REVIEWING COMPUTATIONAL THINKING IN COMPULSORY EDUCATION IN EUROPE

State of play and recommendations

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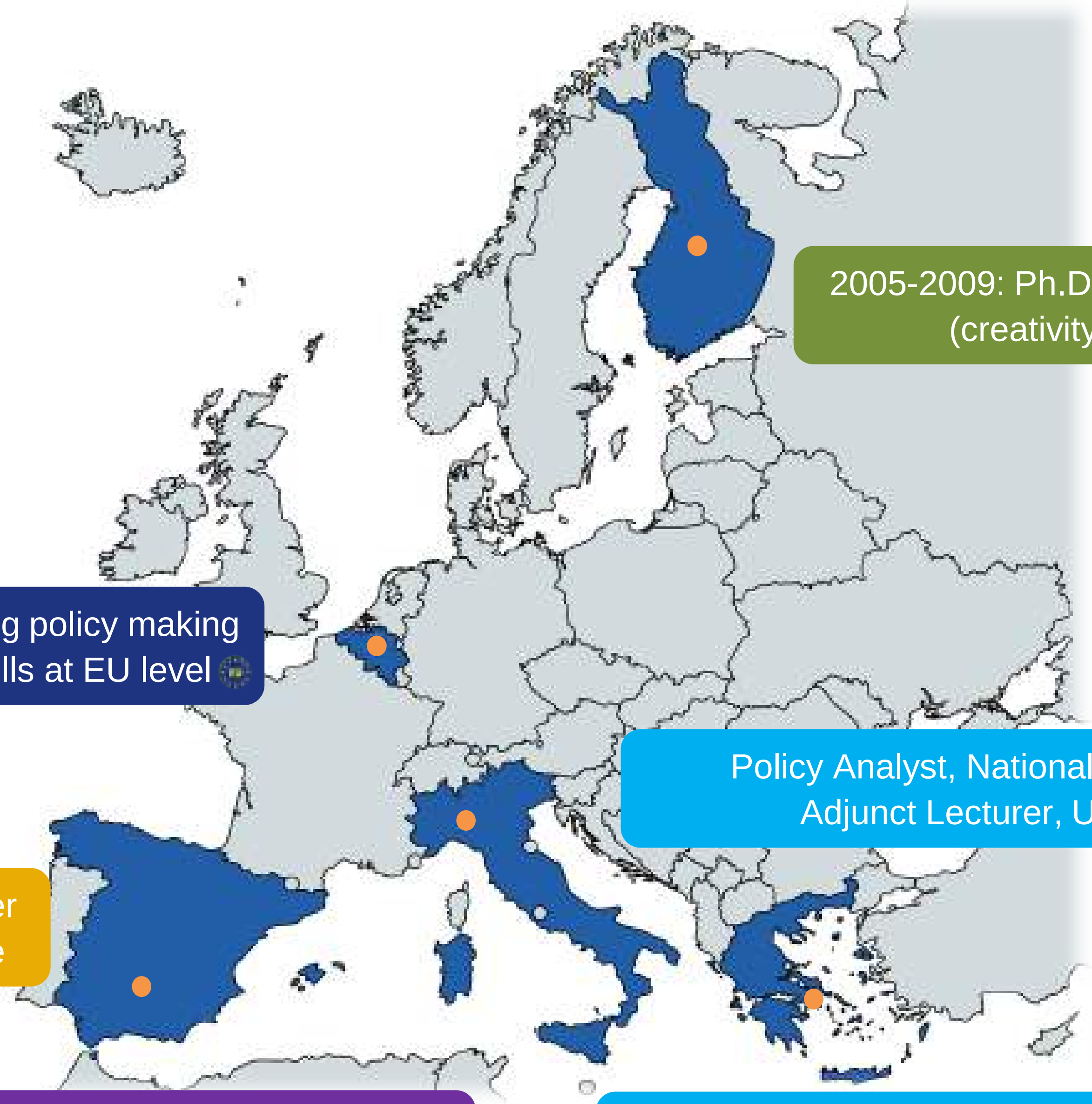


We live in the digital age…

Smart Refrigerator Features

While exact features included will vary by brand and model, here is an overview of some of the many things you never knew a fridge could do. Keep in mind, not all smart refrigerators have the same features.

Use the touchscreen interface to:

- Coordinate schedules for every member of the family.
- Look up recipes and have your fridge read the steps while you cook.
- Create grocery lists that sync to your smartphone in real-time.
- Set expiration dates and receive notifications to use food while it's fresh.
- Upload photos for display.
- Create individual profiles for each family member to send them personal notes and to-do lists.
- Use a whiteboard option to leave messages for your family.
- Transparent touchscreens allow you to look inside the fridge without opening the door.
- Cast from a smart TV in another room to watch from the kitchen.

The touchscreen is not the only novel thing a smart fridge can do. You can also use your smart fridge features to:

- Customize temperature by drawer or compartment.
- Use interior cameras while at the store to double-check if you're low on milk or eggs.
- Alert you when the water filter needs to be changed.
- Turn the ice maker on or off from your smartphone.

7 Strange But (Probably) True Jobs of the Future

Food Engineering

Virtual Tour Filmographer

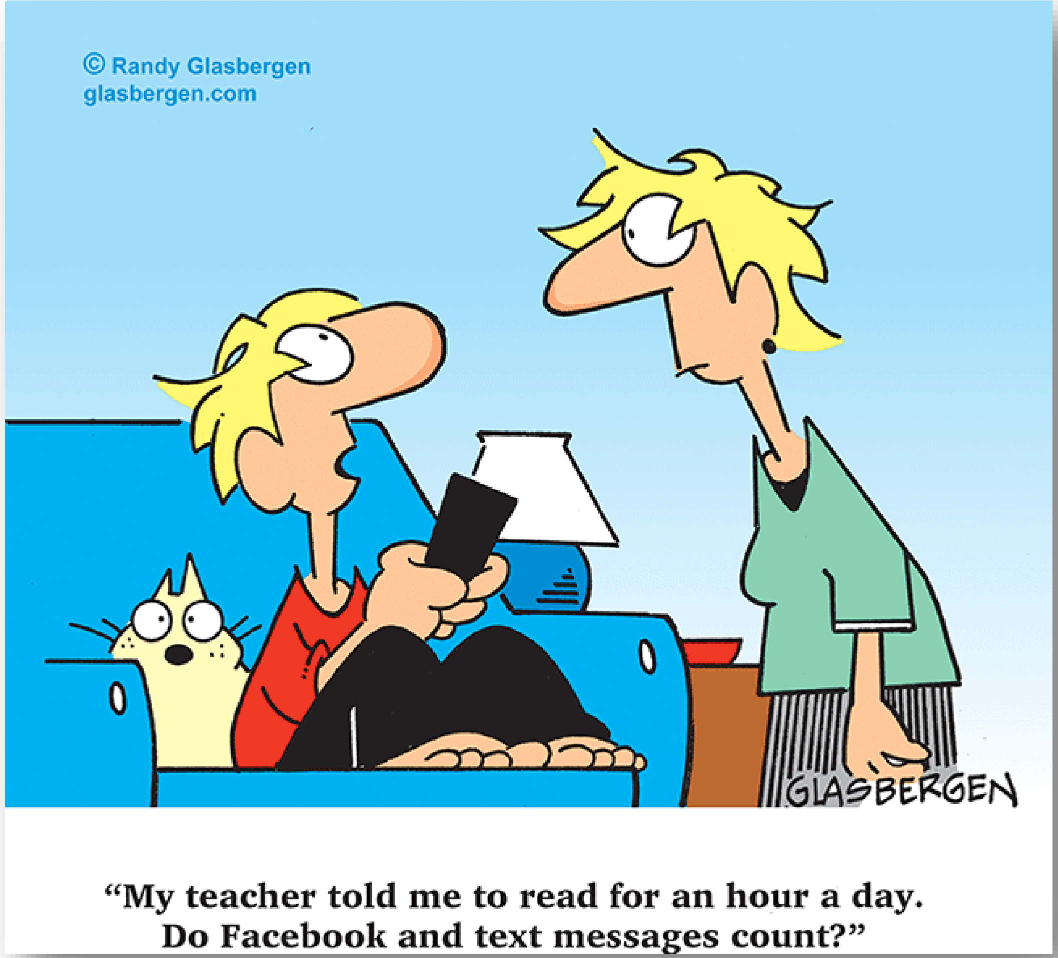
Crowdfunding Organizer

Privacy Specialist

https://www.lifewire.com/smart-refrigerator-4158327

https://www.thejobnetwork.com/7-strange-but-probably-true-jobs-of-the-future/

...but how ready are we?



Does use of technology imply digital competence?

Exposure to technology is NOT enough to make people digitally competent!

nature

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nature › editorials › article

Published: 27 July 2017

The digital native is a myth

Nature 547, 380 (2017) | Cite this article

933 Accesses | 1 Citations | 2412 Altmetric | Metrics

The younger generation uses technology in the same ways as older people – and is no better at multitasking.

Exposure to technology does not make young people digital natives. Credit: Thomas Trutschel/Photothek/Getty

Some people put the cut-off at 1984, but for most it is 1980. People born after that date are

https://www.nature.com/articles/547380a

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ELSEVIER

Teaching and Teacher Education

Volume 67, October 2017, Pages 135-142

The myths of the digital native and the multitasker

Paul A. Kirschner, Pedro De Bruyckere

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https://doi.org/10.1016/j.tate.2017.06.001 Get rights and content

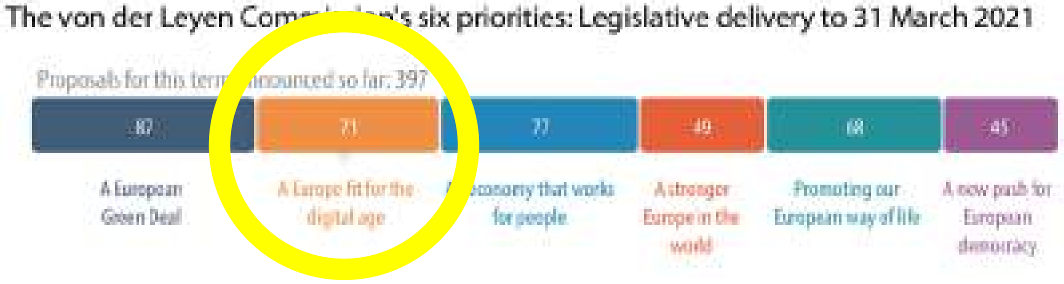
Highlights

- Information-savvy digital natives do not exist.
- Learners cannot multitask; they task switch which negatively impacts learning.
- Educational design assuming these myths hinders rather than helps learning.

