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A global measure of digital and ICT literacy skills

By Australian Council for Educational Research 2016

1 Abstract

Digital and ICT literacy is considered an important competence for full participation in a knowledge economy and an information society. Consequently, interest at national and international level has emerged to explore the best ways of measuring the extent to which, and how equitably, competence in this area is being achieved. This paper reviews the definitions of digital and ICT literacy that have been adopted in cross-national studies, investigates the approaches to the assessment of digital and ICT literacy that have been employed in those studies and articulates the criteria that should guide the development of a global measure of digital and ICT literacy skills. Furthermore, the paper includes an appraisal of prospects for such a development. [1]

2 Introduction

Information and communications technologies (ICT) have become pervasive in modern societies as tools for transforming education systems, supporting economic development through the creation of new products and services, providing access to information and expertise to support improvements in agriculture, health and education, and connecting communities, teachers and students. ICT provides teachers and students with the resources to collect and analyse data, create multimedia presentations and acquire greater depth of knowledge.

However, one of the conditions for using the potential of ICT is to have access to the technology and the internet, and it is evident that there are wide disparities in the extent to which those technologies are available to people, both between and within countries (Anderson & Ainley, 2010). A second condition for employing the whole range of prospects offered by ICT is the development of expertise to use ICT in effective ways. The European Commission suggested that digital literacy is "increasingly becoming an essential life competence and the inability to access or use ICT has effectively become a barrier to social integration and personal development" (European Commission, 2008: 4). There are also many national statements of goals that include similar statements (MCEETYA, 2008; QCA, 2009; Office of Educational Technology, US Department of Education, 2010).

As the value of proficiency in using and managing digital technologies has become increasingly evident, its assessment has become an important component of monitoring the extent to which students develop "skills and knowledge for tomorrow's world" (OECD, 2004). Various forms of assessment of ICT literacy, either as part of large assessment programs or as tools for teachers, are evident in countries such as Australia (ACARA, 2015), Chile (Claro et al, 2012), Norway (Hatlevik, 2009) and the United States (Institute of Education Sciences, National Center for Education Statistics, 2012). International projects such as *Preparing for Life in a Digital Age* (Fraillon, Ainley, Schulz, Friedman & Gebhardt, 2014) and the *Assessment and Teaching of 21st Century Skills* (Griffin, McGaw & Care, 2012) are indicative of the increased interest at the international level in defining appropriate capabilities for the emerging age and exploring how those competencies can be assessed. With regard to adult skills in working with ICT, the Programme for the International Assessment of Adult Competencies (PIAAC) has examined the capacities of adults to solve problems in rich technological environments (OECD, 2013).

In this paper we review possible future approaches to the measurement of digital and ICT literacy skills across a wide range of countries at a global scale.

[1] This paper was written by John Ainley, Wolfman Schulz and Julian Fraillon of Australian Council for Educational Research.

3 Definition of digital and ICT literacy skills

ICT literacy and digital literacy are conceptualised in a variety of ways. In general, the term digital literacy has been used in relation to a wider range of technologies than ICT literacy but the terms overlap to a considerable extent and are often used interchangeably. Neither has had a focus on technical aspects of the field such as programming and computer operations. Rather, they (and ICT literacy in particular) have had a focus on using ICT in various ways. The emphasis has been on computer applications because computers (and similar devices) have been regarded as an important element of ICT.

Understandings of ICT literacy over the past 15 years have been much influenced by definition developed by the International ICT Literacy Panel in 2002 (International ICT Literacy Panel, 2002). This definition stated that:

> *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.* (International ICT Literacy Panel, 2002, p. 2*)*

An important feature of this definition is that it lists a set of cognitive processes associated with ICT literacy. Moreover, those processes were argued to represent a sequence of "increasing cognitive complexity".

ICT literacy has drawn on principles from the field of information literacy and focussed on the use of these information technologies to locate and collect information, evaluate information, transform (analyse and create) information and communicate ideas (Catts & Lau 2008). Catts and Lau (2008) argue that, although these processes have been seen traditionally as part of information literacy, they have been substantially changed by digital technologies given the volume and variable quality of digital information. Erstad (2010) succinctly states that ICT literacy combines technological expertise with information literacy. Binkley et al. (2012, p. 52) have synthesized and documented the operational definitions of the ICT literacy construct that have developed over the past decade. These combine aspects of technological expertise with concepts of information literacy, and extend to the inclusion of ways in which digital information can be transformed and used to communicate ideas.

The European Commission identified digital competence as a key foundation of life-long learning argued that this extended beyond functional ICT skills to embrace the critical, collaborative, creative use of new technologies for employability and societal inclusion (European Commission, 2006). The components of digital competence included information management, collaboration, communication and sharing, creation of content, and problem-solving (European Commission Joint Research Center-IPTS, 2013).

