European Commission

The 2018 International Computer and Information Literacy Study (ICILS)

Main findings and implications for education policies in Europe

Education and Training

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Executive Summary

Digital competences constitute an essential skill for participating in a technology-driven world. At the same time, digital competences are an area with research gaps, and insufficient data. The International Computer and Information Literacy Study (ICILS) seeks to bridge these gaps by studying the extent to which young people are able to use information and communication technology (ICT) productively in school, at home, in society, and their future workplaces. This is achieved by directly assessing pupils' competence in computer and information literacy ('CIL score') and through an optional assessment of pupils' computational thinking ('CT score'). The study was first conducted in 2013, with a second cycle completed in 2018, and is set to repeat every five years.

ICILS data makes it possible to analyse national performance in digital competence by gender, socio-economic status and immigrant background. The data also includes contextual information on participating schools and education systems.

The following points sum up the main findings of ICILS for the participating EU education systems:

1. Being born in a digital world does not necessarily make one digitally competent. Contrary to the common view of the young generation of today as a generation of 'digital natives', findings from the first two cycles of ICILS indicate that young people do not develop sophisticated digital skills just by growing up using digital devices. In 9 out of 14 Member States participating in ICILS, more than one third of the pupils achieved scores below level 2 on the ICILS CIL scale, which can be defined as the threshold for underachievement in digital competence.
2. There is greater variation within countries than across countries in computer an information literacy achievement. The focus must thus not only be on the underachieving students, but also on the students working at higher proficiency levels in digital competence.
3. There is a significant gender gap in computer and information literacy, with girls outperforming boys in all participating Member States. This gap is, however, not evident in the assessment of computational thinking.
4. Low socio-economic status is associated with underperformance in computer and information literacy and in computational thinking. This poses a risk of a potential future digital divide.
5. There are still structural hindrances present in Member States, such as limited availability of computers for students, impeding learning of digital competence.
6. Results from ICILS suggests that a holistic approach to the pedagogical use of ICT in school is required. Providing pupils and teachers with ICT equipment is not enough to improve their digital skills. They also have to be encouraged and supported in their use of digital tools.

1 Assessing digital competence

Digital competence is a multi-dimensional construct that includes knowledge, skills and attitudes in a range of areas, including creative use of digital technologies, safe and responsible use and data literacy. The EU has acknowledged the importance of digital competence for all learners including it as one of eight key competences for lifelong learning. Within this framework, digital competence is defined as the confident, critical and responsible use of, and engagement with, digital technologies for learning, work, and participation in society. This understanding of digital competence has been further elaborated in the European Digital Competence Framework (DigComp), featuring 21 competences described under five 'main competence areas': information and data literacy, communication and collaboration, digital content creation, safety and problem solving[1].

Promoting policies for fostering digital competence in education is the long-term solution of preference to secure a sound base level of digital competence among EU citizens. However, digital competence is an area with research gaps and insufficient data. When data is available it is often indirect measures of digital competence obtained through self-assessment or other proxies, such as the annual Eurostat survey 'ICT Usage in Households and by Individuals'. The recently published results from the International Computer and Information Literacy Study (ICILS) expands the current knowledge base by providing a direct assessment of pupils' digital competences and enabling comparisons over time[2].

ICILS assesses the capacities of young people to use information and communication technology (ICT). The study was first conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 2013, with a second cycle completed in 2018 and the third and fourth cycles scheduled for 2023 and 2028. The study measures international differences in pupils' computer and information literacy (CIL): their ability to use computers to investigate, create and communicate in order to participate effectively at home, at school, in their future workplaces and in society. Starting in 2018, the participating countries also had the option for their pupils to complete an assessment of computational thinking (CT): the ability to use the concepts of computer science to formulate and solve problems.

This report presents key findings from ICILS 2018 for the participating EU Member States, supported by findings from ICILS 2013[3] in the assessment of pupil CIL scores, with implications for the EU policy agenda in education. In total, 14 Member States participated in the two ICILS cycles, 7 in 2018 and 9 in 2013[4]. Due to the limited coverage of Member States, EU averages have not been calculated and implications for policies should be interpreted with caution. In the following section main findings and implications for education policies in Europe are highlighted.

1 Carreto, S., Vuorikari, R. and Punie, Y. (2017). DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use. Luxembourg: Publications office of the European Union.

2 Fraillon, J. Ainley, J., Schulz, W., Friedman, T., Duckworth, D. (2019). Preparing for Life in a Digital World: IEA International Computer and Information Literacy Study 2018 International Report. Amsterdam: International Association for the Evaluation of Educational Achievement (IEA).

3 Fraillon, J. Ainley, J., Schulz, W., Friedman, T., Gebhardt, E. (2014). Preparing for Life in a Digital Age: the IEA International Computer and Information Literacy Study International Report. Cham: Springer.

4 ICILS 2018: DK, DE, FR, IT, LU, PT, FI.
ICILS 2013: CZ, DK, DE, HR, LT, NL, PL, SI, SK.

ICILS 2018

The primary purpose of ICILS 2018 was to measure pupils' ability to use computers to collect and manage information and to produce and exchange information (CIL) as well as formulate solutions to problems so that those solutions could be operationalised with a computer (CT)[5]. In addition, ICILS 2018 investigated the use of computers and other digital devices by pupils and teachers, and pupils' and teachers' attitudes toward the use of digital technologies.

Data for ICILS 2018 was collected using six instruments (seven in countries participating in the CT assessment): pupils completed the test of CIL, a questionnaire and (where applicable) the test of CT. Separate questionnaires were completed by teachers, school ICT coordinators, principals and staff in national research centres.

In total, ICILS 2018 gathered data from 46 561 grade eight (ISCED 2) pupils in more than 2 226 schools from 12 countries and 2 benchmarking participants. Data from 26 530 teachers in those schools and contextual data from ICT coordinators, principals and staff in national research centres augmented the pupil data. The main survey data collection took place in the first half of 2018 for participants in the Northern Hemisphere and in the second half of 2018 for participants in the Southern Hemisphere.

Countries participating in ICILS 2018[6]

EU Member States: Denmark, Germany, France, Italy, Luxembourg, Portugal and Finland.
Non-EU countries: Chile, Kazakhstan, South Korea, Russia, the United States and Uruguay.

Computer and information literacy (CIL) achievement scale[7]

The digital competence scale as measured by the CIL instrument in ICILS is described across four levels of increased sophistication: level 1 (407 to 491 scale points), level 2 (492 to 576 scale points), level 3 (577 to 661 scale points) and level 4 (above 661 scale points). Pupil scores below level 1 (below 407 scale points) indicate CIL proficiency below the lowest level targeted by the assessment instrument. The proficiency levels are informative of the nature and the complexity of the tasks pupils are able to solve. Pupils' CIL proficiency becomes more sophisticated as they progress up the scale, and a pupil located at a particular place on the scale will be able to undertake and successfully accomplish tasks up to that level of achievement.

The CIL achievement scale was established for ICILS 2013, based on the average CIL scale score across countries. The 2013 scale has a mean of 500 score points and a standard deviation of 100 score points for the equally weighted national samples. Data for the 2018 cycle has been equated to the ICILS 2013 reporting scale, thus enabling comparison between the 2018 and 2013 cycles.

Computational thinking (CT) achievement scale[8]

CT is a new assessment construct introduced in ICILS 2018. Although the assessment of CT differs from that of CIL, the CT achievement scale is structured similarly to the CIL achievement scale: CT proficiency becomes more sophisticated as pupil achievement progresses up the scale. We can therefore assume that a pupil located at a particular place on the scale because of their achievement score will be able to undertake and successfully accomplish tasks up to that level of achievement. The CT achievement scale is divided into three regions: the lower region is below 459 scale points, the middle region is that between 459 and 589 scale points (inclusive), and the upper region is above 589 scale points.