https://www.sciencedirect.com/science/article/pii/S0742051X16306692

Digital is one of the eight key competences

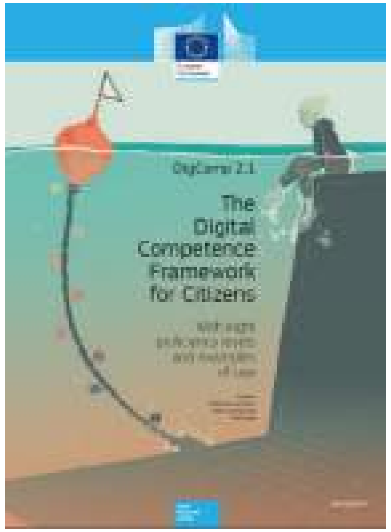
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01)



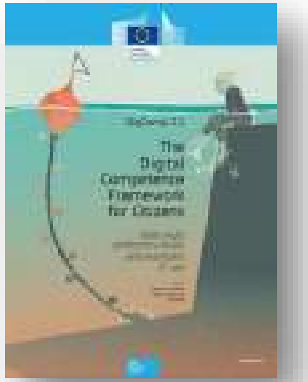
https://www.europarl.europa.eu/RegData/etudes/IDAN/2021/690584/EPRS_IDA(2021)690584_EN.pdf

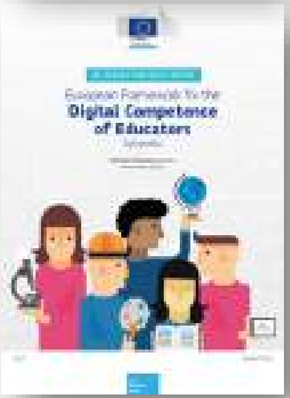
JRC/EC Digital Competence frameworks

- Digital Competence framework for citizens (DigComp) and DigCompSAT
- Digital Competence framework for educators (DigCompEdu) and SELFIE4TEACHERS
- Digital Competence framework for educational organisations (DigCompOrg) and self-reflection tool for general and vocational schools (SELFIE)



Available frameworks and tools

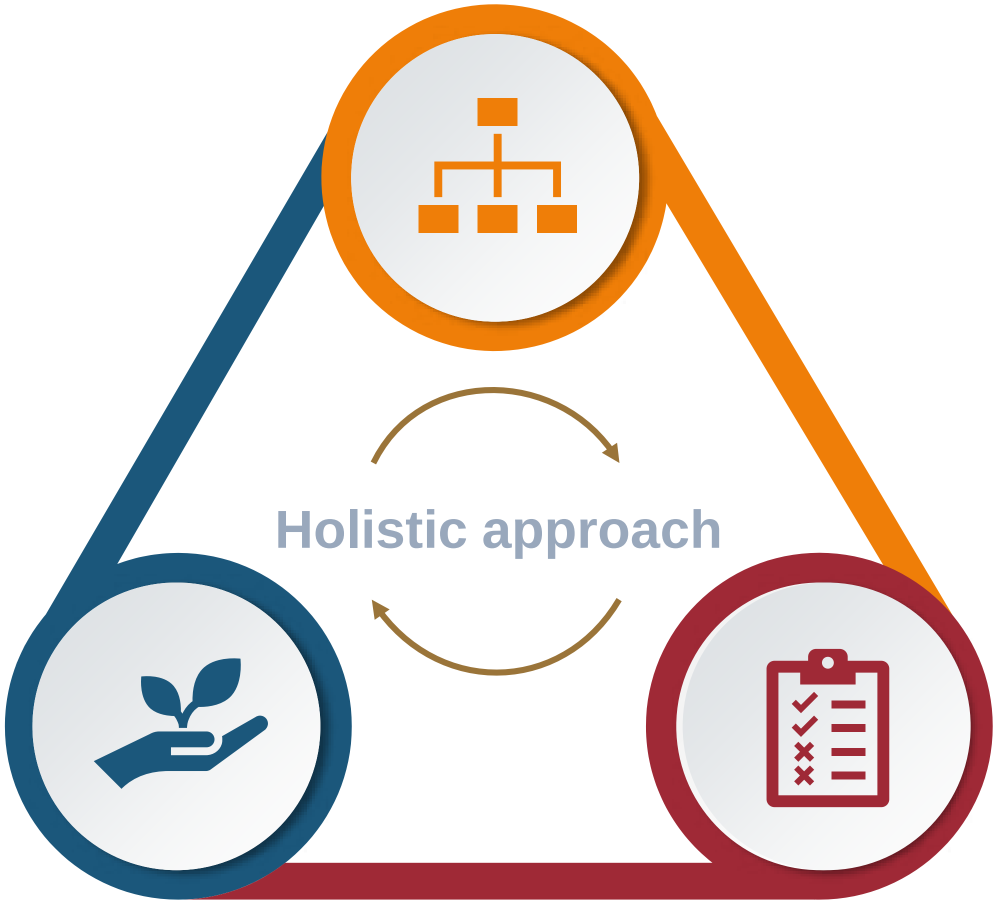




A holistic approach for competence development

Establishing a common language

Conceptual frameworks, working definitions, awareness-raising events, consultations…



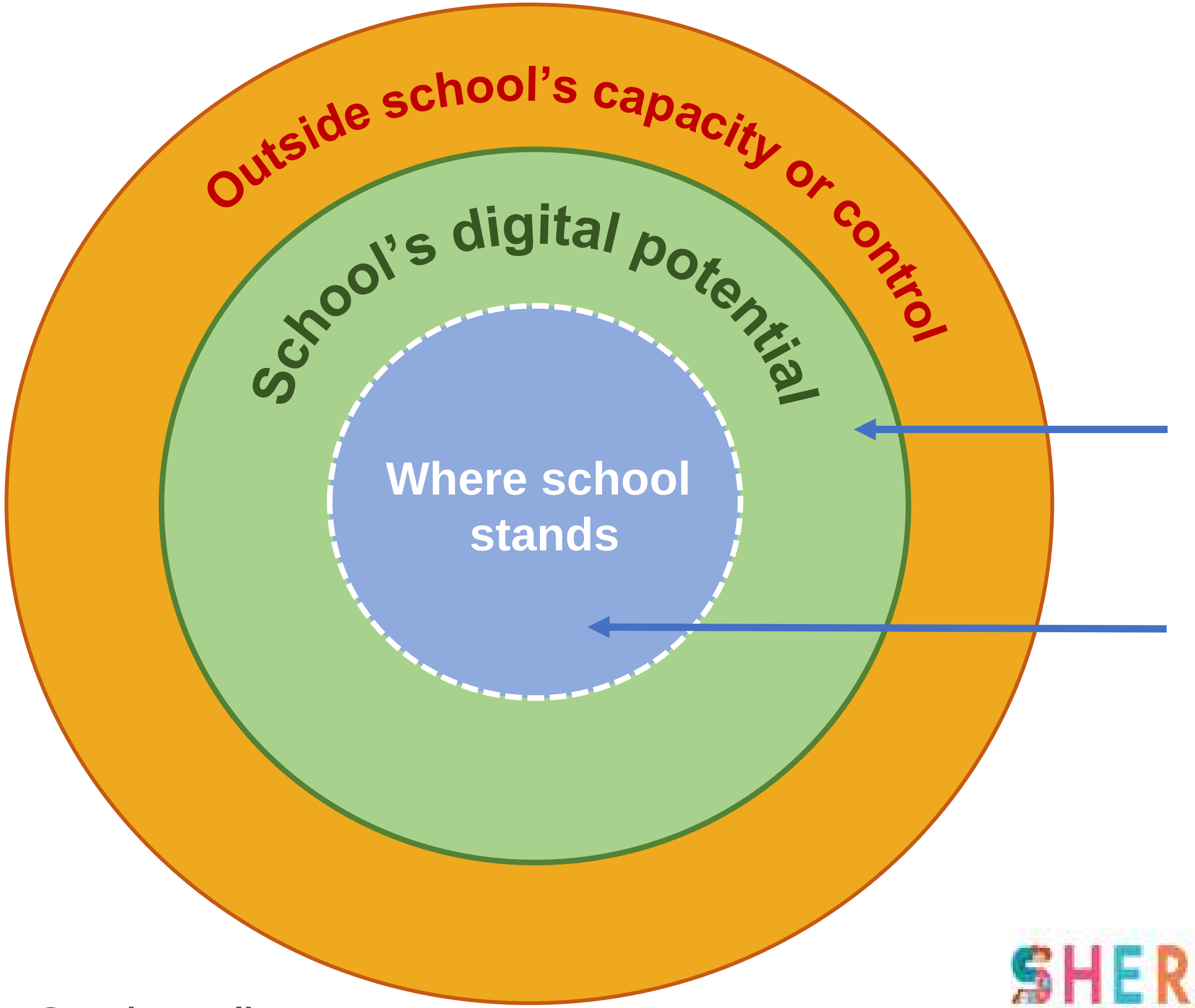
Ecosystem

Regional, national, international level

Capacity building of key stakeholders

Self-assessment/reflection tools, courses…

How to fulfil your [school's] potential



Lev Vygotsky
Zone of proximal development

SELFIE PTK

SELFIE-based action plan

SELFIE

Collective reflection

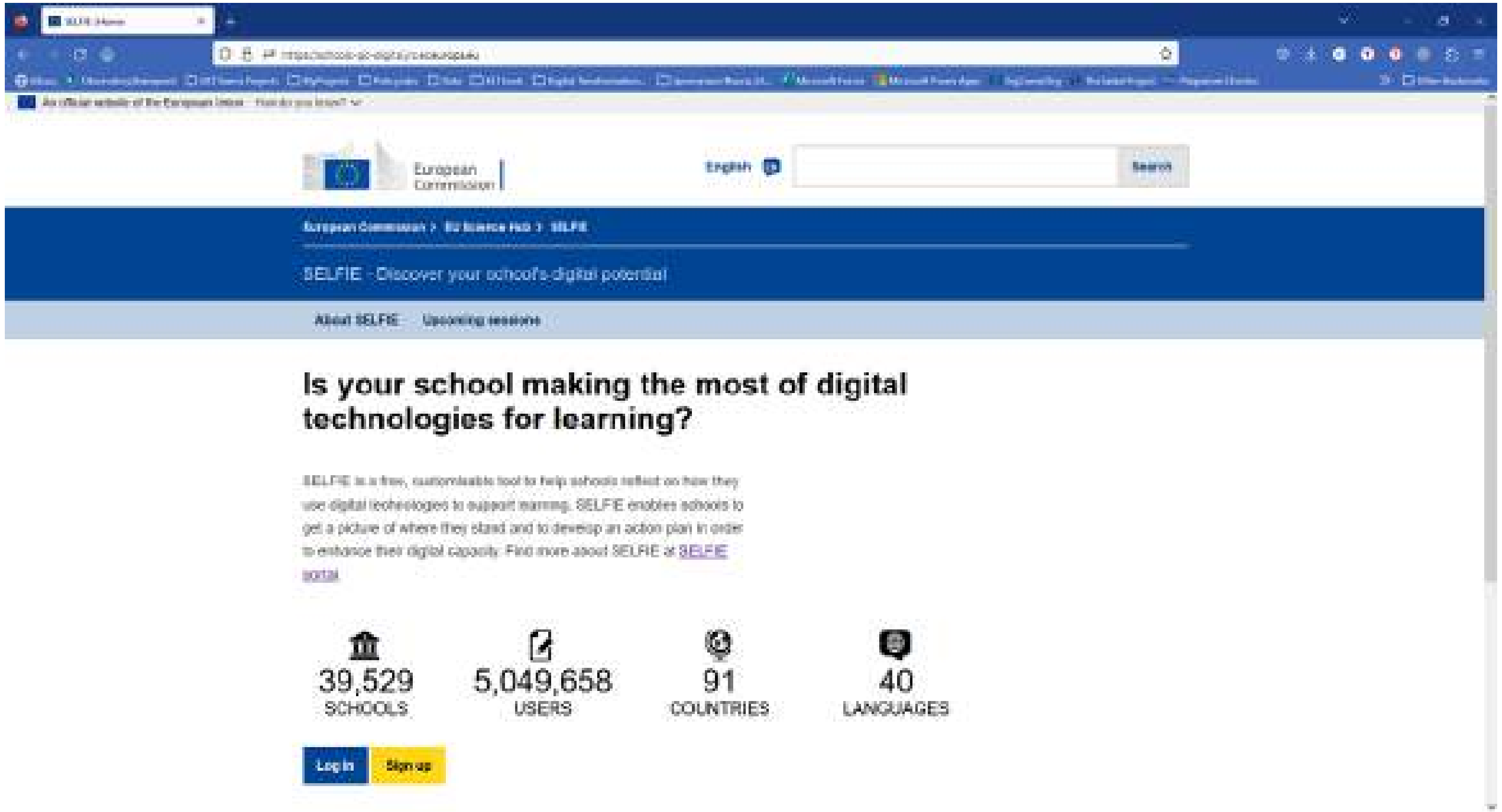
SHERPA
SELFIE HElper & Pedagogical innovation Assistant