The United States recently included an assessment of technology competency (which has ICT as one of its three areas) in the National Assessment of Educational Progress (NAEP) (WestEd, 2010). The assessment of ICT covers proficiency with computers and software learning tools, networking systems and protocols, hand-held digital devices, and other technologies that enable users to access, create, and communicate information and engage in creative expression. The assessment includes construction and exchange of ideas and solutions, information research, investigation of problems, acknowledgement of ideas and information, and selection and use of digital tools (Institute of Education Sciences, National Center for Education Statistics, 2012).

The IEA International Computer and Information Literacy Study (ICILS) explicitly recognized the two contributing elements (technology and information literacy) that are evident in most definitions of ICT literacy. It defined computer and information literacy 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, Schulz, & Ainley, 2013, p. 18*).*

The elaboration of this definition in the study's conceptual framework identified two strands. Strand 1 of the construct, entitled "collecting and managing information" focused on the receptive and organizational elements of information processing and management. It incorporated three aspects:

- Knowing about and understanding computer use
- Accessing and evaluating information (the processes that enable a person to find, retrieve, and make judgments about the relevance, integrity, and usefulness of computer-based information.
- Managing information (the capacity of individuals to adopt and adapt classification and organization schemes to arrange and store information efficiently)
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(Fraillon, Ainley, Schulz, Friedman & Gebhardt, 2014, pp. 34-35)

Strand 2 of the construct, titled "producing and exchanging information", focused on using computers as tools for thinking, creating, and communicating. This strand had four aspects:

- Transforming information (the use of computers to change how information is presented so that it is clearer for specific audiences and purposes)
- Creating information (the use of computers to design and generate information products for specified purposes and audiences)
- Sharing information (the use of computers to communicate and exchange information with others)
- Using information safely and securely (understanding legal and ethical issues of computer-based communication)

(Fraillon, Ainley, Schulz, Friedman & Gebhardt, 2014, pp. 34-35)

Analyses of data from ICILS showed that there was no empirical distinction between the receptive and productive strands of the construct. The data also revealed a progression of difficulty so that at the most basic level of proficiency students had a functional understanding of computers and could apply conventional software commands under direction through to the most advanced (of four) proficiency levels where students could evaluate the quality of information, independently select information and use a range of software resources to restructure that information and communicate main ideas to others, (Fraillon, Ainley, Schulz, Friedman & Gebhardt, 2014, pp. 72-94).

The OECD Programme for the International Assessment of Adult Competencies (PIAACC) included a measure of problem solving in technology rich environments (PSTRE). That programme defined PSTRE as:

> *using digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks.*
> *(OECD, 2014, p. 9)*

Although there appears to be a broad consensus in most studies that digital and ICT literacy is defined in terms of broad applications of technology, recent years have seen the emergence of an interest in computational thinking as related to digital or ICT literacy (Barr, Harrison & Conery, 2011). Computational thinking refers to the style of thinking used when programming a computer or developing an algorithm. It includes formulating, representing and analysing problems in terms of their component parts. Computational thinking was once a core of introducing children to computers through the Logo programming language (Papert, 1980). Recently, in a number of countries there has been a revived interest in computational thinking (Jones, 2011). It is argued that computational thinking will help students to better understand the bases of digital information systems and enable them to become creators of knowledge. It is also argued that computational thinking embodies skills that can be applied across a range of contexts. In the near future, it may have an influence on the conceptual thinking about the nature of ICT literacy.

4 Cross-country comparative assessments of digital and ICT literacy

There are four cross-country assessments of digital and ICT literacy skills that are reviewed in this section of the paper. These are the IEA International Computer and Literacy Study (ICILS), the Programme for International Student Assessment (PISA) Digital Reading Assessment, the Assessment and Teaching of 21st Century Skills (AT21CS), and the Programme for the International Assessment of Adult Competencies (PIAAC). All of these involve performance assessments of respondents using computer technology to perform a task or series of tasks.

IEA International Computer and Literacy Study

ICILS investigated differences among and within 21 education systems countries in computer and information literacy (CIL). It focused on variations in computer and information literacy between and within countries and student and school factors that were related to those variations (Fraillon et al., 2014). The study took place in 2013 and involved almost 60,000 Grade 8 students in more than 3,300 schools[2]. It was delivered using USB drives that contained all required software resources and could be run on school computers.