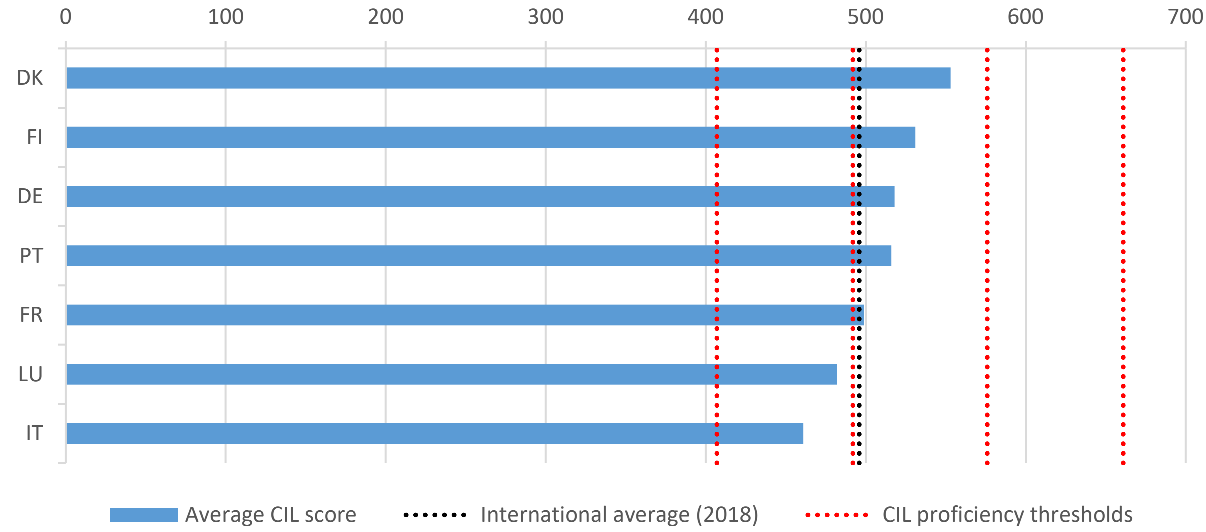
5 The way CIL and CT are conceptualised in ICILS is further elaborated in annex A.
6 In the following, only results from EU Member States are covered by this note.
7 The CIL achievement scale is further elaborated with examples in annex B.
8 The CT achievement scale is further elaborated with examples in annex C.

2 Key findings relevant for education policies in Europe

2.1 Comparing computer and information literacy across and within countries

Digital competence, as measured by the CIL instrument in ICILS 2018, is unevenly distributed across the seven participating EU Member States (see Figure 1). Denmark (553 points) is the top performer, followed by Finland (531 points), Germany (518 points), Portugal (516 points), France (499 points), Luxembourg (482 points) and Italy (461 points[9]). In four of the seven participating Member States, the average pupil CIL score was significantly higher than the ICILS 2018 average of 496 points[10], while two of the seven Member States achieved average CIL scores significantly lower than the average.

Figure 1 – Average pupil score in computer and information literacy (CIL) 2018



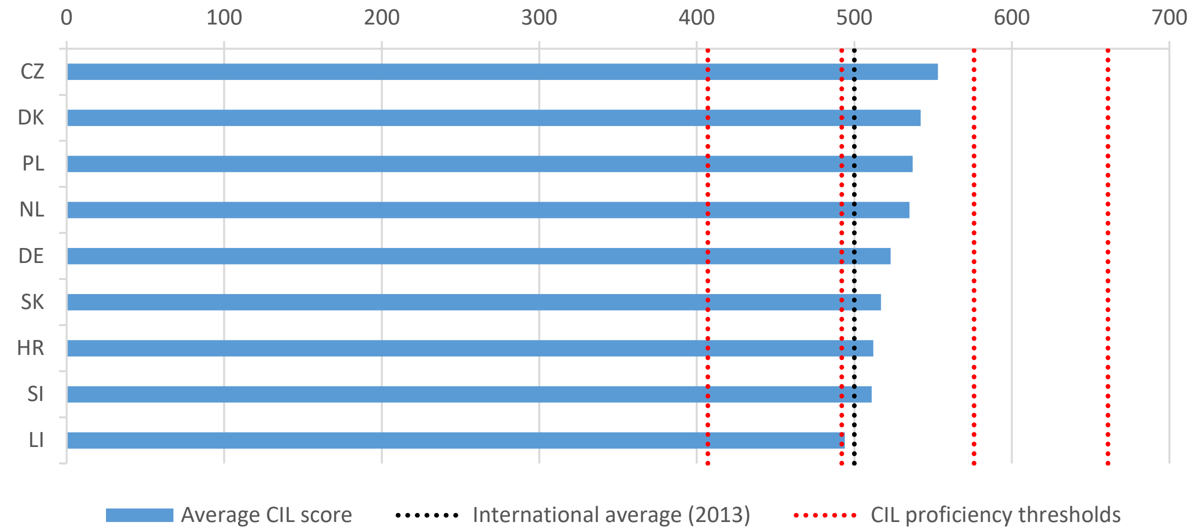
Source: IEA, ICILS 2018.
Note: CIL proficiency thresholds: L1: 407 points, L2: 492 points, L3: 576 points, L4:661.

There is substantial variation in the average CIL scores across EU Member States in ICILS 2018, with 92 points differentiating the top scoring country, Denmark, and the lowest scoring country, Italy. A similar variation in the average CIL score across EU Member States was visible in ICILS 2013, where the difference in score between the lowest scoring country, Lithuania, and the top scoring country, Czechia, was 59 points (see Figure 2).

9 Testing in Italy took place at the beginning of the school year and their pupils are thus much younger on average than those in other countries. Results from Italy are consequently not entirely comparable to the other participating countries.

10 See the IEA ICILS 2018 International Report for details on the calculation of the international average. EU averages have not been calculated due to the limited participation rate, but the international averages are included as a point of reference.

Figure 2 – Average pupil score in computer and information literacy (CIL) 2013



Source: IEA, ICILS 2013.
Note: CIL proficiency thresholds: L1: 407 points, L2: 492 points, L3: 576 points, L4:661.

From Figure 1 and Figure 2 we see that on average, pupils in the majority of the participating Member States in both ICILS 2018 and 2013 achieved scores placing them within the lower end of the level 2 proficiency interval of the CIL scale (492 to 576 points)[11]. At this level pupils demonstrate basic use of computers as information resources, and are able to complete basic and explicit information-gathering and management tasks such as inserting information to a specified cell in a spreadsheet or locating explicitly stated simple information within a website with multiple webpages. In five out of seven Member States in ICILS 2018, and in all Member States in ICILS 2013, the country average falls within this level. Luxembourg and Italy are the only two Member States where the average score did not reach the level 2 proficiency threshold.

The variation within countries is greater than the variation across countries in ICILS. When looking at the difference in score between the bottom 5% and the top 5% within countries, we see that it ranges from 215 points in Denmark to 277 points in Luxembourg in ICILS 2018, and from 203 points in Czechia to 297 points in Slovakia in ICILS 2013[12]. In comparison, the difference between the highest and lowest average scores across countries was 92 points in 2018 and 59 points in 2013.