https://selfieptk.eu
http://bit.ly/aboutselfieptkmooc

@pankampylis

Brings together different perspectives
(school leaders, teachers, students)

SELFIE for schools



Official EU languages

- български
- español
- Czech
- dansk
- Deutsch
- eesti
- ελληνικά
- English ✓
- français
- Irish
- hrvatski
- Italian
- latviešu
- lietuvių
- Hungarian
- Maltese
- Nederlands
- polski
- português
- română
- slovenčina
- slovenščina
- suomi
- svenska

Other languages

- Albanian
- Azerbaijani
- Basque
- Bosnian
- Catalan
- Galician
- Georgian
- Icelandic
- Kazakh
- Macedonian
- Montenegrin
- Russian
- Serbian
- Turkish
- Ukrainian
- Valencian

SELFIE **takes a snapshot** of the school's use of digital technology. It's **online** and **anonymous**.

In a nutshell

1

ADAPT the tool to your school's context

2

COLLECT views and experiences from school leaders, teachers and students

3

DISCUSS the results & **PLAN** for improvement

4

MONITOR progress and adapt your plan

ABOUT THIS EC-JRC STUDY

- Follow-up to the 2016 EC CompuThink study
- *Focus*: Developments regarding the integration of CT skills into formal compulsory education curricula between 2016 and 2021
- Findings contributing to two upcoming EU Council Recommendations, on ***enabling factors for digital education*** and ***improving digital skills in E&T***

https://education.ec.europa.eu/focus-topics/digital-education/digital-education-action-plan/action-10

Press release | 18 April 2023 | Strasbourg

Commission calls for massive boost in enabling digital education and providing digital skills

Page contents

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Quote(s)
Related media
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Today, the Commission adopted two proposals for a Council Recommendation in the context of the European Year of Skills, with the aim to support Member States and the education and training sector in providing high-quality, inclusive and accessible digital education and training to develop the digital skills of European citizens.

The proposals address the two main common challenges jointly identified by the Commission and EU Member States: 1) the lack of a

Coordinated and funded by **EC – JRC** jointly with **DG EAC**

CNR - ITD

European Schoolnet
Transforming education in Europe

Vilnius University

Related publications

Kampylis, P., Dagiene, V., Bocconi, S., Chioccariello, A., Engelhardt, K., Stupuriene, G., Masiulionyte-Dagiene, V., Jasute, E., Malagoli, C., Horvath, M., & Earp, J. (2023). Integrating Computational Thinking into Primary and Lower Secondary Education: A Systematic Review. *Educational Technology & Society, 26*(2), 99-117. https://doi.org/10.30191/ETS.202304_26(2).0008

Integrating Computational Thinking into Primary and Lower Secondary Education: A Systematic Review

Panagiotis Kampylis[1], Valentina Dagienė[2], Stefania Bocconi[1*], Augusto Chioccariello[1], Katja Engelhardt[3], Gabrielė Stupurienė[2], Vaida Masiulionytė-Dagienė[2], Eglė Jasutė[2], Chiara Malagoli[1], Milena Horvath[3] and Jeffrey Earp[1]

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ABSTRACT: In recent years, many countries have introduced Computational Thinking (CT) concepts into compulsory education as part of general curriculum reform efforts. A systematic review of academic and grey literature has been conducted to analyse the state of the art in implementing CT in primary and secondary education. In total, 1977 publications were identified, out of which 98 met the inclusion criteria for the review. The results show that, despite a lack of consensus on a common definition, a core set of key CT skills is addressed in primary and lower secondary education. Implementation approaches that emerged from the analysis are discussed and presented according to the European Commission's Joint Research Centre (2016) classification: (i) embedding CT across the curriculum as a transversal theme/skill set; (ii) integrating CT as a separate subject; and (iii) incorporating CT skills within other subjects such as Mathematics and Technology. New approaches to formative assessment of CT are emerging, reflecting different conceptualisations and differences in contextual and motivational aspects of CT curriculum integration. However, further investigation is needed to understand better how gender/equity/inclusion issues impact the quality of computing education integration.

Keywords: Computational thinking, Computer Science education, Compulsory education, CT skills

https://computhink2study.eu

https://doi.org/10.30191/ETS.202304_26(2).0008

Coordinated and funded by **EC – JRC** jointly with **DG EAC**

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UNIVERSITAS VILNENSIS 1579

METHODOLOGY

DESK RESEARCH

Systematic literature works review - PRISMA approach

1869 title/abstract screening
1143 academic
726 grey literature works

478 full-text screening

98 in-depth analysis
53 academic
45 grey literature works

SURVEY

21 EU Member States
AT, BE fr & BE nl, CY, CZ, DK, EL, ES, FI, FR, HR, HU, IE, IT, LT, LU, MT, PL, PT, RO, SI, SK

7 non-EU countries
CH, GE, IL, NO, RS, RU, SG

6 topics
e.g., definition of terms

120 new sources
e.g., policy strategy

CONSULTATIONS

20 participants in an expert workshop
International experts from 13 countries

37 participants in an validation workshop
Policymakers, researchers, school leaders and teachers from 23 countries

CASE STUDIES

3 multiple-case studies

9 countries
FI, FR, HR, LT, PL, SE, SK, NO, UK-ENG

38 semi-structured interviews with experts, policymakers, school leaders, teachers

10 focus groups
with 50 students

April 2021 → December 2021

IN-DEPTH CASE STUDIES

Replication strategy	MCS1: CT skills as a cross-curriculum theme at primary level	MCS2: CT skills as part of a separate subject at lower secondary level	MCS3: CT skills within other subjects at lower secondary level
Literal replication	C1 - Lithuania C2 - Norway	C4 - Croatia C5 - Poland	C7 - France C8 - Finland
Theoretical replication	C3 - Slovakia	C6 – UK-England	C9 - Sweden

Multiple-case study methodology (Yin, 2014)

3 multiple-case studies

9 countries
FI, FR, HR, LT, PL, SE, SK, NO, UK-ENG

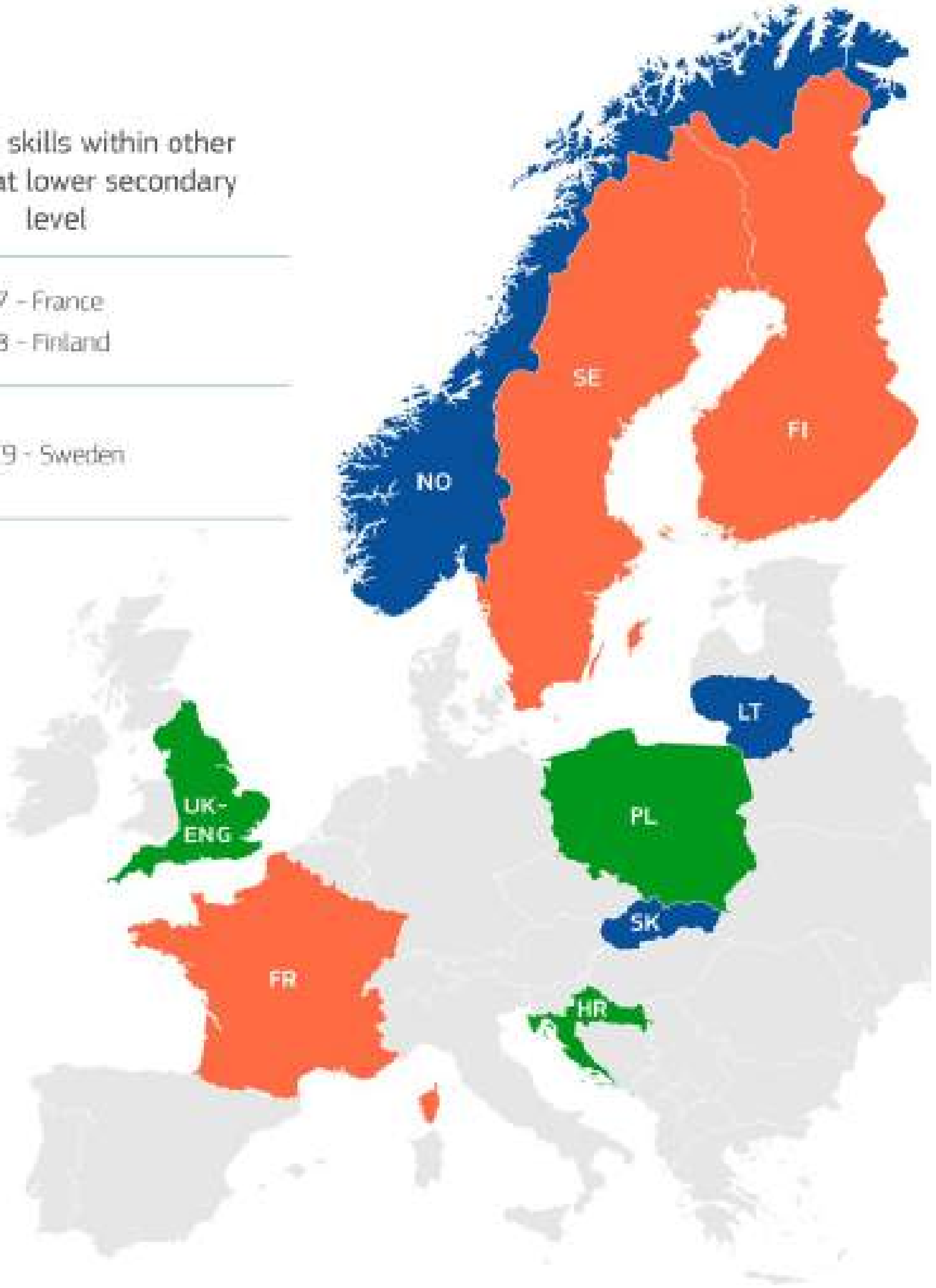
38 semi-structured interviews with experts, policymakers, school leaders, teachers