In ICILS students completed a computer-based test of CIL that consisted of questions and tasks that were presented in four 30-minute modules. Each student completed two modules that were randomly allocated from the set of four so that the total assessment time for each student was one hour[3]. Each module consisted of a set of tasks based on a theme and following a linear narrative structure, and consisted of a series of small discrete tasks followed by a large task. The four modules were:

- *After School Exercise*. Students set up an online collaborative workspace to share information and then select and adapt information to create an advertising poster for the after school exercise program.
- *Band Competition*. Students plan a website, edit an image and use simple website builder to create a webpage with information about a school band competition.
- *Breathing*. Students manage files, evaluate and collect information to create a presentation to explain the process of breathing to 8 or 9 year-old students.
- *School Trip*. Students help plan a school trip using online database tools and select and adapt information to produce an information sheet about the trip for their peers. The information sheet includes a map created using an online mapping tool.

Rasch item response theory was used to derive a cognitive scale from the data collected and the psychometric properties of the scale were consistent across countries (Fraillon, Schulz, Friedman, Ainley, & Gebhardt, 2015). The reporting scale was set to a metric that had a mean of 500 and a standard deviation of 100 for the combined equally weighted national samples. In addition, the scale was described in terms of four proficiency levels. Each level referenced the characteristics of students' use of computers to access and use information and to communicate with others. Student achievement varied considerably across countries. The average national scores on the scale ranged from 361 to 553

[2] In addition data were gathered from almost 35,000 teachers (15 Grade 8 teachers from each school), principals, and ICT-coordinators. National research coordinators coordinated information procured from national experts about policies for the use of ICT in education.

[3] In addition a 30-minute questionnaire was completed on a computer by students following completion of the test modules.

scale points which is equivalent to almost two standard deviations. However, the distribution of country means was skewed because the means of two countries were more than an international standard deviation below the ICILS 2013 average while the vast majority of countries had national averages at or above the international average.

The results also showed that higher socioeconomic status was associated with higher proficiency both within and across countries, and that female students had higher scores than male students in all but two countries. With regard to student experience of computer use and their frequency of computer use at home were positively associated with proficiency in most countries. Students with access to a home internet connection and higher numbers of computers tended to have higher scores in computer and information literacy in about half of the participating education systems. In addition, student reports about having learned about ICT at school were positively associated with achievement in eight education systems.

Assessment and Teaching of 21st Century Skills

The Assessment and Teaching of 21st Century Skills is a project that sought to define the capacities that needed to be developed so that people progressing through school would be better prepared for life in modern society (Griffin & Care, 2015). After an extensive process of reviews and consultations with experts it developed assessments in two areas that involve digital technology. One of these was an assessment of collaborative problem solving that utilized computer technology (Hesse, Care, Buder, Sassenberg, & Griffin, 2015; Care, Griffin, Scoular, Awwal, & Zoanetti, 2015). The other was an assessment of learning in digital networks (Wilson & Scalise, 2015). In both cases the emphasis was on formative assessments for teachers to use and the focus was on students aged between 11 and 15 years. This paper focuses on the area related to learning in digital networks as it represents one aspect of digital literacy.

The framework for learning in digital networks, as was the case for collaborative problem solving, was developed through consultation with an expert group. The construct was developed so that it was underpinned by notions of order, direction and magnitude. This was followed by the articulation of an assessment plan that formed the bases for the assessment tasks. The tasks were reviewed by panels of teachers and national project managers. The tasks were then reviewed and refined through cognitive laboratory procedures with small groups of students who articulated what they were thinking while solving the tasks. The tasks were then further trialled with samples of students in Australia, Finland, Singapore and the United States.

The construct "learning in digital networks" was seen as comprising four strands:

- Functioning as a consumer in networks;
- Functioning as a producer in networks;
- Participating in the development of social capital through networks;
- Participating in intellectual capital (i.e., collective intelligence) in networks.

(Wilson & Scalise, 2015, p. 59)

These strands were envisaged as parallel and interconnected but they were not seen as being at the same level of difficulty or sophistication. The assessments were developed to cover all strands but were built around three "scenarios". The first of these was called "Artic Trek" and was based on the so-called "Go North" website. In this task, students work in small teams (networks) to investigate scientific and mathematics expeditions of scientists. The second scenario, called "Webspiration", involved becoming part of a poetry work unit in which students read and analyse some well-known poems. The students use a collaborative graphic organiser through the "Webspiration" online tool to create an "idea map" and collaboratively analyse each poem. The third scenario, called "Second Language Chat", involves students interacting with peers in learning a second language. Students are asked to set up a technology or network-based chat room, invite participants and facilitate a chat in two languages. They are also required to evaluate the process (Wilson & Scalise, 2015, pp. 62-65).

The project has thus far only involved small samples of students. However, the psychometric properties appear to be promising and could be the basis for further development and wider application (Care & Griffin, 2015).