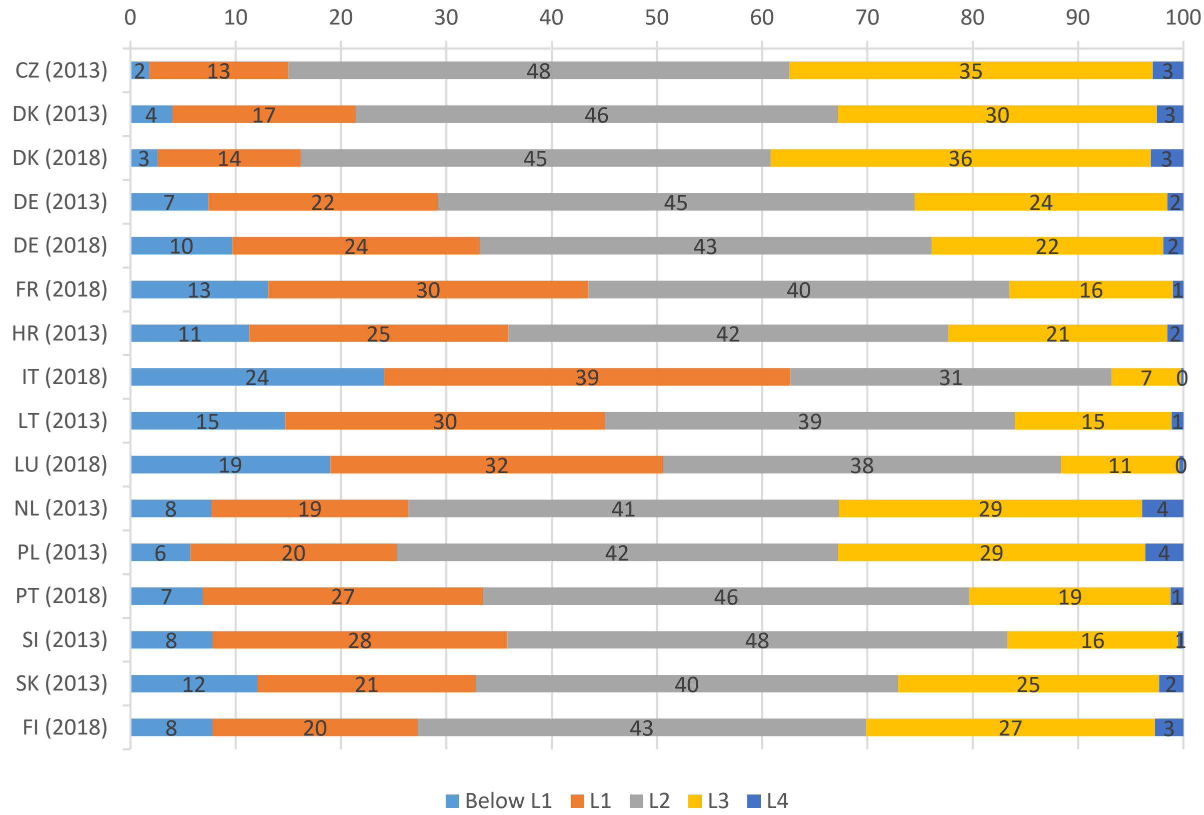
Figure 3 presents the distribution of pupil scores over the different CIL proficiency levels for each Member State, and consequently a more nuanced picture than the average score across countries. While the proportion of pupils at level 2 is fairly equal across Member States, there is significant variation in the distribution of percentages over the remaining competence levels. In Czechia, Denmark, the Netherlands, Poland and Finland, the proportion of pupils above level 2 is higher than the proportion of pupils below level 2. Conversely, in Germany, France, Croatia, Italy, Lithuania, Luxembourg, Portugal,

11 In 19 of 26 participating countries, the country average was within the level 2 proficiency interval. Countries participating in both ICILS iterations did not experience changes in the average levels between cycles.

12 Calculated based on the data presented in table C.1 in the IEA ICILS 2018 International Report and table C.1 in the IEA ICILS 2013 International Report.

Slovenia and Slovakia, the proportion of pupils below level 2 is higher than the proportion above level 2[13].

Figure 3 – Distribution of CIL proficiency levels (%)



Source: IEA, ICILS 2013 and ICILS 2018.

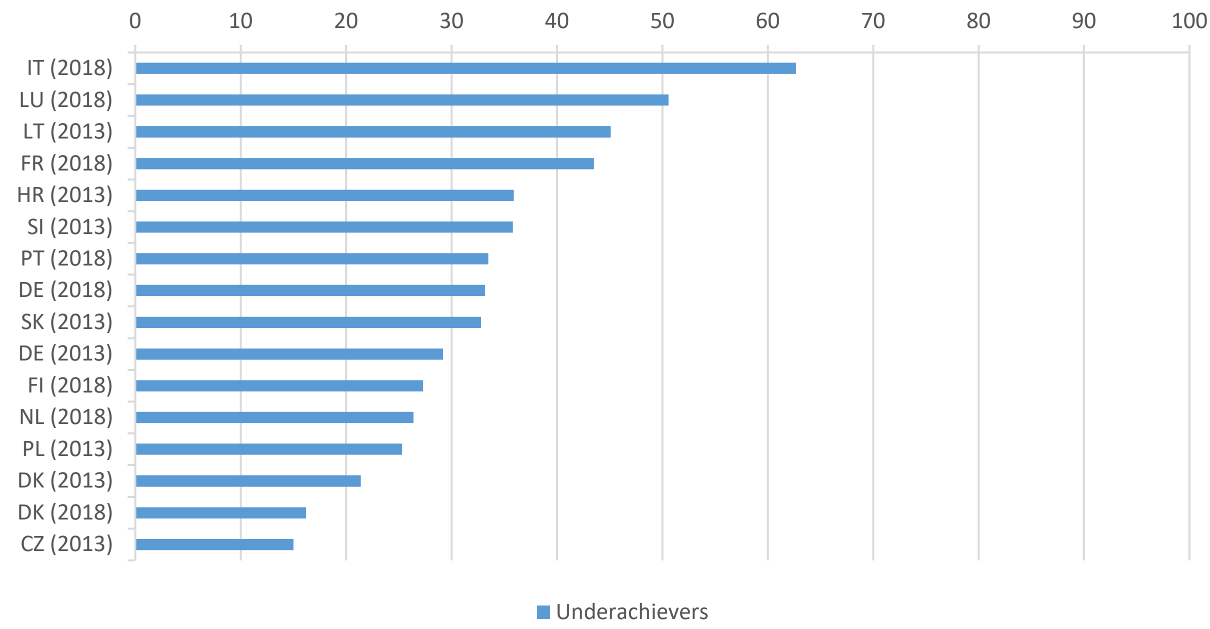
2.1.1 Underachievement in digital competence

Underachievement in digital competence can be defined as the share of pupils that fail to reach proficiency level 2 as measured by the ICILS CIL construct. In an educational setting, pupils at level 1, although able to perform basic digital tasks during their learning activities, will most likely require teacher intervention and supervision to benefit academically from the use of digital tools. Pupil performing at level 2 or above, in contrast, are increasingly independent in their use of digital tools for learning, and are likely to demonstrate higher levels of critical thinking when using information sources. The ability to use and assess information sources is also important outside of the educational setting. Pupils working at level 2 know, for example, that search engines can prioritise sponsored content over non-sponsored content, and are able to differentiate between paid and non-paid search results returned by a search engine. These are key skills in an era of 'fake news'. Digital competence at level 2 should hence be considered the minimum for successfully implementing digital tools and practices at scale in general education, and for citizens to make informed decisions in the digital age.