10 focus groups
with 50 students

MCS1 CT SKILLS AS *CROSS-CURRICULAR THEME* [Primary Education - ISCED 1]

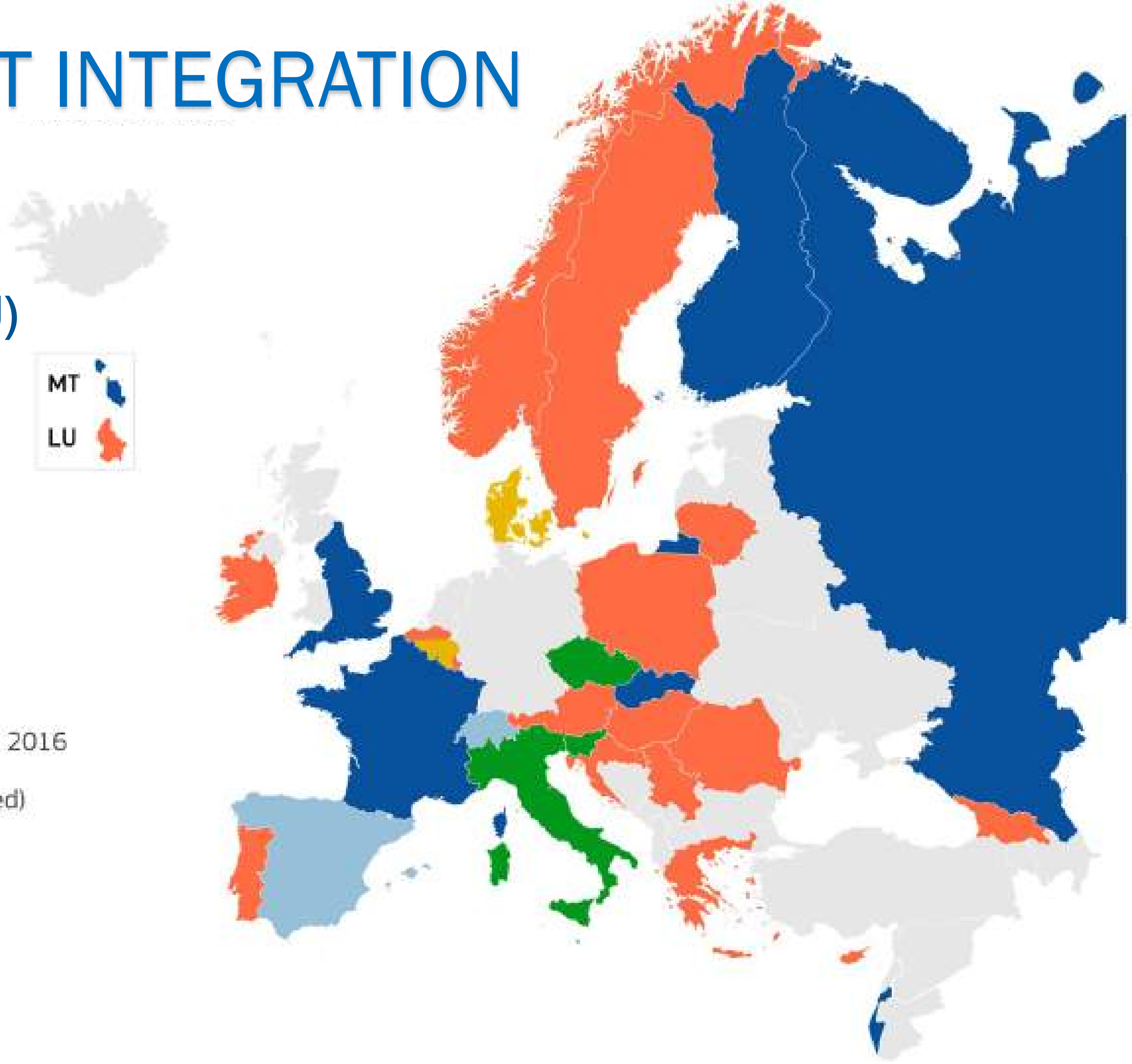
MCS2 CT SKILLS AS *PART OF A SEPARATE SUBJECT* [Lower Secondary - ISCED 2]

MCS3 CT SKILLS *WITHIN OTHER SUBJECTS* [Lower Secondary - ISCED 2]



MAJOR TRENDS IN CT INTEGRATION

- **29 countries analysed**
- **25 countries (18 EU MS & 7 EU)** already included CT in their statutory curriculum



- CT skills in curricula or policy approved or enacted before 2016
- CT skills in curricula or policy enacted from 2016 (included)
- Policy defined at regional level from 2016 (included)
- Draft curricula/policy or ongoing pilots
- CT skills in strategic plans for future actions
- Countries not covered by the survey or case studies

11 recommendations for policy & practice

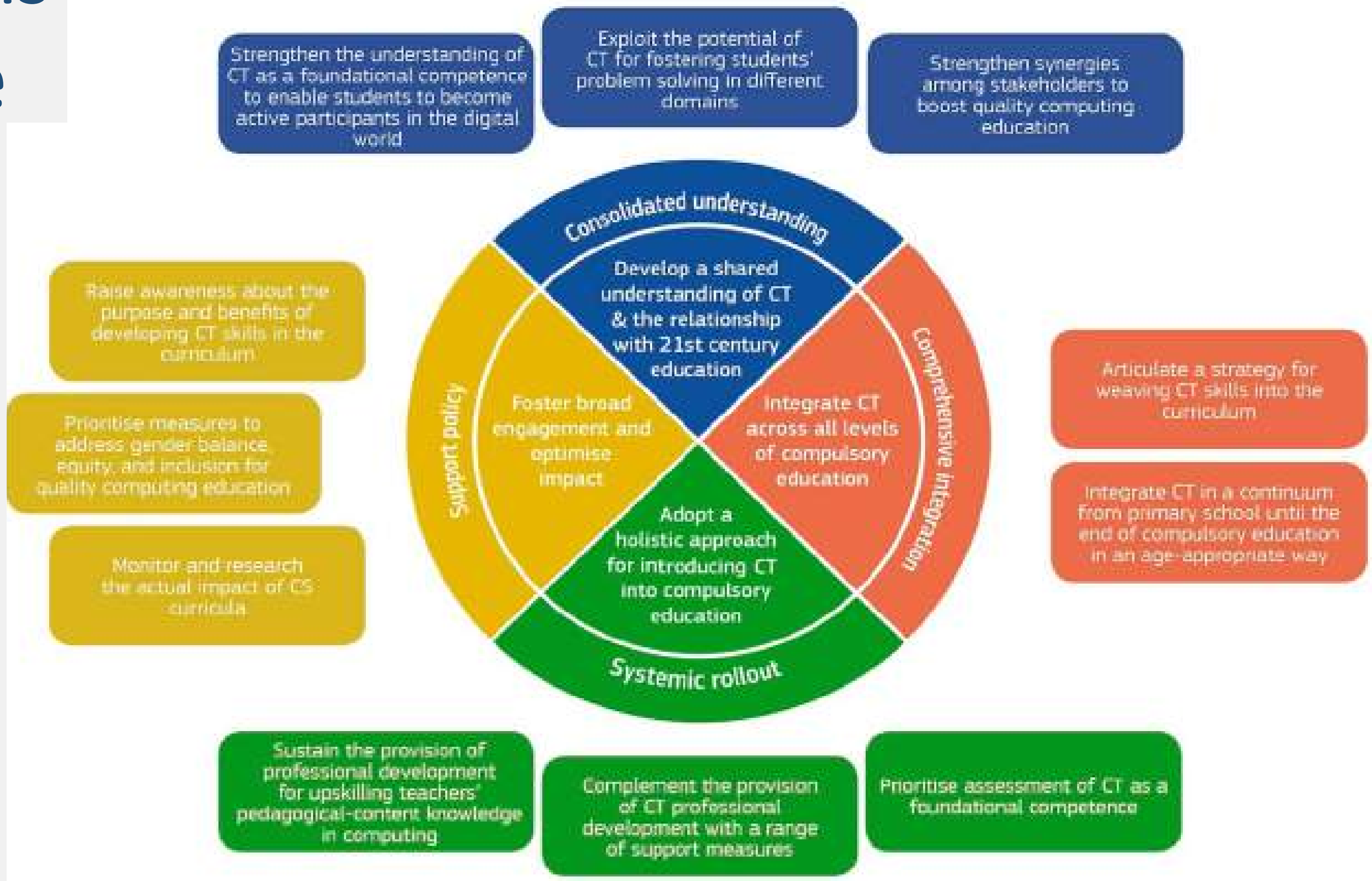
Four main areas:

#1 Consolidated understanding

#2 Comprehensive integration

#3 Systemic rollout

#4 Support policy



#1 Consolidated understanding of CT core skills & link to digital skills

KEY TERMS ADOPTED

Great variety of terms still used by stakeholders…

(image from CompuThink report 2016)

…Differences in definition have implications for how CT is taught and assessed

PROGRAMMING

PROBLEM SOLVING

DIGITAL COMPETENCE

KEY TERMS ADOPTED

Great variety of terms still used by stakeholders…

(image from CompuThink report 2016)

Computing education

encompasses basic *Computer Science* concepts (i.e., algorithms and programming) for developing *Computational Thinking skills.*