Programme for International Student Assessment (PISA): Digital Reading

As part of the 2009 cycle of the Programme for International Student Assessment (PISA) sub-samples (36,500 students from 3277 schools) of the national samples of 15-year-old students in 19 countries answered additional questions via computer to assess their capacity to read digital texts (OECD, 2011). The construct called "digital reading" referred reading in a digital medium rather than being simply a computer-delivered assessment of print reading. It was argued that digital texts included dynamic windows and frames, hyperlinks and networks, multimedia and augmented reality and provided for engaging with on line discussion and social networks (OECD, 2011, pp. 34-35). Furthermore, there was the contention that, although reading a digital text was similar to reading a print text in many ways, additional skills were needed to read digital texts because readers had to construct their own paths through digital texts and had greater opportunities to engage with text by adding comments to blogs or responding to email messages (Mendelovits, Ramalingam & Lumley, 2012). Navigation appeared to be an important skill in digital reading.

The assessment involved 29 digital reading tasks (38 score points) organised in three 20-minute clusters with each student completing two of these clusters (OECD, 2011, p. 45). The digital reading tasks were organised in terms of: text characteristics (familiarity, complexity, vocabulary); complexity of navigation (scrolling, visiting several pages, use of hyperlinks or menus); explicitness of task demands (directions, terminology, constructing responses); and the nature of the response (inferences, evaluations, abstractness).

Data based on student responses to these tasks were used to construct a scale with a mean of 499 score points and a standard deviation of 90. That scale was divided into four proficiency levels, each of which was described in terms of the skills and knowledge needed to successfully complete those tasks (OECD, 2011, p. 46). Student achievement varied considerably across countries with national scores ranging from 361 to 553 scale points (about one and a half standard deviations). There were also large differences among students within countries. Although girls performed higher than boys, the difference was less on digital reading than on print reading (Mendelovits, Ramalingam & Lumley, 2012). Digital reading literacy was also associated with socioeconomic background and with the extent of computer use at home (but not at school). Student performance in digital and print reading was closely related but in some countries students performed relatively better in digital reading and in other countries students performed relatively better in print reading.

Programme for International Assessment of Adult Competencies (PIAAC)

The OECD Programme for the International Assessment of Adult Competencies (PIAACC) provides internationally comparable measures of three sets of skills: literacy, numeracy, and problem solving in technology rich environments (PSTRE) (OECD, 2013). It provides national estimates for people aged 16 to 65 as well as relationships with a range of characteristics. The most recent cycle was conducted in

2011-2012 and involved around 166 000 adults in 24 countries or sub-national regions. Twenty of those countries or regions administered the PSTRE assessment.

According to the PIAAC technical report, the focus of the assessment was not on computer skills but on the cognitive skills required to access and make use of computer-based information to solve problems. The construct “aimed to encompass more than the purely instrumental skills related to the knowledge and use of digital technologies” (OECD, 2014, p. 10). PIAAC reports indicated that the cognitive dimensions of PSTRE were considered the central object of the assessment, while the use of ICT was regarded as secondary. Consequently, the measurement was concerned with both computer familiarity and the ability to solve problems in technology rich environments. The focus was on the “abilities to solve problems for personal, work and civic purposes by setting up appropriate goals and plans, and accessing and making use of information through computers and computer networks” (OECD, 2014, p. 10).

The PIAAC assessment delivered on laptop computers to respondents in their homes as part of an integrated computer-delivery platform. The *computer assisted personal interview* (CAPI) system included the questionnaires and the *direct assessment*. The direct assessment took an average of 50 minutes (it was not time-limited). The assessment design was complicated because an adaptive test procedure was used and only those respondents with some computer experience and facility were directed to the PSTRE assessment (OECD, 2013, p. 86).

The PSTRE assessment involved a series of problems set in realistic computer environments. Respondents had to solve each problem using the information and tools that were accessible in simulated computer environments. Different applications were provided, such as an Internet browser and web pages, common applications, such as e-mail, word processing and spreadsheet tools and special applications such as a room-reservation system. The problems involved different levels of complexity, numbers of steps, levels of inferential reasoning, and requirements for the evaluation of the relevance and credibility of information. (OECD, 2013, p. 86)

The report of PIAAC provides examples of tasks at three levels of complexity and difficulty. One was a simple task of sorting e-mails into pre-existing folders. Five e-mails with responses to a party invitation were presented in an in-box. The task was to place those e-mails into a pre-existing folder so as to keep track of who could and could not attend a party. A second task was more advanced and involved responding to a request for information. The task was to locate information in a spreadsheet and e-mailing that information to the person who asked for it. The required information had to be extracted from a spreadsheet using a sort function and pasting the information in a word processor document. The third and most advanced task involved managing requests to reserve a meeting room using a reservation system. The task was set up so that one of the reservation requests could not be accommodated. Consequently, the respondent had to send an e-mail declining the request. The task involved taking into account constraints (e.g. the number of rooms available and existing reservations) and resolving the issue by sending a message to decline one of the requests. The problem involves using an e-mail interface, with a number of e-mails stored in an inbox containing the room reservation requests, and a web-based reservation tool that allows the user to assign rooms to meetings at certain times. The task involves multiple applications, a large number of steps, a built-in impasse, and the discovery and use of ad hoc commands in a novel environment. In addition, it involved transferring information from one application (e-mail) to another (the room-reservation tool) (OECD, 2013, p. 89).

