E., Abrami, P., & Schmid, R. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research*, *81*(1), 4–28.

Talsma, K., Schüz, B., Schwarzer, R., & Norris, K. (2018). I believe, therefore I achieve (and vice versa): A meta-analytic cross-lagged panel analysis of self-efficacy and academic performance. *Learning and Individual Differences*, *61*, 136–150.

Tatnall, A., & Davey, B. (2014). Reflections on the beginnings of an educational revolution. In A. Tatnall & B. Davey (Eds.), *Reflections on the history of computers in education: Early use of computers and teaching about computing in schools*. IFIP Advances in Information and Communication Technology (pp. 417–422). New York, NY: Springer.

Tuhkala, A., Wagner, M.-L., Nielsen, N., Iversen, O. S., & Kärkkäinen, T. (2018). Technology comprehension: Scaling making into a national discipline. In M. Giannakos, M. Divitini, L. Jaccheri, & O. S. Iversen (Eds.), *Proceedings of the Conference on Creativity and Making in Education* (FabLearn Europe'18) (pp. 72–80). New York, NY: ACM. Retrieved from https://doi.org/10.1145/3213818.3213828.

UNDP. (2016). *Human Development Report: Human development for everyone*. New York, NY: United Nations Development Programme. Retrieved from http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf.

UNESCO. (2003). *The Prague Declaration: Towards an information literate society*. Paris, France: United Nations Education Scientific and Cultural Organisation.

UNESCO. (2011). *International Standard Classification of Education: ISCED 2011*. Paris, France: United Nations Education Scientific and Cultural Organisation. Retrieved from http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf.

UNESCO. (2014). *Fostering digital citizenship through safe and responsible use of ICT: A review of current status in Asia and the Pacific as of December 2014*. Paris, France: United Nations Education Scientific and Cultural Organisation. Retrieved from http://www.unescobkk.org/fileadmin/user_upload/ict/SRU-ICT/SRU-ICT_mapping_report_2014.pdf.

US Department of Education, National Center for Education Statistics. (2016). *The Nation's Report Card: 2014 Technology & Engineering Literacy (TEL) Report Card at Grade 8, NCES2016119*. Washington DC: National Center for Education Statistics. Retrieved from https://www.nationsreportcard.gov/tel_2014/.

US Department of Education, Office of Educational Technology (2017). *Reimagining the role of technology in education: 2017 National Education Technology Plan update*. Washington, DC: US Department of Education, Office of Educational Technology. Retrieved from https://tech.ed.gov/files/2017/01/NETP17.pdf.

Van Laar, E., van Deursen, A.J.A.M., van Dijk, J.A.G.M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, 577–588. Retrieved from https://doi.org/10.1016/j.chb.2017.03.010.

Vanderlinde, R., Aesaert, K., & van Braak, J. (2014). Institutionalised ICT use in primary education: A multilevel analysis. *Computers & Education*, *72*, 1–10. Retrieved from https://doi.org/10.1016/j.compedu.2013.10.007.

Virkus, S. (2003). Information literacy in Europe: A literature review. *Information Research: An International Electronic Journal*, *8*(4), 329–345. Retrieved from http://www.informationr.net/ir/8-4/paper159.html.

Vuorikari, R., Punie, Y., Carretero Gomez S., & Van den Brande, G. (2016). *DigComp 2.0: The Digital Competence Framework for Citizens. Update Phase 1: The conceptual reference model*. Joint Research Centre Report EUR 27948 EN. Luxembourg Publication Office of the European Union. Retrieved from https://doi.org/10.2791/11517.

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, *20*(4), 715–728.

Voogt, J., & Roblin, N. P. (2012) A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies, *Journal of Curriculum Studies*, *44*(3), 299–321. Retrieved from https://doi.org/10.1080/00220272.2012.668938.