Computer Science

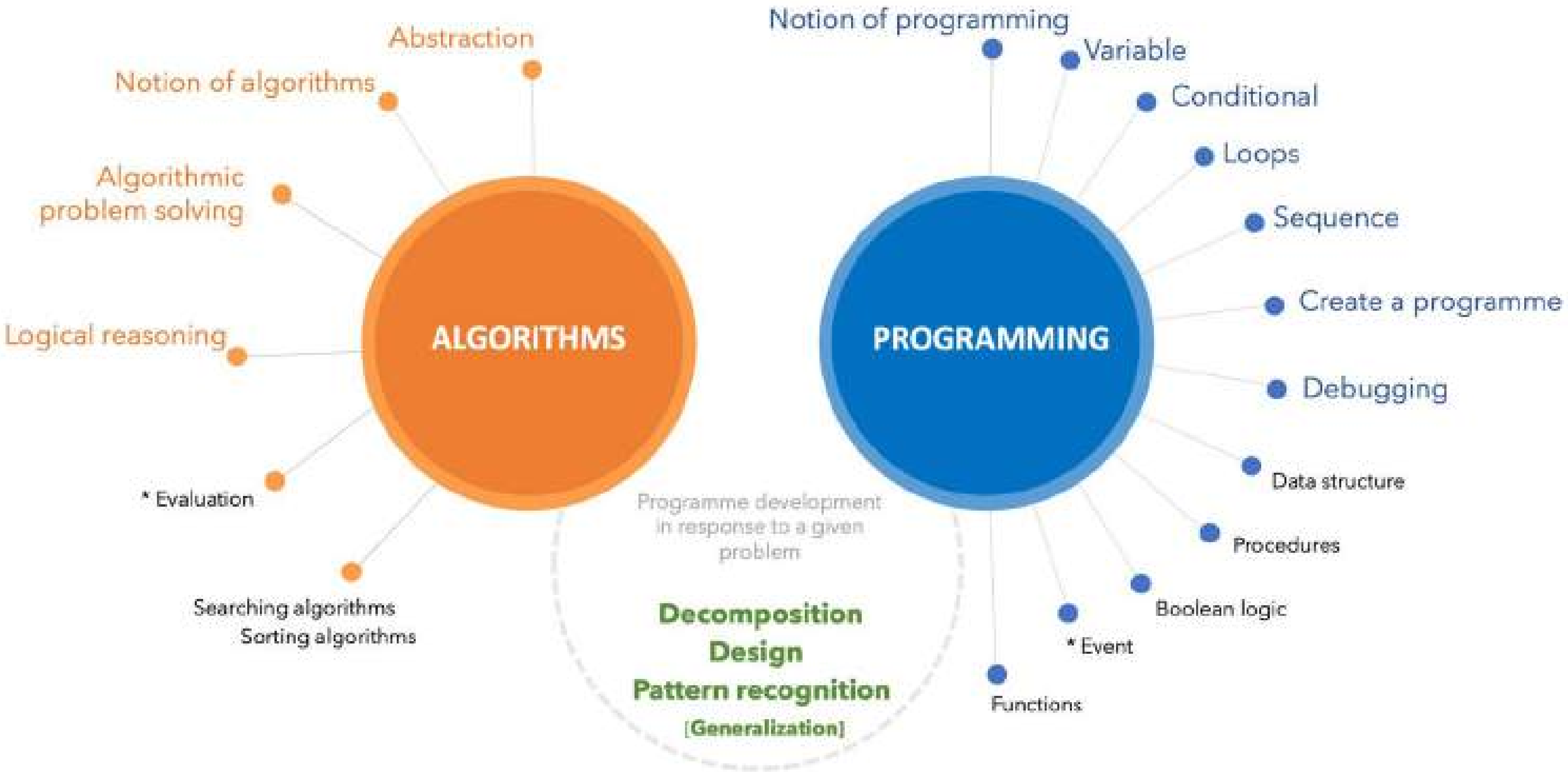
is used interchangeably with *Computing* and *Informatics*, in line with the European Commission's Digital Education Action Plan 2021-2027.

Computational Thinking skills

encompasses abstraction, algorithmic thinking, automation, decomposition, debugging and generalization (2016 EC Computational Thinking Study, Bocconi et al, 2016 p.18)

CS CONCEPTS SUPPORTING CT SKILLS

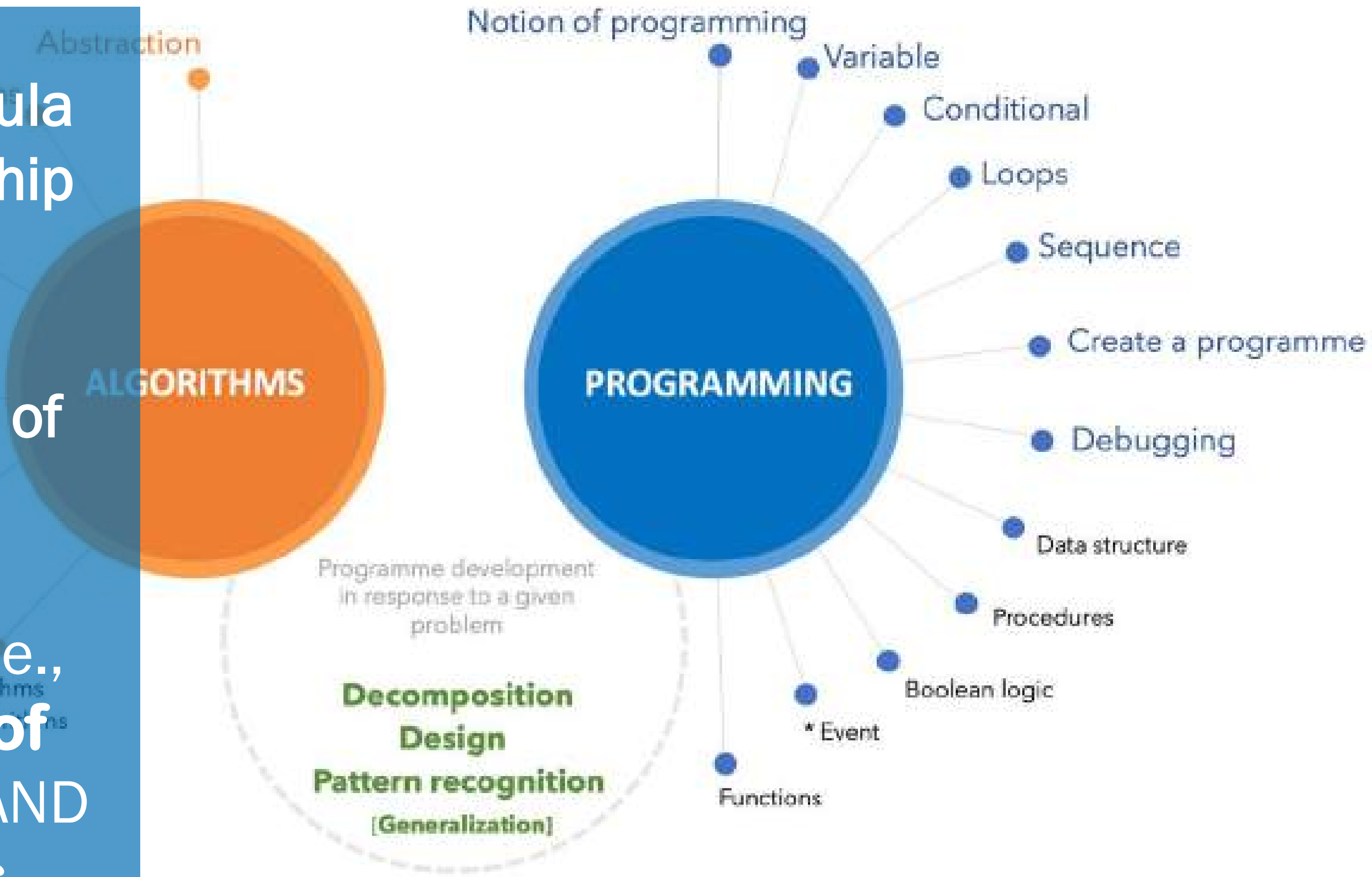
FROM 9 CASE-CURRICULA



CS CONCEPTS SUPPORTING CT SKILLS

FROM 9 CASE-CURRICULA

- Basic CS concepts in curricula centre around the relationship between “**Algorithms**” & “**Programming**”
- Addressed at different level of age-appropriate complexity
- CT skills developed through problem solving activities, i.e., **formulation and design of the solution** (algorithms) AND **implementation process** (programming)



CASE 9: SWEDEN

Mathematics

Aims: to develop knowledge in using digital tools and programming to explore problems and mathematical concepts.

Grades 7 - 9

Core content: *Algebra*

- How algorithms can be created and used in programming.
- Programming in different programming environments.

Core Content: *Problem Solving*

- How algorithms can be created, tested and improved when programming for mathematical problem-solving.

Technology

Aims: to develop students' technical expertise and technical awareness so that they can orient themselves and act in a technologically intensive world; to deal with technical challenges in a conscious and innovative way.

Grades 7 - 9

Core Content: *Technological solution*

- Technical solutions that use electronics and how they can be programmed.

Core Content: *Working methods for developing technological solutions*

- Pupils' own constructions in which they apply control and regulations, including with the aid of programming.

Core Content: *Technology, man, society and the environment*

- The internet and other global technical systems. The benefits, risks and limitations of these systems.
- The relationship between technological development and scientific progress. How technology has enabled scientific discoveries to be made, and how science has made possible technological innovations. Security when using technology, for example storing and protecting data.
- How cultural attitudes towards technology have an impact on men's and women's choice of occupation and use of technology.

Civics

Aims: to understand the importance of digitalisation for social development and for personal integrity.

Grades 7 - 9

Core content: *information and communication*

- The role of the media in disseminating information, forming public opinion, as a source of entertainment and to scrutinise society's power structures.
- Different kinds of media, their structure and context, for example social media, websites and daily newspapers.
- Different types of media, their structure and content, such as the different parts of a newspaper. How individuals and groups are portrayed, e.g., on the basis of gender and ethnicity, and how information in digital media can be controlled by underlying programming.
- Opportunities and risks associated with the internet and digital communication, and how to act responsibly when using digital and other media with reference to social, ethical and legal aspects.

CASE 9: SWEDEN

Mathematics

Aims: to develop knowledge in using digital tools and **programming** to explore problems and mathematical concepts.

Grades 7 - 9

Core content: *Algebra*

- How **algorithms** can be created and used in **programming**.
- **Programming** in different **programming** environments.