13 DK and DE retained similar proportions in both ICILS cycles: a higher proportion above level 2 and a higher proportion below level 2, respectively

Figure 4 presents the share of underachievers in the Member States participating in ICILS 2013 and ICILS 2018. **The underachieving pupils are comprised of pupils at level 1, who have a basic albeit limited understanding of computers and software**, and pupils who fall below level 1. **Below level 1, the pupils do not have a functional working knowledge of computers as tools and are unlikely to be able to create digital information products** without substantial support and guidance. The share ranges from 63% in Italy to 15% in Czechia. In nine Member States, more than one third of the pupils performed below the level 2 threshold[14].

Figure 4 – Share of underachievers in CIL proficiency (%)



Source: IEA, ICILS 2013 and ICILS 2018.

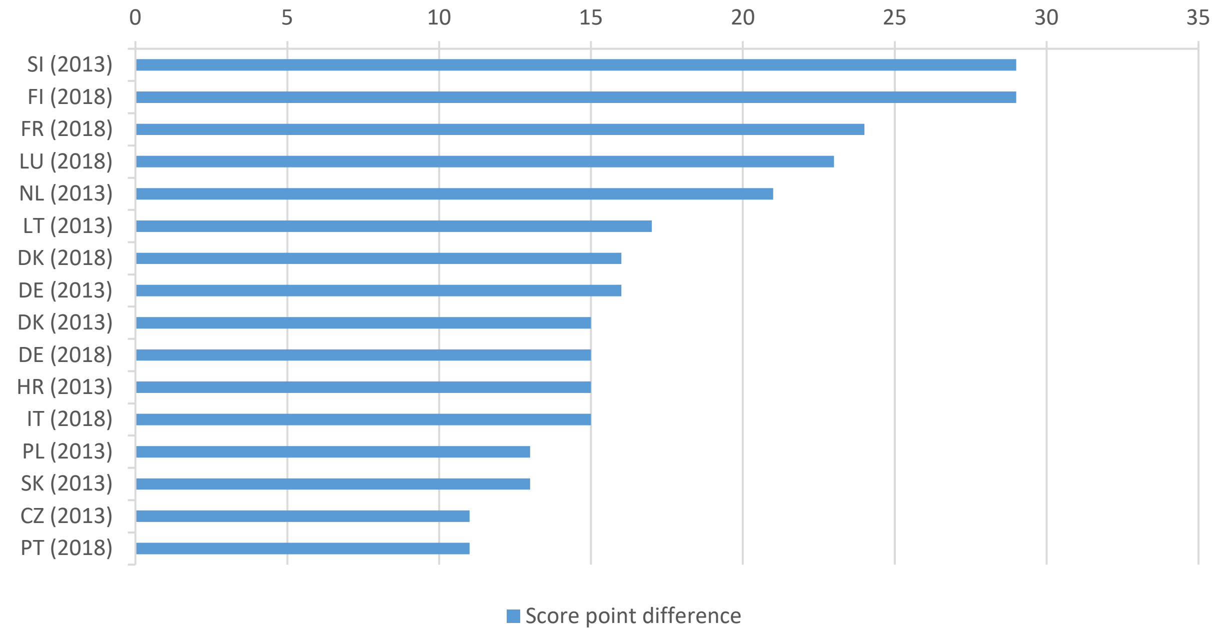
2.1.2 Gender differences in pupils' CIL scores

In both ICILS cycles girls' computer and information scores were statistically significantly higher than those of boys in all participating Member States. The average score point difference ranges from 11 points in Czechia and Portugal to 29 points in Slovenia and Finland, as presented in Figure 5. The impact of the gender difference becomes clearly visible when looking at the average country scores by gender. The female average CIL score falls within the level 2 interval of the CIL proficiency scale in all Member States, with the exception of Italy where it is below the level 2 threshold. In comparison, the male average is below the level 2 threshold of 492 points in four countries: France, Lithuania, Luxembourg and Italy.

The average score point difference between female and male pupils does not appear to be directly related to a high or low country average. Of the five countries with the highest average score point difference, two have country averages above 530 score points (the Netherlands and Finland) and three have country averages ranging from 511 score points to 482 score points (Slovenia, France and Luxembourg).

14 Germany's share of underachievers increased from 29% in 2013 to 33% in 2018.

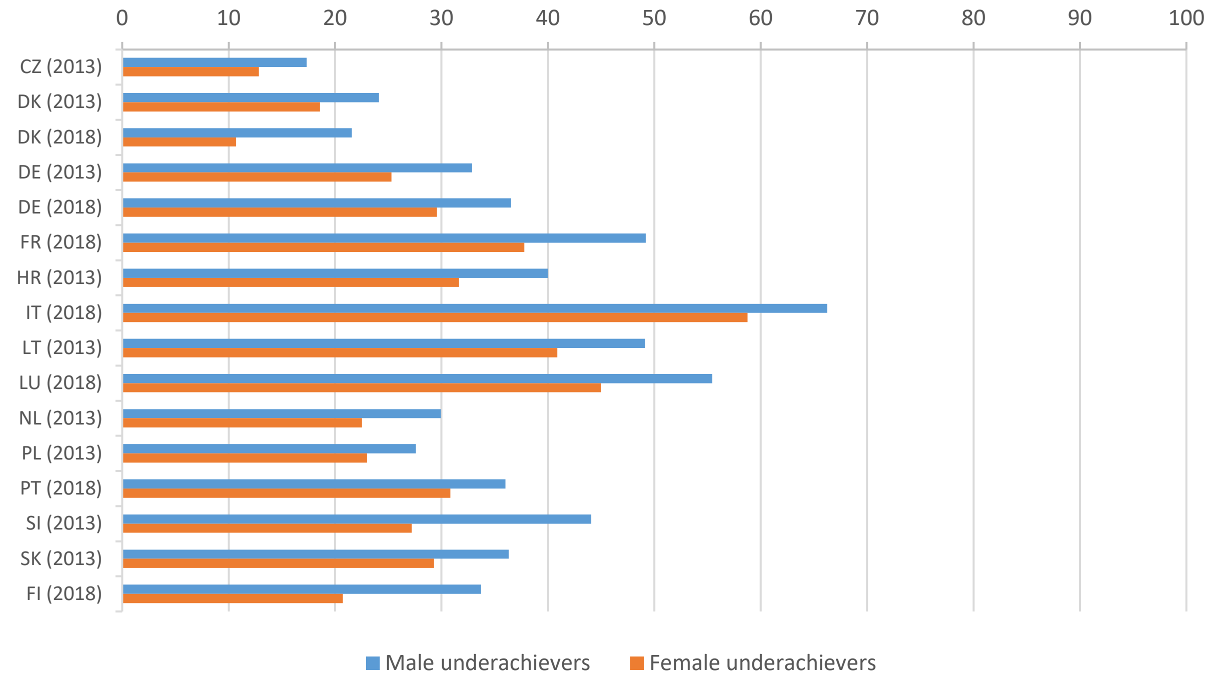
Figure 5 – Gender differences in CIL (mean score point difference female-male)



Source: IEA, ICILS 2013 and ICILS 2018.

Gender differences in underachievement reflects the overall relationship between the scores of male and female pupils. From Figure 6 we see that **the share of male underachievers was higher than the share of female underachievers in all Member States in both ICILS cycles.** In five countries, the share of male underachievers was more than 10 percentage points higher than the share of female underachievers (DK 2018, FR 2018, LU 2018, SI 2013, FI 2018).

Figure 6 – Underachievement in computer and information literacy (%), by gender



Source: IEA, ICILS 2013 and ICILS 2018.