5 Challenges in developing a globally comparable measure of digital and ICT literacy skills

Any global learning assessment of digital and ICT literacy should ideally have the following features:

- It should cover all aspects of digital and ICT skills (see previous section) which would range from basic skills to more advanced competent use of ICT;
- It should allow robust comparisons between vastly diverse countries ranging from low-income, developing contexts to those that are industrialised with average high income levels;
- It should allow the inclusion of new aspects in any future assessments so that new developments in this rapidly changing domain can be incorporated when appropriate; and
- It should permit an assessment of all sub-groups in the target population while still producing comparable measures across a highly diverse populace.

There are many challenges regarding the development of *comparable* measures of digital and ICT literacy skills. Some of these challenges are common to cross-national assessments in other areas of student learning, while others are specific to digital and ICT literacy. Challenges can be classified with regard to over-time comparisons, cross-country comparisons and cross-group comparisons (e.g. gender of socioeconomic groups).

With regard to the coverage of the assessment, firstly it should be noted that any in-depth assessment of digital and ICT literacy skills will require the use of digital devices (e.g. computer, tablets). To assess digital and ICT skills, it will be necessary to create authentic virtual environments, in which test-takers have to show their competencies regarding different applications of ICT. This will not only require a delivery platform that allows creating a range of relevant virtual contexts, the assessment design will also have to account for newer types of ICT use in future assessments. ICILS 2013, the Digital Reading Assessment of PISA 2009 and the Assessment of 21st Century Skills were mostly conducted in developed countries and there is little or no experience regarding the implementation of this type of study in low-income countries.

Over-time comparisons

While assessment domains in general (and with them the coverage of evaluations) may be subject to changes over time (e.g. in case of a trend to include new topics or a shift of emphasis on teaching), an assessment of digital and ICT literacy skills needs to react to changes in the patterns of use of ICT. It is a fairly new area for assessments and the past decades have shown rapid changes in ICT-related technologies which have impacted on the way ICT is used and applied. In particular, the introduction of tablets and smartphones has provided new ICT applications and with it new ways of working digitally which have been taken up widely across the globe. It is expected that further changes may occur in the near future and any assessment of digital and ICT literacy skills needs to be designed in a way that it can incorporate new aspects without losing comparability over time.

One possibility to deal with changes in nature of ICT use is choosing a modular design, where some of test modules are replaced with new ones reflecting "newer" aspects of ICT while keeping others. Thorough analyses of data with regard to test item dimensionality and item fit would have to be carried out to provide information about the degree to which the test is still measuring a similar construct, so that over-time comparisons can be made across assessment cycles. The Australian national assessment program of ICT Literacy (ACARA, 2015), which has been conducted every three years since 2005, has implemented such an approach which has provided comparable test results over a span of nine years in which a number of changes have occurred in the field of ICT and the use of digital devices.

For a successful monitoring of digital and ICT literacy skills over time, it will be crucial to develop an assessment which has the following features:

- It should include in each assessment cycle sufficient item material from previous surveys to permit equating over time;
- It should be designed in a way that permits the inclusion of new item material to address new developments in ICT (e.g. through a modular approach with new and old modules);
- It should be administered on a delivery platform that is sufficiently flexible to cater for changing conditions in ICT use both in terms of its use for delivery to test takers (e.g. at schools where equipment may change over time) as well as the inclusion of newer aspects of ICT use.

Cross-country comparisons

Assessing learning outcomes across a wide range of diverse contexts is an ongoing challenge for all cross-national studies. Many efforts are made to design instruments that provide comparable measures across countries. These efforts include strict procedures to ensure similarity of adaptation and translation of item material as well as in survey administration procedures, and quality monitoring is undertaken to review the adherence to agreed standards for the implementation of data collections. Furthermore, there have been significant advances in the statistical analyses undertaken to ensure that instruments have similar measurement properties across countries participating in these studies.

The establishment of an assessment of digital and ICT literacy skills faces particular challenges for its cross-national implementation. As any performance-based assessment of digital and ICT literacy needs to be done on computers or equivalent electronic devices, it is important to provide those being assessed with the required tools. The implementation of the chosen mode of delivery should be feasible across all countries participating in the assessment.