Core Content:

- How alg
  problem

Technology

Aims: to develop students' technical expertise and technical awareness so that they can c
challenges in a conscio

Digital Comptence/Literacy contents

Grades 7 - 9

Core Content: *Technological solution*

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Core Conten

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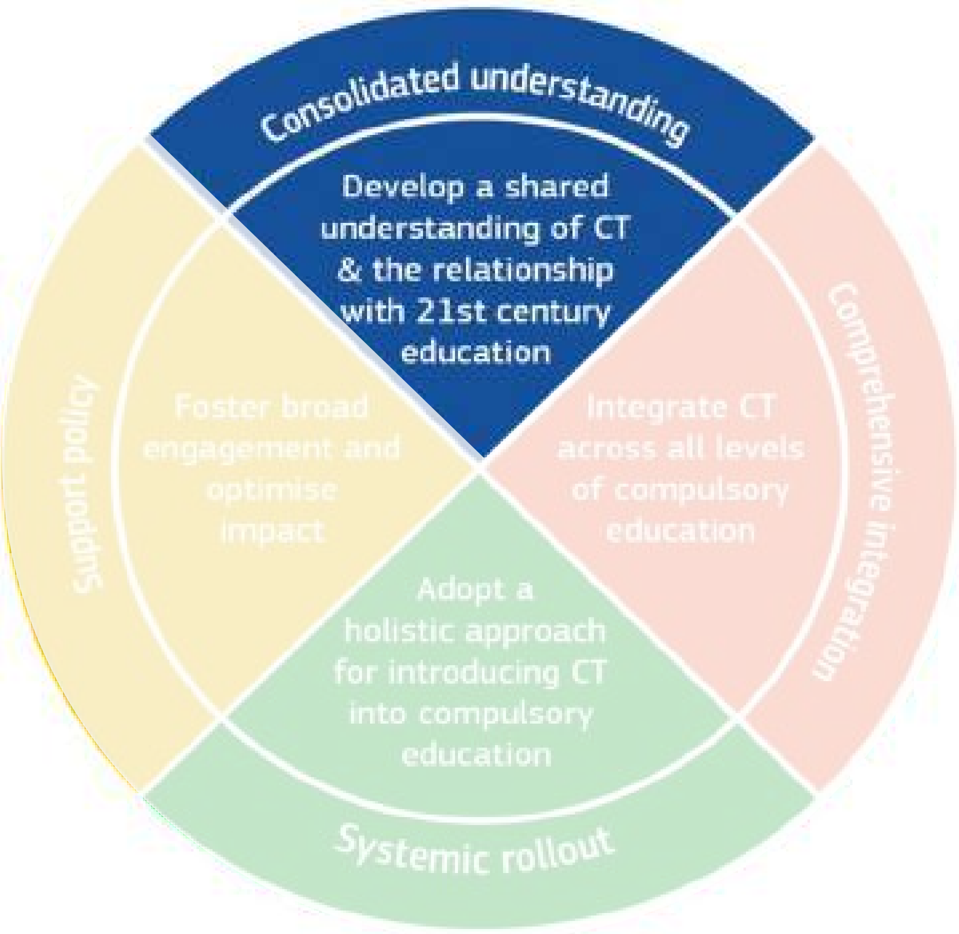
- Opportunities and risks associated with the internet and digital communication, and how to act responsibly when using digital and other media with reference to social, ethical and legal aspects.

CASE 5: POLAND

Subject name: *Informatyka*

[EN:Computer Science]

Learning objectives of the Computer Science subject	Grades 4-6:	Grades 7-9
• To understand, analyse and solve problems based on **logical** and **abstract thinking**, **algorithmic thinking** and ways of representing information. • **Programming** and problem solving using a computer and other digital devices: arranging and **programming algorithms**, organizing, searching for and providing access to information, using computer applications. • Using a computer, digital devices and computer networks, including knowledge of the principles of digital devices and computer networks, and performing calculations and programs. • Developing social skills, such as communication and cooperation in a group, including in virtual environments, participation in team projects, and project management. • To respect the law and safety rules. Respect the privacy of information and data protection, intellectual property rights, etiquette in communication and norms of social coexistence, assessing risks associated with technology and their consideration for the safety of themselves and others.	• Understanding, analysing and solving problems: create and organize as a **sequence** (linear) or tree (non-linear) information, formulate and write in the form of **algorithms instructions**, distinguish basic steps in **algorithmic problem solving**. • **Programming** and problem-solving using computer and other digital devices: design, create and write in a visual **programming** language, **test the program** on a computer for compliance with the adopted assumptions and correct if necessary (**debug**), prepare and present solutions to problems, use text and graphics editors, gather, organise and select the results of the work and the necessary resources on the computer or in virtual environments. • Using the computer, digital devices and computer networks: use devices to record images, sounds and videos, to collect, organise and select personal resources, use the network to find needed information and educational resources, navigating between sites, as a communication medium, to work in a virtual environment. • Developing social skills (equality in access to technology, collaboration, team problem solving). • Observance of the law and safety rules (health and safety rules, digital rules, IPR).	Understanding, analysing and solving problems: formulate a problem in the form of a specification (i.e. describes **data** and results) and distinguished steps in **algorithmic problem solving**, applies basic **algorithms** in solving problems (e.g. searching and ordering), represent **logical values**, numbers, signs and text in a computer, perform experiments with **algorithms**, present examples of applications of computer science in other fields. • **Programming** and problem-solving using computer and other digital devices: **design, create and test programs** in the process of problem solving (**conditionals** and **iterative instructions**, **functions** and **variables**, and **array** designs); **design, develop and test** software to control a robot, use computer applications, prepare documents, save results and **data**, search for information on the web. • Using the computer, digital devices and computer networks: diagram the structure and functioning of a computer network, use various devices to create digital resources, correctly use CS terminology. • Developing social skills: take part in various forms of cooperation (e.g. programming in pairs or in a team), critically assess information, identify the range of IT competences necessary for different professions. • Observance of the law and safety rules: describes ethical issues and act ethically, distinguish between types of licences.



#1 Strengthen the understanding of CT as a foundational competence

- Take appropriate measures so that relevant educational stakeholders, **school inspectors** and **evaluation agencies** have a consolidated understanding of CT as a foundational competence.

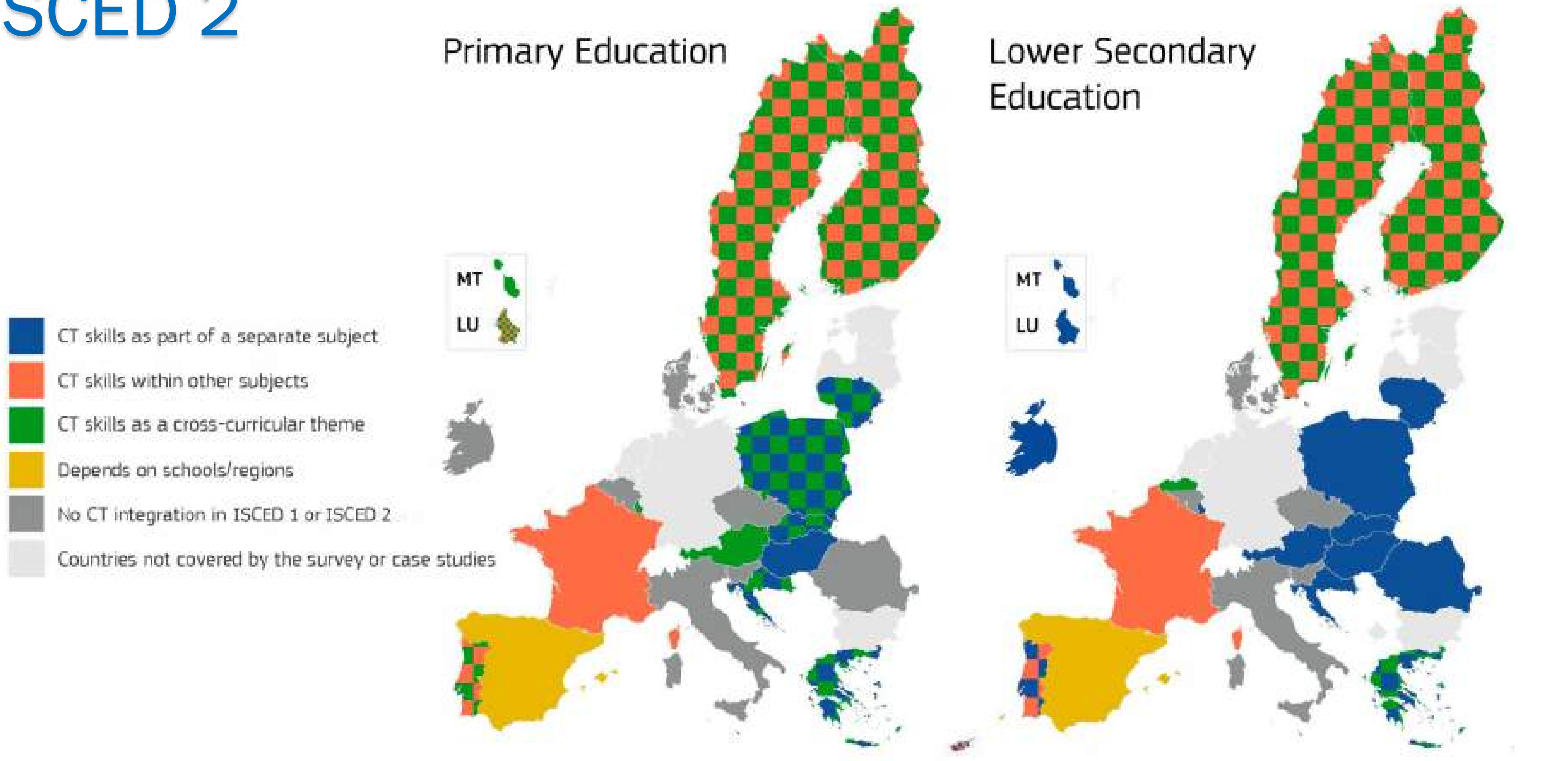
#2 Exploit the potential of CT for fostering students' problem solving in different domains

- Regardless of the CT integration approach in curricula, prioritise the areas that can benefit most from creating connections between computational approaches and essential characteristics of the application domain

#3 Strengthen synergies among stakeholders to boost quality computing education

#2 Comprehensive integration of CT core skills across all levels

17 EU countries included CT in both ISCED 1 and ISCED 2



FACTORS AFFECTING IMPLEMENTATION

➢ Type of CT integration approach adopted at a specific education level

Basic CS concepts **first need to be developed in the context of a specific subject**, and only later applied across disciplines (i.e. *cross-curricular approach* coupled with *separate subject* or *within other subjects* approaches mostly at primary level)

- **E.g., abstract components of CS** developed in **Maths**, whereas physical computing (e.g., robots) in Tech, together with elements of digital competence