2.1.3 Background factors influencing pupils' digital competence

Socioeconomic background factors are identified in both ICILS 2013 and ICILS 2018 as having a statistically significant effect on pupil achievement. In all participating Member States, **parental occupational status**, **parents' educational attainment** and the **number of books at home are positively associated with pupil achievement**. This is clearly visible in the ICILS 2018 results where, with the exception of the difference in average score by parental education in Finland (15 points), the difference in average scores for the socioeconomic background factors exceed 20 points in all Member States.

Migrant status and **language spoken at home are two other factors identified as influencing pupil achievement**. Pupils from families with a migrant background[15] and pupils speaking another language at home than the test language score lower than pupils from non-migrant families and pupils speaking the same language at home as the test language. For instance, in France the difference between the average score for pupils from families with a migrant background and pupils from families without a migrant background is 38 points. A similar difference is found when comparing language spoken at home and the test language, where the difference in average score is 54 points in France.

The negative associations are, however, not evident in all countries. In Portugal, for example, there is no statistically significant difference between the achievement of pupils with a migrant background and pupils without a migrant background. Similarly, there is no significant association between achievement and language use in Portugal. Poland is another example where the association between the test language and the language used at home and pupil achievement is not statistically significant.

Access to computers at home and experience using computers are, perhaps not surprisingly, positively associated with pupil CIL scores[16]. Evidence from ICILS 2018 show that access to two or more computers at home has a significant positive impact on pupil achievement: the average score difference ranges from 16 points in Portugal to 37 points in Luxembourg. **A similar positive effect comes from years of experience with computer use**: the average score difference between five or more years of experience and fewer than five years of experience in ICILS 2018 ranges from 10 points in Germany to 34 points in Finland.

2.2 Comparing computational thinking across and within countries

Computational thinking (CT) and related concepts such as coding and programming have received increasing attention in the education field in the past decade[17]. CT is a concept which is related but different to that of computer and information literacy (CIL). While **computer and information literacy is primarily concerned with the ability to collect and manage information and produce and exchange information**, **computational thinking encompasses 'an individual's ability to recognise aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those**

15 'Family with a migrant background' is defined in ICILS as both parents of a pupil being born outside the country of assessment, regardless of where the pupil was born.

16 The term 'computer' refers exclusively to desktop and laptop computers in this specific context.

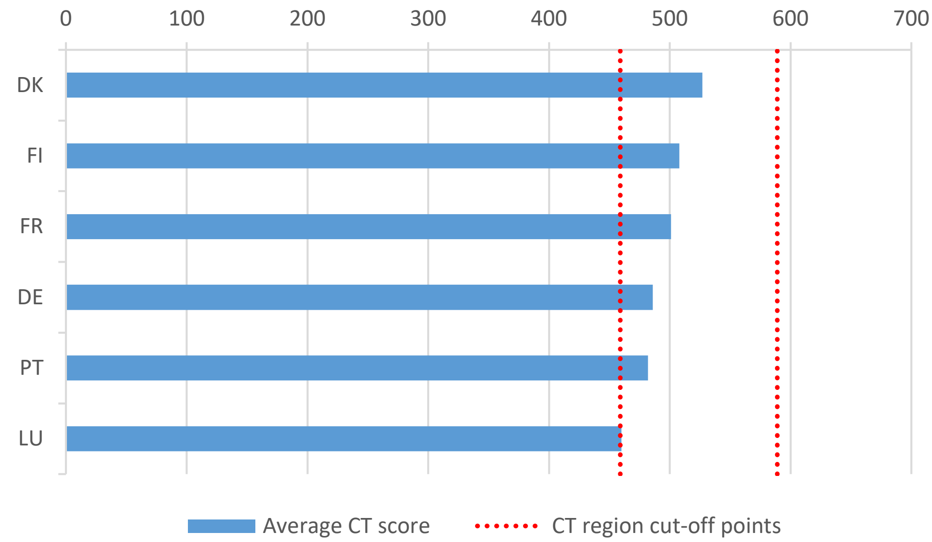
17 Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., Engelhardt, K., Kampylis, P., Punie, Y. (2016). Developing Computational Thinking in Compulsory Education - Implications for policy and practice. Luxembourg: Publications Office of the European Union.

problems so that the solution could be operationalised with a computer'[18].The two domains can be regarded as complementary aspects of a broader notion of digital competence as described in the DigComp framework[19].

Eight countries participated in the CT instrument in ICILS 2018, six of which were Member States (Figure 7). The presence of emphasis on aspects of computational thinking, such as creating algorithms or creating visual presentations of data, in the national curriculum of the participating Member States varies. However, all countries, with the exception of Luxembourg, include at least some aspects of computational thinking in the national curriculum[20].

The achievement on the CT scale is described across three distinct regions rather than different levels as used for the CIL scale: the lower region (below 459 scale points), the middle region (459 to 589 scale points) and the upper region (above 589 scale points). Pupils were given a set of tasks to assess their achievement on the computational thinking scale. An example of a task is a farm drone simulator where pupils were required to use a visual coding environment to make a drone perform a series of actions, such as dropping water on specific areas but not others. Score points were awarded according to the completion of objectives and the effectiveness of the solution. Figure 7 provides an overview of the average score for the six participating Member States. The scores range from 460 points in Luxembourg to 527 points in Denmark, and are within the middle region of the scale.

Figure 7 – Average pupil score in computational thinking (CT) 2018



Source: IEA, ICILS 2018.
CT region cut-off points: 459 points and 589 points.

18 Fraillon, J. Ainley, J., Schulz, W., Duckworth, D., Friedman, T. (2019). IEA International Computer and Information Literacy Study: Assessment Framework. Cham: Springer. p. 27.

19 Carreto, S., Vuorikari, R. and Punie, Y. (2017). DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use. Luxembourg: Publications office of the European Union.

20 See table 2.5 of the ICILS 2018 International Report for an overview of aspects related to computational thinking emphasised in the national curriculum of Member States.

On average, across all countries participating in the CT assessment, **there is a strong positive correlation between pupils' CIL and CT scale scores**. Consequently it is not unexpected that **the background factors affecting the CIL score also affect the CT score**. The proxies for socioeconomic background, parental occupational status, parents' educational attainment and the number of books at home, are positively associated with pupils' CT achievement. This is also the case for computer availability at home and years of experience of ICT use. Coming from a migrant background or speaking another language at home than the test language adversely affects the average pupils' CT score as it did with the CIL score.

Gender differences in computational thinking are, however, different than in computer and information literacy. In both ICILS cycles the CIL scores of female pupils were statistically significantly higher than those of male pupils in all participating Member States. This difference is not reflected in the CT domain. There were only statistically significant differences between female and male pupils in two Member States, Finland and Portugal. Interestingly, the differences had opposite directions in the two countries. In Finland, female pupils scored on average 13 points higher than male pupils, while male pupils in Portugal scored on average 16 points higher than female pupils.

The differences in average score between female and male pupils in three of the four remaining Member States, albeit not statistically significant, are also interesting. In France, Germany and Luxembourg, the average score of male pupils appear to be higher than those of female pupils. Pupils in Denmark did not demonstrate any notable differences in average scores.

The authors of the ICILS 2018 International Report note that findings on the relationship between pupils' computer and information literacy, computational thinking skills and gender are 'consistent with current beliefs about the differences in female and male pupils' attitudes towards, and uses of, ICT'[21]. They found that **female pupils are stronger users of ICT for general school-related tasks, such as locating information from within digital sources and creating digital content to communicate information to others. Male pupils, in their view, are more confident to approach, and slightly stronger at dealing with, specialist ICT tasks such as adjusting computer settings or creating programs**. Although the data is too limited to draw any certain conclusion on the relationship between gender and CT scores at present, the results from ICILS 2018 suggests that this relationship should be explored further. A broader knowledge base is required when deciding how to address these differences in curricular and educational policy.