The following four different ways could be used to deliver computer- (or tablet-) based assessments to students at schools:

A. Bringing electronic devices (e.g. laptops) to schools and use these for the assessment.

B. Using portable drives (e.g. USB sticks) to schools which can be used to upload the assessment to existing computers.

C. Using existing intranets at school to administer the assessment to connected computers.

D. Delivering the assessment online.

Option A is the only possible way to implement computer-based surveys when few schools are appropriately equipped with computing devices. Earlier assessments of this type in developed countries relied on this method. It should be noted that option A has the advantage of ensuring control all aspects of the assessment (e.g. by having exactly the same assessment device), however, it has many logistic and financial implications, in particular when using (heavier) laptops. The introduction of tablets (which can easily be transported to schools) makes option A less difficult to implement provided that a tablet-based assessment is appropriate.

Option B was applied in a number of recent international surveys, and both the OECD PISA study (in 2009, 2012 and 2015) and IEA ICILS (in 2013) relied on this method. It requires that schools are appropriately equipped with computers and that flash drives are compatible with the computers used in an assessment. It is possible to program the USB application in a way which still ensures a control of the test session (so that respondents are unable to use other devices on the computer).

Option C is similar to A and B in its characteristics as a "local application" but may not allow complete control of test sessions. It also requires access to the school network and may possibly encounter problems with its security settings.

Option D requires not only sufficient equipment of schools with computers but also with internet connections of sufficient capacity (bandwidth). It has the advantage of a central delivery directly to schools or assessment venues; however, it may not (yet) be possible to control the test session so that test-takers may (in principle) be able to use other resources on their computers.

Implementing a digital and ICT literacy assessment may often require alternative delivery modes so that schools with insufficient computer equipment or internet bandwidth (option D) can be included in the survey and thus avoid potential bias in the population estimates that would result from systematic non-participation. The use of tablet and netbook devices at schools, as well as "bring-your-own-device (BYOD) approaches, rather than conventional computers, provide challenges for ensuring uniformity of the test experience.

For an international assessment of digital and ICT literacy skills, it will be necessary to use an assessment design which ensures similar conditions for testing across all contexts. Given that in low-income countries schools tend to be insufficiently equipped with computers (and internet connections), using portable devices brought into school may remain a necessity with important financial and logistic implications. Tablets could be appropriate for an assessment but this type of device may limit the scope of the assessment of ICT skills (e.g. due to the lack of a keyboard or limited screen sizes).

The diversity of contexts for digital and ICT learning across countries also has a potential impact on cross-national assessment. While in many developed countries vast majorities of students have access to ICT at home as well as at school, and are expected to have developed familiarity, young people in developing, low-income countries may have little experience with ICT neither at home nor at school. These differences may also exist within countries and their implications for developing globally comparable measures are discussed in the next section reviewing the challenges with regard to comparison across population groups.

Finally there are open questions relating to the role of language proficiency (in particular English) and internet use in languages other than users' first languages. While there is a range of measures of language prevalence and use on the internet, it is widely accepted that English has the broadest reach. Estimates of the proportion of web-content in English vary with different methods of estimation, but typically fall somewhere in the range of 40 to 60 per cent. For example, the W3Techs survey of language content for March 2016 estimates that 54 per cent of internet websites use English as the main content language (W3Tech, 2016), and a 2009 UNESCO study *Twelve years of measuring linguistic diversity in the Internet: balance and perspectives* estimated 45 per cent in 2007 with a slowing trend for this percentage to decrease (Pimienta, Prado, & Alvaro, 2009). The key question this raises relates to the degree to which effective internet use can be demonstrated with no, or limited proficiency in English language. This leads to an ancillary question relating to the degree to which internet participation is influenced by the prevalence of 'first language' content available to users (with some languages such as Chinese, Spanish and German having large amounts of content, but others having relatively smaller amounts). These questions should be considered when understanding the contexts in which cross-country comparisons of internet use can be made.

Cross-group comparisons

Assessment data on digital and ICT literacy should enable comparisons not only across time and countries but also across different population groups. As in other assessments, measuring digital and ICT literacy should be done a way that does not advantage or disadvantage certain sub-groups in a population. For example, responses to a specific test items or sets of items should only be influenced by the ability of test-takers but not (in addition) by their gender or socio-economic background. Large-scale assessment programs usually review interactions between background variables and individual test items (or groups of items) with sophisticated analysis, primarily using item response modelling. When developing the instrument, piloting and/or field trial assessments are regularly used to review the occurrence of such issue and to discard items with such characteristics prior to the main data collection.