➢ Amount of time dedicated to develop CT core skills

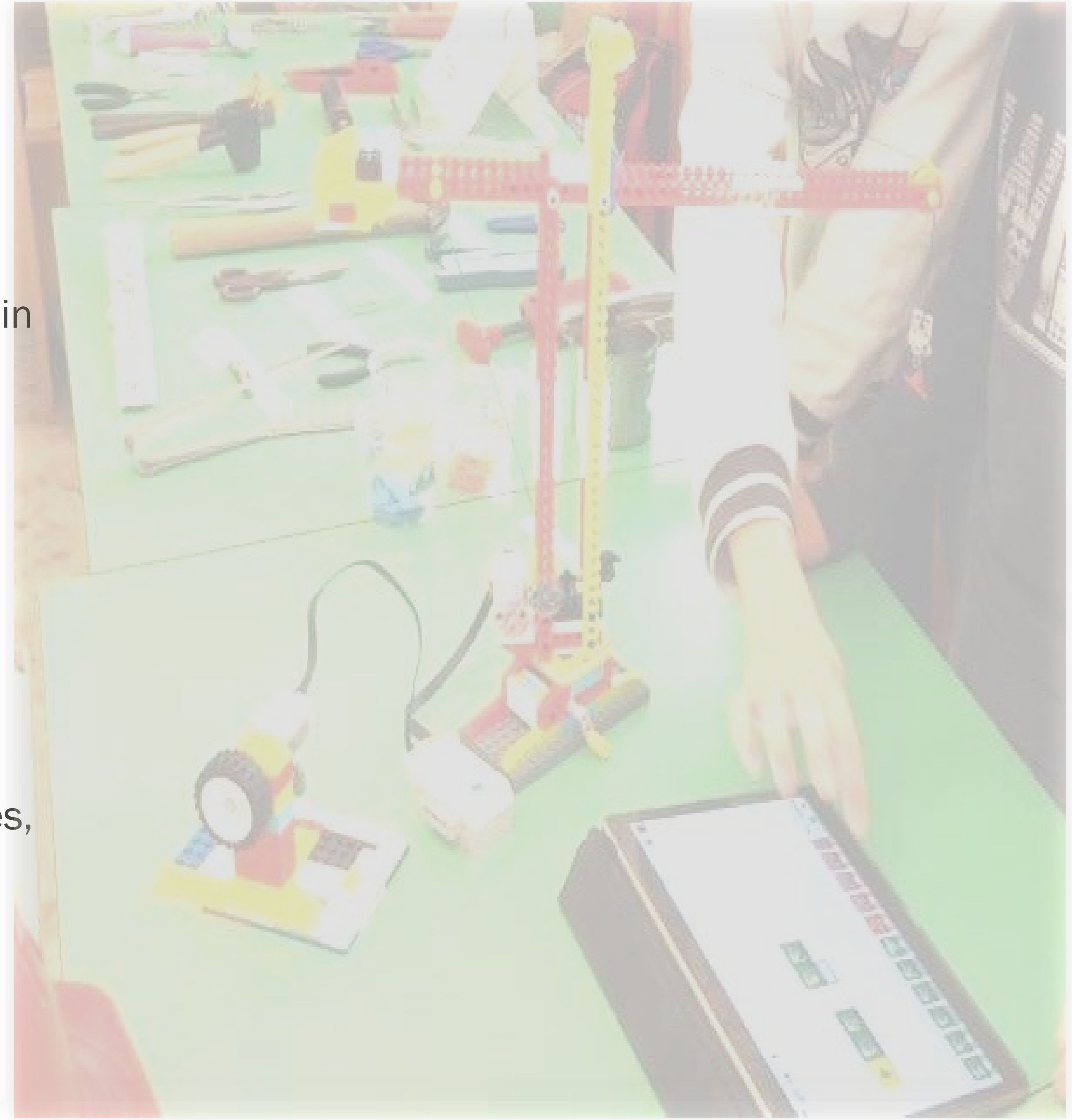
- *Within other subjects:* CS concepts addressed ***< 1h per week*** *depending on* two inter-related aspects:

  (i) overall time allocated to the subjects involved (e.g. Math), and

  (ii) content load to be addressed within those subjects

- *As a separate subject:* CS concepts PLUS digital competence/literacy concepts addressed: ***1h per week***

Age-appropriate way

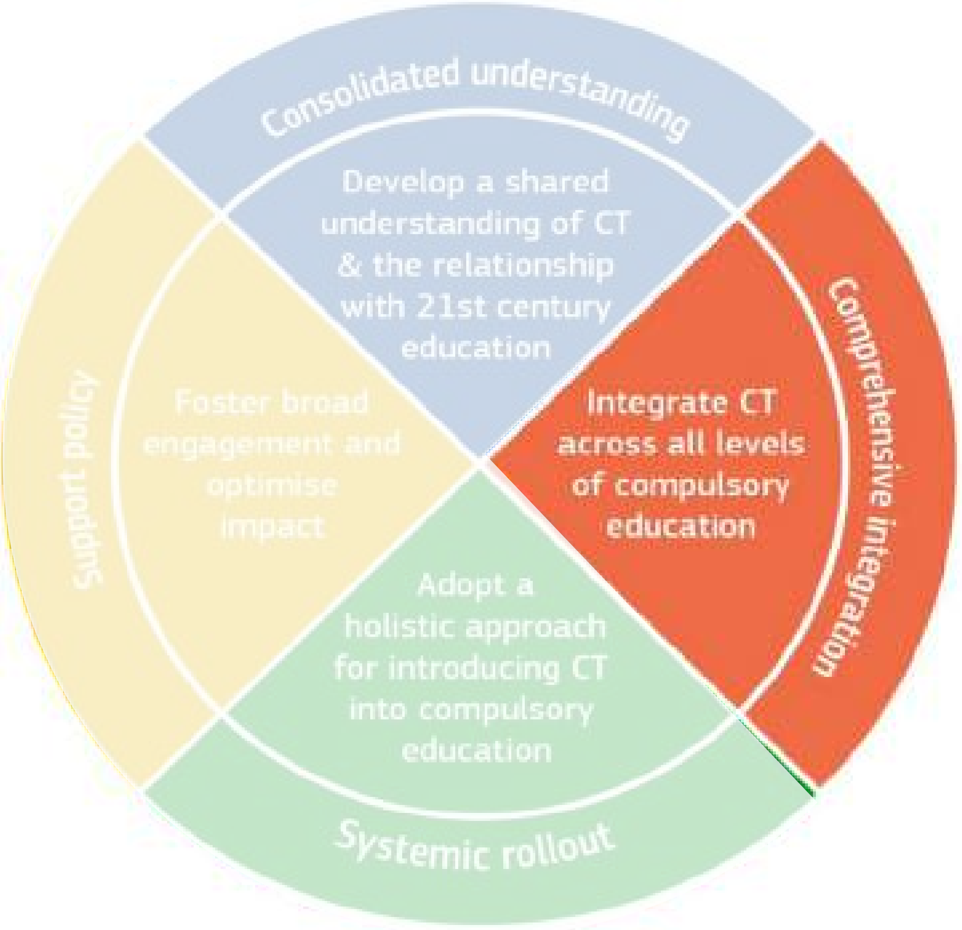


At the primary level (ISCED 1)

- playful learning, learning by doing and working in small groups.
- hands-on, playful activities with programmable robots and block-based **visual programming** environments.

At the lower secondary level (ISCED 2)

- fostering problem-solving and logical thinking skills
- promoting student autonomy/agency through project-based learning, game-based approaches, pair-programming
- **text-based languages**.



#4 Articulate a strategy for weaving CT skills into the curriculum

- **make space** in the curriculum for developing CT skills
- Set a minimum number of hours for the regular teaching of CS concepts.
- allocate resources for developing **high-quality instructional material** and examples of pedagogical practices
- provide sustained funding to ensure **suitable digital equipment** is available in all schools to support programming

#5 Integrate CT in a continuum from primary school till the end of compulsory education in an age-appropriate way

- define a clear vision for the integration of CT starting in primary education, as well as for facilitating students' readiness to use CT skills in other domains.

#3 Systemic roll-out

Main challenges in in-service teacher training

- **Upskilling teachers on CS contents and related pedagogy**

  - Quality training involving medium and long-term, regular interventions
  - Qualitative methodological support on how to handle the progression in teaching basic CS concepts in an age-appropriate way
  - Measures to support teachers' participation in in-service training courses (e.g. provision of replacement teachers)

- **Activate peer-support actions among teachers**
- **High-quality teaching and learning materials provided by different sources**
- **Sustain school hubs for mutual support**

Integration of CT skills in summative and final assessment

CT conceptualisation and strands in **ICILS CT 2018 framework**

Computational thinking refers to 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 problems so that the solutions could be operationalised with a computer.

Strand 1: *Conceptualising problems*

Aspect 1.1
Knowing about and understanding digital systems

Aspect 1.2
Formulating and analysing problems

Aspect 1.3
Collecting and representing relevant data

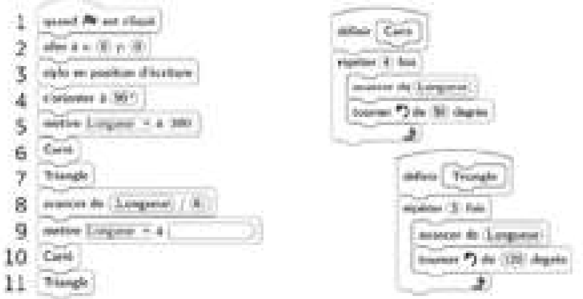
Strand 2: *Operationalising solutions*

Aspect 2.1
Planning and evaluating solutions

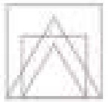
Aspect 2.2
Developing algorithms, progams and interfaces

Exercise 6 (16 points)

The lengths are in pixels.
The expression "point in direction 90" (s'orienter à) means that you are facing to the right.
The following program is given:



1. The scale is 1 cm for 50 pixels.
   a. Show on your copy the figure obtained if the program is executed up to and including line 7.
   b. What are the coordinates of the pen after running line 8?
2. The complete program is executed, and the figure below is obtained which has a vertical axis of symmetry.



Copy and complete line 9 of the program to obtain this figure.

3.
   a. Among the following transformations (translation, homothety, rotation, axial symmetry), which one allows you to obtain the small square from the large square? Specify the reduction ratio.
   b. What is the ratio of the areas between the two squares drawn?

CT Test item included in the French Diplome National du Brevet for Mathematics (2018 session)

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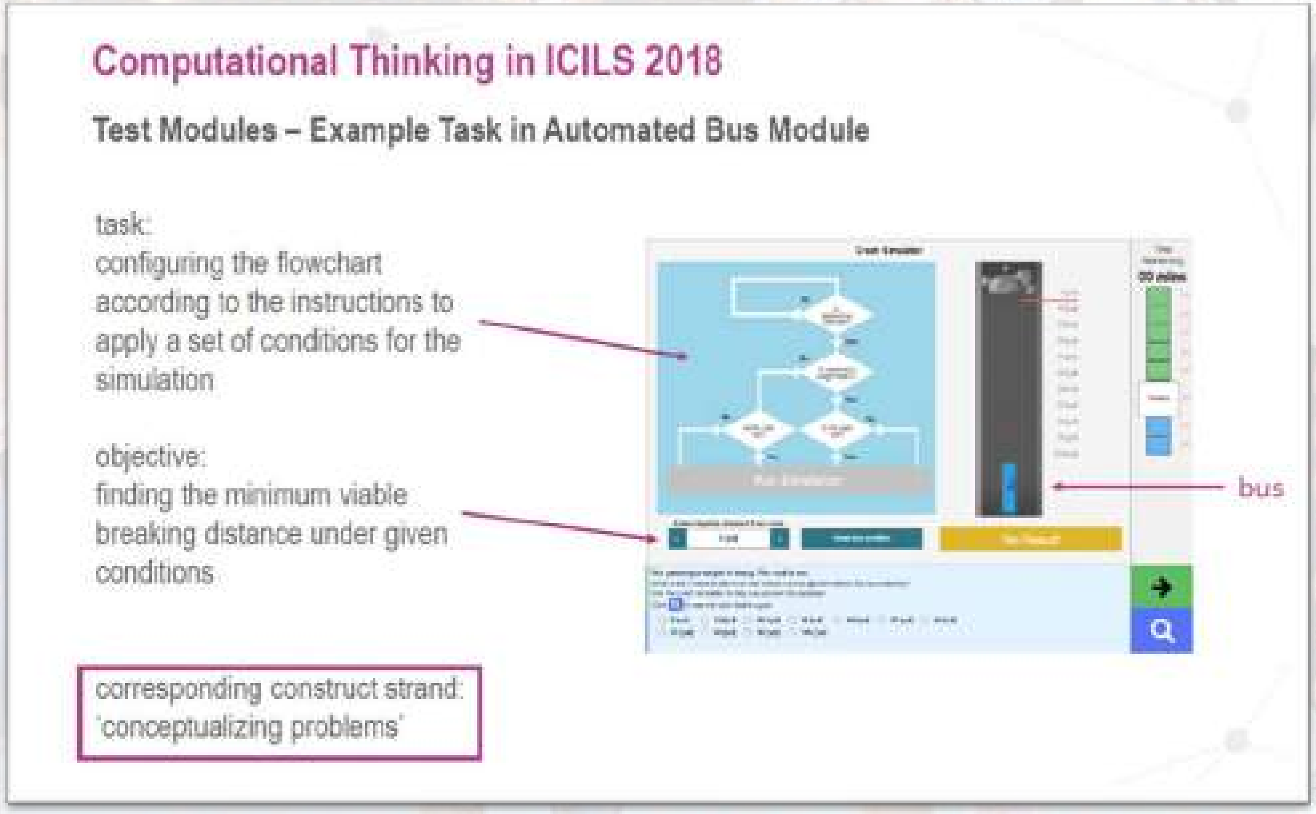