Voogt, J., & ten Brummelhuis, A. (2014). Information literacy in the Netherlands: rise, fall and revival. In A. Tatnall & B. Davey (Eds.), *Reflections on the history of computers in education: early use of computers and teaching about computing in schools*, IFIP Advances in Information and Communications Technology, No. 424 (pp. 83–93). Berlin, Heidelberg: Springer. Retrieved from https://doi.org/10.1007/978-3-642-55119-2_5.

Warschauer, M., & Matuchniak, T. (2010). New technology and digital worlds: Analyzing evidence of equity in access, use, and outcomes. *Review of Research in Education*, *34*, 179–225.

Wilson, M., Scalise, K., & Gochyyev, P. (2015). Rethinking ICT literacy: From computer skills to social network settings. *Thinking Skills and Creativity*, *18*, 65–80.

Wilkinson, K. (2006). Students' computer literacy: Perception versus reality. *Delta Pi Epsilon Journal*, *48*(2), 108–120.

Wing, J.M. (2006) Computational thinking. *Communications of the ACM*, *49*, 33–35. Retrieved from https://doi.org/10.1145/1118178.1118215.

Woessmann, L. (2004). *How equal are educational opportunities? Family background and student achievement in Europe and the United States*. IZA Discussion Papers 1284. Bonn, Germany: Institute for the Study of Labor (IZA).

World Bank (2016). *World development report 2016: Digital dividends*. Washington, DC: The World Bank. Retrieved from http://www.worldbank.org/en/publication/wdr2016.

Yadav A., Sands P., Good J., & Lishinki A. (2018) Computer science and computational thinking in the curriculum: Research and practice. In J. Voogt. G. Knezek, R. Christensen, & K.W. Lai (Eds.), *Second handbook of information technology in primary and secondary education*. Cham, Switzerland: Springer. Retrieved from https://link.springer.com/referenceworkentry/10.1007/978-3-319-71054-9_6.

Zhong, B., Wang, Q., Chen, J., & Li, Y. (2016). An exploration of three-dimensional integrated assessment for computational thinking. *Journal of Educational Computing Research*, *53*(4), 562–590. Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/0735633115608444.

APPENDIX

Organizations and individuals involved in ICILS 2018

International study center

The international study center is located at the Australian Council for Educational Research (ACER) and serves as the international study center for ICILS. Center staff at ACER were responsible for designing and implementing the study in close cooperation with the IEA in Hamburg, Germany, and Amsterdam, the Netherlands.

Staff at ACER

Julian Fraillon, *research director*
John Ainley, *project coordinator*
Wolfram Schulz, *assessment coordinator*
Tim Friedman, *project researcher*
Daniel Duckworth, *test developer*
Melissa Hughes, *test developer*
Laila Helou, *quality assurer*
Alex Daraganov, *data analyst*
Renee Kwong, *data analyst*
Leigh Patterson, *data analyst*

International Association for the Evaluation of Educational Achievement (IEA)

IEA provides overall support in coordinating and implementing ICILS. The IEA Amsterdam, the Netherlands, is responsible for membership, translation verification, quality control monitoring, and publication. The IEA Hamburg, Germany is mainly responsible for field operations, sampling procedures, and data-processing.

Staff at the IEA Amsterdam

Dirk Hastedt, *executive director*
Andrea Netten, *director IEA Amsterdam*
Roel Burgers, *financial director*
Isabelle Gémin, *senior financial officer*
David Ebbs, *senior research officer (project team)*
Michelle Djekić, *research and liaison officer (project team)*
Sandra Dohr, *junior research officer (project team)*
Sive Finlay, *communications officer*
Mirjam Govaerts, *public relations and events officer*
Jennifer Ross, *media and outreach officer*
Jan-Philipp Wagner, *junior research officer (project team)*
Gillian Wilson, *senior publications officer*

J. Fraillon et al., *IEA International Computer and Information Literacy Study 2018 Assessment Framework*,
https://doi.org/10.1007/978-3-030-19389-8

