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.”

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 Sääntti (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 initiative), 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' CIL¹
- questions and tasks set in authentic contexts designed to measure CT².

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.

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