3 Developing digital competence

Pupils' CIL and CT scores are influenced by contextual factors. In the previous section we covered pupil background characteristics and how they were related to the pupils' digital competence. This section examines the role of teachers and schools play by drawing on results from the teacher questionnaire and the two school level questionnaires[22] presented in chapter two and chapter six of the ICILS 2018 International Report.

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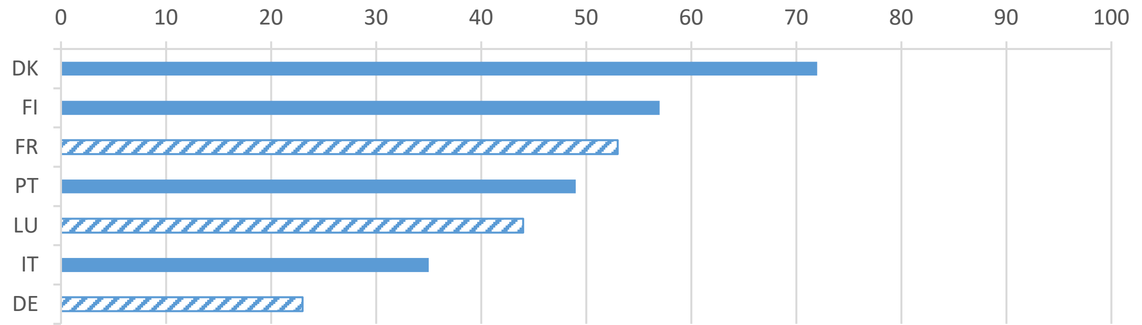
[21] ICILS 2018 International Report, p.244.

[22] Questionnaires were distributed to principals and ICT coordinators at each surveyed school in ICILS 2018.

3.1 Teachers experience and attitudes towards ICT in teaching and learning

Results from ICILS 2018 show that **experience with ICT use in preparation for lessons is more prevalent than ICT use when teaching**. This is also reflected in the reported use of ICT both for teaching and in preparation for lessons. Figure 8 shows the percentage of teachers reporting daily use of ICT when teaching. The highest percentage is found in Denmark and Finland, followed by France. In the remaining four countries the percentage of teachers reporting daily use of ICT in teaching is below 50%.

Figure 8: Teachers reporting daily use of ICT at school when teaching (%)



Source: IEA, ICILS 2018.
Note: Bars with patterns indicate that the country did not met the IEA teacher sample participation requirements.

Teachers' confidence in performing ICT tasks and their attitudes regarding the use of ICT in teaching and learning are important aspects to consider in relation to the development of pupils' CIL and CT skills, as they may influence ICT use in the classroom. In ICILS 2018 teachers were asked to rate how well they can do a range of different ICT tasks[23]. On average the digital competence of teachers in Member States appears to be high, with **high confidence levels in tasks such as finding useful teaching resources on the internet, producing presentations with simple animation functions and preparing lessons that involve the use of ICT by pupils**. **Lower confidence levels were found when assessing the knowledge of using a learning management system and contributing to a discussion forum or user group on the internet**. Interestingly, statistically significant differences between teachers older than 40 years and teachers younger than 40 years were observed in the results, with **younger teachers displaying more confidence than older teachers**.

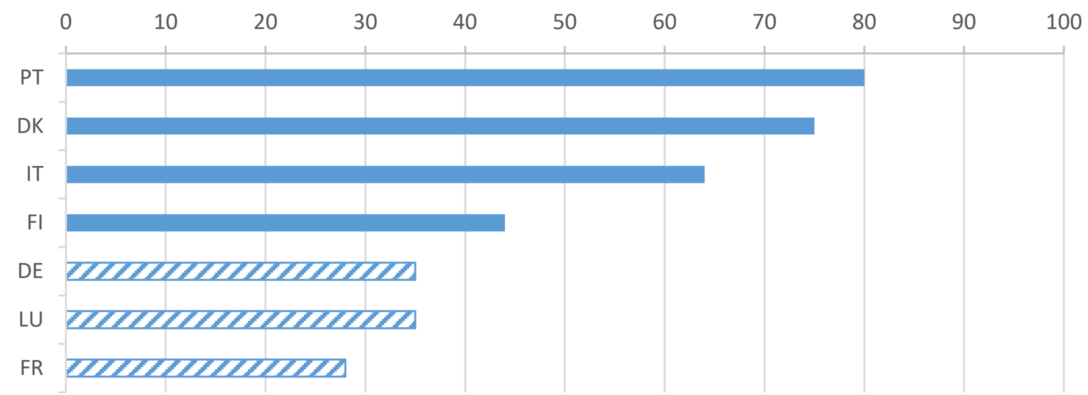
In ICILS 2018, teachers were also asked about their level of agreement or disagreement with a number of statements to gather their views on ICT for teaching and learning[24]. The statements reflected both positive and negative outcomes of using ICT in education. From the responses to the positive statements, we see that teachers display generally positive attitudes to the use of ICT for teaching and learning. When questioned whether ICT 'helps pupils develop greater interest in learning' and 'enables pupils to access better sources of information', more than 80% of the teachers on average across the Member States were in agreement.

We do, however, also see variation across the Member States in the degree of agreement with the positive statements on ICT use. Figure 9 shows teachers in the Member States' response to the statement 'improves academic performance of pupils'. In four out of seven countries less than 50% of the teachers agree that the use of ICT for teaching and learning improves the academic performance of pupils.

23 Presented in table 6.2 of the ICILS 2018 International Report.

24 Presented in tables 6.4 and 6.5 in the ICILS 2018 International Report.

Figure 9: Teachers agreeing that the use of ICT for teaching and learning improves the academic performance of pupils (%)



Source: IEA, ICILS 2018.
Note: Bars with patterns indicate that the country did not met the IEA teacher sample participation requirements.

On the negative statements on the use of ICT for teaching and learning there tends to be agreement across Member States and less variation than on the positive statements. However, only two statements were endorsed by more than half of the teachers across countries[25], namely that ICT use for learning results in 'pupils copying material from the internet' and 'poorer written expression among pupils'.

ICILS 2018 found that **daily use of ICT is associated with a higher reported self-efficacy in ICT amongst teachers**, which was also reported in ICILS 2013. Teachers using ICT for teaching on a daily basis are also more likely to acknowledge the positive outcomes when using ICT for teaching and learning. Correspondingly, daily users of ICT are less likely to recognise negative consequences of using ICT.

3.2 Structural hindrances to learning environments

Responses from school ICT coordinators show that **lack of resources and infrastructure, such as limited connectivity or availability of computers for instruction, are still present in Member States**[26]. In four out of seven Member States, more than 25% of the surveyed pupils were enrolled at schools reported to have too few computers with an internet connection. Another pressing issue is that **in five out of seven Member States more than 50% of the pupils are enrolled at schools reported to not have enough computers for instruction**. **Lack of sufficiently powerful computers, problems in maintaining ICT equipment and not enough computer software are other factors identified as hindering teaching and learning**.

Pedagogical resources is another factor addressed in the ICILS ICT Coordinator survey[27]. The percentage of pupils enrolled at schools where lack of pedagogical resources was identified as hindrances to using ICT for teaching and learning was generally higher compared to the percentage of pupils enrolled at schools where the lack of computer resources were reported as hindrances. **More than 50% of the pupils across the surveyed Member States are enrolled at schools where insufficient ICT skills among the teachers was reported to hinder the use of ICT for teaching and**

25 Teachers in Denmark being the exception, where only the statement 'distracts pupils from learning' was endorsed by more than half the teachers.