Staff at the IEA Hamburg

Heiko Sibberns, *director*
Ralph Carstens, *co-head of international studies unit*
Sebastian Meyer, *ICILS international data manager*
Ekaterina Mikheeva, *ICILS deputy international data manager*
Sabine Meinck, *head of research, analysis and sampling unit*
Sabine Tieck, *research analyst (sampling)*
Sabine Weber, *research analyst (sampling)*
Oriana Mora, *research analyst*
Adeoye Oyekan, *research analyst*
Christine Busch, *research analyst*
Alena Becker, *research analyst*
Hannah Köhler, *research analyst*
Wolfram Jarchow, *research analyst*
Lorelia Nithianandan, *research analyst*
Rea Car, *research analyst*
Clara Beyer, *research analyst*
Dirk Oehler, *research analyst*
Tim Daniel, *research analyst*
Yasin Afana, *research analyst*
Guido Martin, *head of coding unit*
Katharina Sedelmayr, *research analyst (coding)*
Meng Xue, *head of software unit*
Kevin Mo, *programmer*
Deepti Kalamadi, *programmer*
Maike Junod, *programmer*
Limiao Duan, *programmer*
Juan Jose Carmona Vilas, *programmer*
Svetoslav Velkov, *software tester*
Bettina Wietzorek, *meeting and seminar coordinator*

SoNET Systems

SoNET Systems was responsible for developing the software systems underpinning the computer-based student assessment instruments for the Main Survey. This work included development of the test and questionnaire items, the assessment delivery system, and the web-based translation, scoring, and data-management modules.

Staff at SoNET Systems

Mike Janic, *managing director*
Stephen Birchall, *deputy CEO*
Erhan Halil, *product development manager*
Rakshit Shingala, *team leader*
James Liu, *analyst programmer*
Nilupuli Lunuwila, *analyst programmer*
Richard Feng, *analyst programmer*
Stephen Ainley, *quality assurance*
Ranil Weerasinghe, *quality assurance*

ICILS sampling referee

Marc Joncas was the sampling referee for the study. He has provided invaluable advice on all sampling-related aspects of the study.

National research coordinators

The national research coordinators (NRCs) played a crucial role in the development of the project. They provided policy- and content-oriented advice on the development of the instruments and were responsible for the implementation of ICILS in the participating countries.

Chile
Carolina Leyton
National Agency for Educational Quality

City of Moscow (Russian Federation)
Elena Zozulia
Moscow Center for Quality of Education

Denmark
Jeppe Bundsgaard
Danish School of Education, Aarhus University

Finland
Kaisa Leino
Finnish Institute for Educational Research, University of Jyväskylä

France
Marion Le Cam
Ministry of National Education

Germany and North-Rhine Westphalia (Germany)
Birgit Eickelmann
Institute for Educational Science, University of Paderborn

Italy
Elisa Caponera
Riccardo Pietracci
INVALSI, National Institute for the Educational Evaluation of Instruction and Training

Gemma De Sanctis (through May 2018)
MIUR, Ministry of Education, University and Research

Kazakhstan
Aigerim Zuyeva
Arailym Soltanbekova
Ruslan Abrayev
Information-analytic Center

Luxembourg
Catalina Lomos
SCRIPT, Ministry of Education, Children and Youth (MENJE)
Luxembourg Institute of Socio-Economic Research (LISER)

Portugal
Vanda Lourenco
João Marôco
IAVE, IP (Institute of Educational Evaluation)

Republic of Korea
Sangwook Park
Kyongah Sang
Korean Institute for Curriculum and Evaluation

United States of America
Lydia Malley
Linda Hamilton
National Center for Educatiotn Statistics, US Department of Education

Uruguay
Cristobal Cobo
Center for Research, Ceibal Foundation
Cecilia Hughes
Evaluation and Monitoring Department at Plan Ceibal