An assessment of ICT skills across a wide range of contexts, however, may encounter specific challenges regarding measurement. For example, there is evidence of inequalities in access to and familiarity with ICT. This may be particularly salient in developing, low-income countries where larger parts of the population are excluded from access to ICT (*digital divide*). Students with no or hardly any familiarity with ICT may not be able to undertake even the simplest assessment tasks. This, in turn, could have a negative impact on the comparability of their results with those from other groups.

There is a question regarding the extent to which an ability dimension stretching across a very wide range of skill levels can still be regarded as a measurable continuum. Given the diversity of familiarity with ICT across highly diverse population sub-groups (also stretching across national boundaries), a measure of digital and ICT skills would have to cover very basic skill levels to sophisticated knowledge about complex applications.

For a learning assessment targeting such a wide range of abilities, it would be necessary to include basic skills assessment at the start of an assessment. This was done in the first two cycles of the Australian national assessment program of ICT Literacy in recognition of sub-groups in the population with very low levels of familiarity with electronic devices at the time of the introduction of the program. However the extent to which an assessment of a wide range of capabilities is genuinely comparable might need to be considered. This would also have implication for cross-national comparability, given that levels of digital and ICT competencies are expected to vary considerably across countries.

6 Prospects for a global measure and priorities for action

The previous section has outlined the challenges with regard to the establishment of a global measure of digital and ICT literacy skills. In this section the focus is on prospects for a global measure of digital and ICT literacy and the actions that need to be taken to develop and implement such a measure.

Recent cross-national studies of digital and ICT literacy, as well as the many national assessments in this field have shown that it is possible to assess students' digital and ICT literacy skills in a comparative manner. In addition, they have shown that it is possible to develop performance assessments in this field that have been accepted as valid and reliable. However, there remain some areas where further analysis and development are required if the work is to be extended beyond the scope of existing experiences.

Firstly, the development of comparative assessments of digital and ICT skills has mainly been based on contexts that reflect developed economies. Although the assessments are concerned with digital and ICT skills, they are embedded in authentic contexts reflecting experiences of students. Most of the examples reviewed in this paper aim to provide authentic assessment experiences and reflect situations that are expected to be familiar to students taking the assessment. It is not clear to what extent the authenticity of these contexts can be maintained when those assessments are implemented in developing low-income countries, where students may have quite different experiences. Similar issues may arise in relation to assessments of minority students within countries.

Solano-Flores and Nelson-Barber (2001, p. 555-557) have referred to this as "cultural validity' and argue that so far it has been given too little attention in the development of learning assessments. In relation to the issue of validity in general, Messick (1995, p.7) had argued that low scores should not be a consequence of the measurement "containing something irrelevant that interferes with the affected students' demonstration of competence." Solano-Flores and Nelson-Barber (2001) argue, in the case of science, that the types of examples used in stimulus material can impact on student responses and that attention needs to be given to including a socio-cultural perspective in the development of tests and test items.

Basterra (2011) suggests a number of ways to promote more culturally valid assessments for use in classrooms. International large-scale assessment surveys typically examine country- specific differential item functioning so as to eliminate those items that appear to yield results that are not consistent with other items on the assessment (Rutkowski, Rutkowski & von Davier, 2013; Glas & Jehangir, 2013). For example, differential item functioning among countries was reviewed at the field trial stage in the development of the assessment instrument in ICILS (Fraillon et al, 2015). It is important that such procedures are applied when developing any new global assessment of digital and ICT literacy.

Secondly, existing cross-national assessments of digital and ICT skills have mainly been conducted in countries with higher levels of ICT development and ICT resources. ICILS 2013 showed for Turkey and Thailand, which were the only participating countries with considerably lower levels of ICT development, that lower secondary students in these countries had very low levels of computer and information literacy compared to those in other participating countries. In these countries, the lack of computer resources at schools can also be challenging as often it may not be possible to rely on existing school computers. Such contexts need to be taken into account when developing a global assessment of digital and ICT skills in a very wide range of countries. Therefore, a priority is to establish delivery platforms that will be applicable in a wide range of technological contexts.

Thirdly, although the review at the beginning of this paper showed that there is a lot that is common in the definitions that underpin existing cross-national assessments, there would be value in looking to ways in which those definitions might be operationalised in a wider range of contexts. A step into the direction of developing a global digital/ICT literacy measure should be the refinement and extension of assessment frameworks to define what should be measured and describing the different types of competencies included in the assessment domain. Ideally, the defined assessment domain should have overlap with existing measures (e.g. computer and information literacy as measured in ICILS, or digital reading literacy as measured in PISA 2009). It could be possible to create links to other assessments via the inclusion of common assessment material.