26 Presented in table 6.8 of the IEA ICILS 2018 International Report.

27 Presented in table 6.9 of the ICILS 2018 International Report.

learning. In six out of seven countries, insufficient time for teachers to prepare lessons was also reported to affect more than 50% of the enrolled pupils. Other significant hindrances affecting the enrolled pupils in the majority of the Member States include lack of effective professional learning resources for teachers, lack of incentives for teachers to integrate ICT use in their teaching and insufficient pedagogical support for the use of ICT by teachers.

4 Conclusions and implications for education policies

The digital transformation of society affects how people live, interact, study and work to the extent that individuals without digital competence are facing increasing difficulties in everyday life. In addition to becoming a crucial component for individuals' societal functioning and labour market inclusion, digital competence is also held as key to Europe's future innovation capacity, entrepreneurial gains and market competitiveness. The ICILS data contributes to expanding the knowledge base on a topic critical for Europe's future, while at the same time dispelling some of the common myths associated with digital education. Increased knowledge will help identify the areas which should be prioritised when developing and revising EU initiatives such as the Digital Education Action Plan, which will be renewed and extended in 2020[28].

With the identified importance of digital competence in the lifelong learning perspective, there is need for an indicator to capture process aspects related to policies that support the pedagogical use of technologies in Member States in the post 2020 Education and Training Framework. The ICILS computer and information literacy index is the preferred measurement for a meaningful indicator of digital competence, as it provides the only internationally comparable, direct measurement of pupils' digital competence. Supported by the assessment of pupils' computational thinking, and contextual data collected through the pupil, teacher and school surveys, ICILS provides a thorough insight into the status of digital education in participating countries. In the following some of the key findings and their implications for European education policies are summarised.

4.1 Digital divides and the myth of the 'digital native'

Contrary to the common view of the young generation of today as a generation of 'digital natives', findings from the first two cycles of ICILS indicate that young people do not develop sophisticated digital skills just by growing up using digital devices. In 9 out of 14 Member States participating in ICILS, more than one third of the pupils achieved scores below level 2 on the ICILS CIL scale, which can be seen as the threshold for underachievement in digital competence. This highlights the importance of focusing on the development of digital skills through formal education.

The evidence from ICILS should be used strategically to understand which parts of the pupil populations in the EU member States that should be targeted by policy and practical interventions to foster a baseline competence that allows for using digital tools as productive resources for learning and participation in the digital society. This can be exemplified by the presence of a digital divide associated with the socioeconomic status of pupils in the ICILS data. On average across Member States, pupils from higher socioeconomic backgrounds scored significantly higher in computer and information literacy than pupils from lower socioeconomic backgrounds.

28 For more information see the EU Digital Action Plan.

4.2 Gender gaps in digital education

Based on the findings from ICILS, there is a need to address gender gaps in digital competence. On average, female pupils outperform male pupils in computer and information literacy. This is consistent across Member States, and is present in both high and low scoring countries and across the achievement levels of the ICILS scale. The share of male underachievers in computer and information literacy is also substantially higher than the share of female underachievers across Member States. Conversely, the gender gap identified in computer and information literacy is not evident in the results from the assessment of pupils' computational thinking, where male pupils tended to perform better than female pupils. These contrasting results point to the need for more knowledge on the underlying factors influencing the pupils performances, particularly in light of the expected need for digital competence to effectively participate in the digital world.

4.3 Pedagogical use of ICT in schools

Results from ICILS suggests that a holistic approach to the pedagogical use of ICT in school is required. Providing pupils and teachers with ICT equipment is not enough to improve their digital skills. They also have to be encouraged and supported in their use of digital tools. From ICILS we find that teachers' confidence in doing ICT tasks and their attitudes regarding the use of ICT in teaching and learning are important aspects to consider in relation to the development of pupils' CIL and CT skills, as they may influence ICT use in the classroom. SELFIE[29], a tool designed to help schools assess where they stand with learning in the digital age, can aid schools in identifying whether they are making the most of digital technologies for teaching and learning.

29 For more information about the SELFIE platform visit the Education and Training section on the Europa website.

Annex A: The concepts of computer and information literacy (CIL) and computational thinking (CT) as assessed in ICILS

The structure of the computer and information literacy construct and the computational thinking construct in ICILS 2018 consist of different conceptual categories, or 'strands', for framing the skills and knowledge addressed by their respective instruments. The strands can be further subdivided into content categories, or 'aspects' subdivided into content categories, or 'aspects'. Below follows an overview of the structures of the two concepts based on the ICILS 2018 Assessment Framework[30].

Computer and information literacy

The computer and information literacy construct in ICILS 2018 is comprised of four strands, each incorporating two aspects:

Strand 1: Understanding computer use

- Foundations of computer use: this includes the knowledge and understanding of the principles underlying the function of computers rather than the technical detail of exactly how they work.
- Computer use conventions: this includes the knowledge and application of the software interface conventions that help computer users make sense of and operate software.

Strand 2: Gathering information

- Accessing and evaluating information: this refers to the investigative process that enable a person to find, retrieve and make judgements about the relevance, integrity and usefulness of computer-based information.
- Managing information: this refers to the capacity of individuals to work with computer-based information.

Strand 3: Producing information

- Transforming information: this refers to a person's ability to use computers to change how information is presented so that it is clearer for specific audiences and purposes.
- Creating information: this refers to a person's ability to use computers to design and generate information products for specified purposes and audiences.

Strand 4: Digital communication

- Sharing information: this refers to a person's understanding of how computers are and can be used, as well as his or her ability to use computers to communicate and exchange information with others.
- Using information responsibly and safely: this refers to a person's understanding of the legal and ethical issues of computer-based communication from the perspectives of both the publisher and the consumer.

30 Fraillon, J. Ainley, J., Schulz, W., Duckworth, D., Friedman, T. (2019). IEA International Computer and Information Literacy Study 2018: Assessment Framework. Cham: Springer.

Computational thinking

The computational thinking construct in ICILS 2018 is comprised of two strands, the first of which incorporates three aspects and the second which incorporates two aspects:

Strand 1: Conceptualising problems

- Knowing about and understanding digital systems: this refers to a person's ability to identify and describe the properties of systems by observing the interactions of the components within a system.
- Formulating and analysing problems: this refers to the ability to decompose a problem into smaller manageable parts and specifying and systematising the characteristics of the task so that a computational solution can be identified. The analytical part consists of making connections between the properties of, and solutions to, previously experiences and new problems to establish a conceptual framework to underpin the process of braking down a large problem into a set off smaller, more manageable parts.
- Collecting and representing relevant data: in order to make effective judgements about problem solving within systems it is necessary to collect and make sense of data from the system. The process of collecting and representing data effectively is underpinned by knowledge and understanding of the characteristics of the data and of the mechanisms available to collect, organise and represent these data for analysis. This could involve creating or using a simulation of a complex system to produce data that may show patterns or characteristics of behaviour that are otherwise not clear when viewed from an abstract system level.

Strand 2: Operationalizing solutions, comprising two aspects

- Planning and evaluating solutions: the first point refers to the process of establishing the parameters of a system, including the development of functional specifications or requirements relating to the needs of users and desired outcomes and with a view to designing and implementing the key features of a solution. Evaluating solutions refers to the ability to make critical judgements about the quality of computational artefacts, such as code or algorithms, against criteria based on a given model of standards and efficiency.
- Developing algorithms, programs, and interfaces: This aspect focuses on the logical reasoning that underpins the development of algorithms to solve problems.