Fourthly, it is important to develop a wide-range assessment so that targeting is not a problem. This may mean developing sufficient materials so that countries may select modules or components that assess at appropriate levels for their populations but with those modules linked to a common scale that underpin all the modules or components in the test.

Finally, the increasing prevalence of social media platforms needs to be considered in the context of assessing digital literacies. Until this point in time, digital literacy competence has largely focused on information-based skills that are typical of ‘conventional’ approaches to education and the workplace (such as searching for and accessing digital information and producing information products in the form of documents and various forms of multimedia presentation). The rapid increase in the use of social media platforms over the past decade and in particular the adoption of their use in education and workplace contexts needs to be considered. The essential question is whether the use of such media has resulted in the need to assess a ‘new’ set of competencies, or whether the existing defined sets of competencies are sufficient to measure digital literacy applied in the social media context.

7 Additional information needed to inform education policy

Collecting data on digital and ICT literacy skills in isolation will provide information about its extent and variation across countries participating in an assessment, but will not provide evidence about the factors which explain the variation and could be malleable to specific educational policies for improvement. Therefore, in order to properly inform education policy, it will be necessary to collect contextual data in addition to those from an assessment of digital and ICT literacy skills. The purpose of such a collection of contextual data is to provide information about factors influencing variation in digital and ICT skills as well as describing the contexts in which they are learned. It will be important to collect contextual information at the following levels:

- *The individual learner*: Here, characteristics like gender, experience with ICT, career expectations and other variables may impact on how much someone knows about how the use of ICT.
- *The school/classroom environment* (in case of school-based surveys): The equipment of schools with ICT resources, teacher preparation, and school policies may all have an influence on the development of ICT skills among students.
- *The home and peer environment*: The development of digital and ICT literacy skills is expected to be influenced by factors associated with home, family and peers. Socioeconomic background, ICT resources at home, and ICT-activities with peers are examples of variables that may be relevant for developing skills in this area.
- *The contexts of the wider community*: It will be important to take supranational, national and sub-national contexts into account when interpreting data from an assessment of digital and ICT literacy skills. Contextual data of interest may relate to curricular policies, general ICT development as well as initiatives to support ICT use in society.

Another distinction between contextual variables is whether they are rather antecedent variables (which are not directly influenced by ICT skills) or process-related factors (which may work in interaction with already existing ICT skills). For example, while antecedent background factors like gender, socioeconomic family background, or school resources set the conditions for learning, process-related variables like classroom climate, teaching strategies or motivation to learn might be influenced by already existing levels of learning about ICT.

The following instruments should be considered for a collection of contextual data:

- A *student questionnaire* (or more generally a "test-taker" questionnaire in case of an adult survey) should be added to the test of digital and ICT literacy skills to collect background data and other variables related to ICT.
- A *school questionnaire* (typically directed at the principal or head teacher) should collect data about the context of the school participating in the survey.
- A *teacher questionnaire* could provide additional information about school and classroom contexts.
- A *parent questionnaire* could provide information about the home context of students, such an instrument would be particularly useful when assessing younger students who may not provide all relevant data on family background.
- An *expert or national-centre questionnaire* may be used to collect data about curricular policies, practices and the education system at the (national) level of participating countries to supplement existing data on the national context for ICT learning.

Data collected from such additional instruments would be used to analyse within and across countries to which extent socioeconomic factors, school and home contexts influence variance in students' (or adults) digital and ICT literacy skills. These analyses would help to review equity issues within countries, provide information about home and school influences and highlight possible associations between policy-relevant factors and the extent of learning about ICT.

The content of the contextual instruments should be guided by a contextual framework defining the constructs and variables considered to be relevant in light of prior research. The instrumentation should be sufficient to answer research questions that guide later analyses of assessment data.

8 Conclusion

A review of the definitions of digital and ICT literacy suggests that, despite differences in terminology, there is a great deal of commonality across those definitions. Moreover, there are also many similarities between the approaches to assessment, and even across the types of tasks that have been adopted in the existing cross-national studies of digital and ICT literacy. Almost all assessments involve computer-based performance assessments rather than assessments of knowledge about digital and ICT literacy. This common feature suggests that there ought to be good prospects for developing a global measure of digital and ICT literacy. However, it needs to be recognised that the existing definitions and assessments have been developed within rather limited contexts, in particular in developed societies. There is considerable work to be done in building on this work so that the measures are appropriate for a wider range of countries. In addition, there are questions about appropriate modes of delivery that need to be considered. Existing cross-country assessments have been able to take advantage of the availability of computer equipment in the countries that have been studied. Extending this work to other environments where ICT resources are scarce may involving thinking about different types of devices that involve the similar capacity for managing information. Many of these alternatives can support receptive aspects of digital and ICT literacy but fewer of them appear to be able to support productive aspects of digital and ICT literacy.

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