Annex B: Description of the CIL achievement scale

Level 1 (from 407 to 491 scale points)	
Pupils working at Level 1 demonstrate a functional working knowledge of computers as tools and a basic understanding of the consequences of computers being accessed by multiple users. They apply conventional software commands to perform basic research and communication tasks and add simple content to information products. They demonstrate familiarity with the basic layout conventions of electronic documents.	Pupils working at Level 1, for example: ▪ Open a link in a new browser tab ▪ Use an appropriate communication tool for a particular communicative context ▪ Identify who receives an email by carbon copy (CC) ▪ Identify problems that can result from mass messaging ▪ Record key points from a video into a text-based note taking application ▪ Use software to crop an image ▪ Place a title in a prominent position on a web-page ▪ Create a suitable title for a slide show ▪ Demonstrate basic control of colour when adding content to a simple document ▪ Insert an image into a document ▪ Suggest one or more risks of failing to log out from a user account when using a publicly accessible computer
Level 2 (from 492 to 576 scale points)	
Pupils working at Level 2 use computers to complete basic and explicit information-gathering and management tasks. They locate explicit information from within given electronic sources. These pupils make basic edits, and add content to existing information products in response to specific instructions. They create simple information products that show consistency of design and adherence to layout conventions. Pupils working at Level 2 demonstrate awareness of mechanisms for protecting personal information and some consequences of public access to personal information.	Pupils working at Level 2, for example: ▪ Add contacts to a collaborative workspace ▪ Explain the advantages of using a communication tool for a particular communicative context ▪ Explain a potential problem if a personal email address is publicly available ▪ Associate the breadth of a character set with the strength of a password ▪ Navigate to a URL presented as plain text ▪ Insert information to a specified cell in a spreadsheet ▪ Locate explicitly stated simple information within a website with multiple web-pages ▪ Know that search engines can prioritize sponsored content over non-sponsored content ▪ Differentiate between paid and non-paid search results returned by a search engine ▪ Explain a benefit of citing sources of information obtained from the Internet ▪ Use formatting and location to denote the role of a title in an information sheet ▪ Use the full canvas when laying out a poster ▪ Control the size of elements relative to one another when laying out a poster ▪ Demonstrate basic control of text layout and colour use when creating a slide show ▪ Use a simple web-page editor to add specified text to a web-page

<table>
<tr><th colspan="2">Level 3 (from 577 to 661 scale points)</th></tr>
<tr><td>Pupils working at Level 3 demonstrate the capacity to work independently when using computers as information gathering and management tools. These pupils select the most appropriate information source to meet a specified purpose, retrieve information from given electronic sources to answer concrete questions, and follow instructions to use conventionally recognized software commands to edit, add content to, and reformat information products. They recognize that the credibility of web-based information can be influenced by the identity, expertise, and motives of the creators of the information.</td><td>Pupils working at Level 3, for example:
Identify that a generic greeting in an email suggests that the sender does not know the recipient
Explain the disadvantages of using a communication tool for a particular communicative context
Evaluate the reliability of information presented on a crowdsourced website
Identify when content published on the Internet may be biased as a result of a publisher’s content guidelines or advertising revenue directing content
Explain the purpose of explicitly labelling sponsored content published on the Internet websites
Select relevant information according to given criteria to include in a website
Explain the benefit of a common information organization and retrieval system
Know what information is useful to include when recording a source of information from the Internet
Use generic online mapping software to represent text information as a map route
Select an appropriate website navigation structure for given content
Select and adapt some relevant information from given sources when creating a poster
Demonstrate control of image layout when creating a poster
Demonstrate control of color and contrast to support readability of a poster
Demonstrate control of text layout when creating a presentation</td></tr>
<tr><th colspan="2">Level 4 (Above 661 scale points)</th></tr>
<tr><td>Pupils working at Level 4 select the most relevant information to use for communicative purposes. They evaluate usefulness of information based on criteria associated with need and evaluate the reliability of information based on its content and probable origin. These pupils create information products that demonstrate a consideration of audience and communicative purpose. They also use appropriate software features to restructure and present information in a manner that is consistent with presentation conventions. They then adapt that information to suit the needs of an audience. Pupils working at Level 4 demonstrate awareness of problems that can arise regarding the use of proprietary information on the Internet.</td><td>Pupils working at Level 4, for example:
Evaluate the reliability of information intended to promote a product on a commercial website
Select and use relevant images to represent a three-stage process in a presentation
Select and use relevant images to support information presented in a digital poster
Select from sources and adapt text for a presentation so that it suits a specified audience and purpose
Demonstrate control of colour to support the communicative purpose of a presentation
Use text layout and formatting features to denote the role of elements in an information poster
Create a balanced layout of text and images for an information sheet
Recognize the difference between legal, technical, and social requirements when using images on a website
Create a supplementary title for a graph</td></tr>
</table>

	▪ Explain that passwords can be encrypted and decrypted ▪ Source relevant facts from electronic sources for use in a social media post to generate support ▪ Explain how communication tools can be used to demonstrate inclusive behaviour ▪ Cite the relevant source of information from the Internet when constructing an information product

Annex C: Description of the CT achievement scale

Lower region (below 459 scale points)	
Pupils showing achievement corresponding to the lower region of the scale demonstrate familiarity with the basic conventions of digital systems to configure inputs, observe events, and record observations when planning computational solutions to given problems. When developing problem solutions in the form of algorithms, they can use a linear (step by step) sequence of instructions to meet task objectives.	Pupils working at the lower region of the scale can, for example: ▪ Create a complete but suboptimal route from one location to another on a network diagram; ▪ Partially debug an algorithm that uses a repeat statement by correcting the logic of connected statements; ▪ Create an efficient algorithm that meets all of the given task objectives for a low-complexity problem (i.e., a problem with a limited set of available commands and objectives); and ▪ Create an inefficient algorithm that meets all of the given task objectives for a medium complexity problem (e.g., a problem with multiple objectives best solved using a repeat statement).
Middle region (459 to 589 scale points)	
Pupils showing achievement corresponding to the middle region of the scale demonstrate understanding of how computation can be used to solve real-world problems. They can plan and execute systematic interactions with a system so that they can interpret the output or behaviour of the system. When developing algorithms, they use repeat statements effectively.	Pupils working in the middle region of the scale can for example: ▪ Adapt information shown in a network diagram to create a complete set of instructions comprising at least five steps; ▪ Configure a simulation tool; ▪ Store and compare data collected using a simulation tool; ▪ Debug, with some redundancy in the solution, an algorithm for a high-complexity problem (e.g., a problem with multiple task objectives best solved using repeat and conditional statements); ▪ Create an efficient algorithm that meets all of the objectives for a medium-complexity problem (e.g., a problem with multiple objectives best solved using a repeat statement); and ▪ Create an inefficient algorithm that meets all of the objectives for a high-complexity problem (e.g., a problem with multiple task objectives best solved using repeat and conditional statements).

Upper region (above 589 scale points)	
Pupils showing achievement corresponding to the upper region of the scale demonstrate an understanding of computation as a generalizable problem-solving framework. They can explain how they have executed a systematic approach when using computation to solve real-world problems. Furthermore, pupils operating within the upper region can develop algorithms that use repeat statements together with conditional statements effectively.	Pupils working in the middle region of the scale can, for example: • Explain the value of a digital system for real-world problem solving; • Complete a simple decision tree with the correct use of both logic and syntax; • Debug, with the most efficient solution, an algorithm for a high-complexity problem (e.g., a problem with multiple task objectives best solved using repeat and conditional statements); and • Create an efficient algorithm that meets all of the objectives for a high-complexity problem (e.g., multiple task objectives best solved using repeat and conditional statements).

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