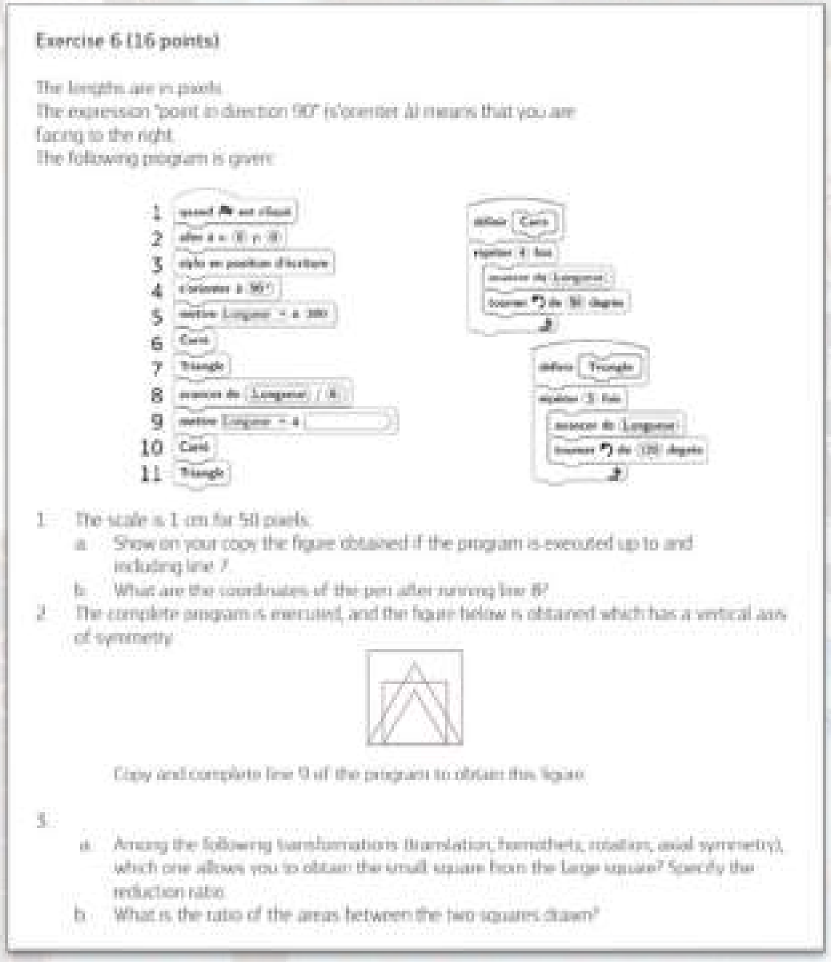
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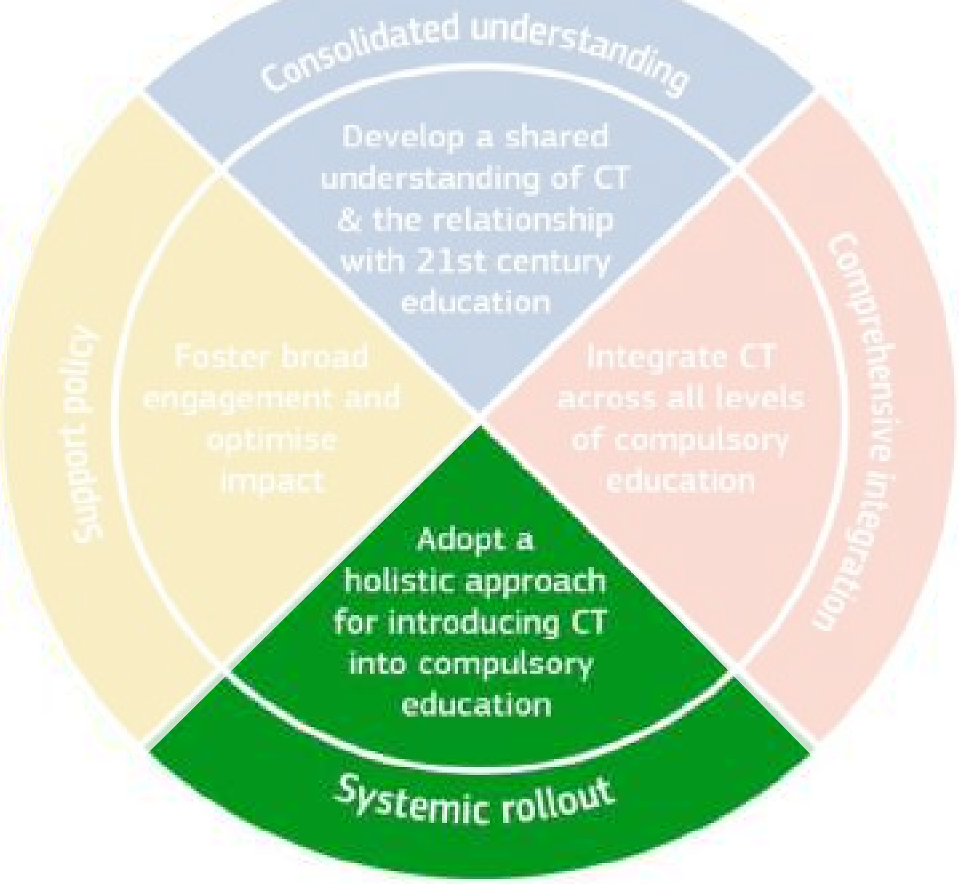


#6 Sustain the upskilling of teachers' pedagogical-content knowledge in computing

- Invest and provide high-quality professional development for teachers (medium and long-term training, on a regular basis)
- include basic computing in pre-service education for compulsory school trainee-teachers.

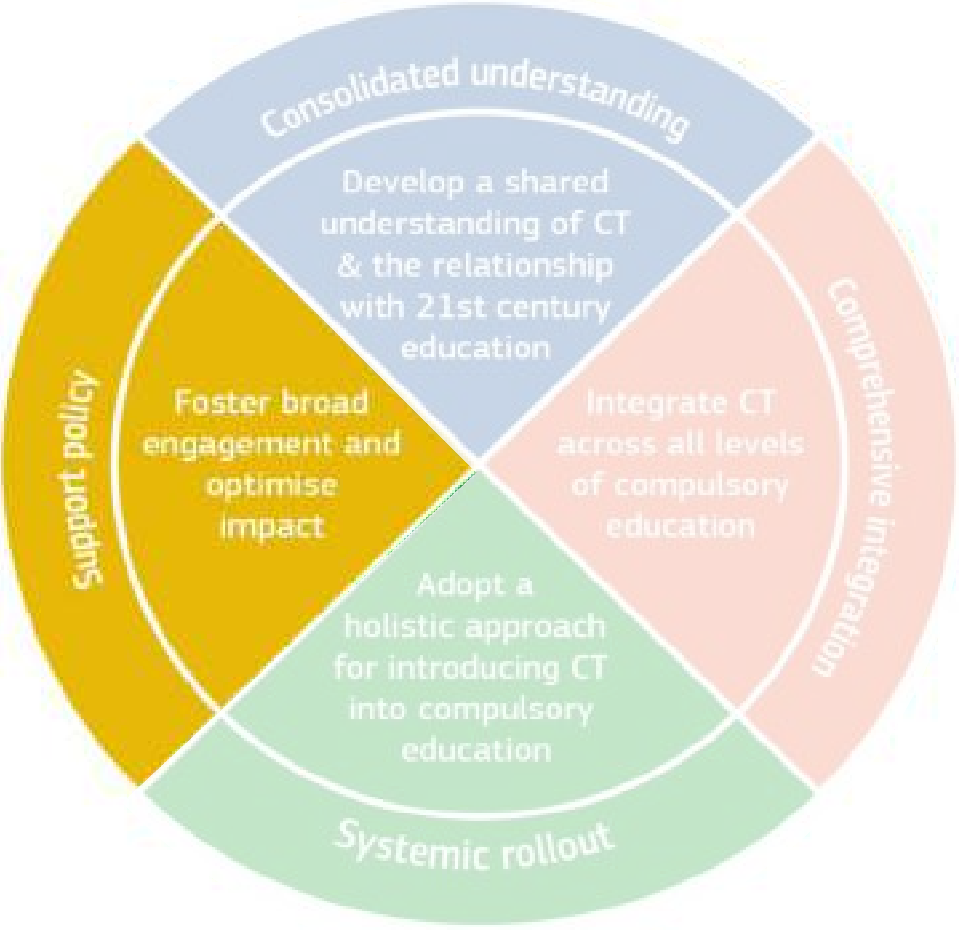
#7 Complement the provision of CT professional development with a range of support measures

- E.g., collaborative peer-support actions among teachers, school hubs

#8 Prioritise assessment of CT as a foundational competence

- Define detailed criteria for assessing CT skills encompassing both students' ability to program & to build up their CT skills.
- Integrate CT skills assessment into the final exam/summative assessment at the end of lower secondary school, indicating the importance of computing education

#4 Support policy



#9 Raise awareness about the purpose and benefits of developing CT skills in the curriculum

- address all educational stakeholder groups (school leaders, school inspectors, teachers, students, parents, policymakers, as well as employers).
- work with industry and grassroots organisations to implement such impactful initiatives

#10 Prioritise measures to address gender balance, equity and inclusion for quality computing education

- further investigate and address non-gendered dynamics in activities for CT skills development.
- made available inside and outside the classroom low-cost computing equipment to ensure equal access to CS education

#11 Monitor and research the actual impact of integrating CT skills in curricula

- ongoing, systematic monitoring and evidence-based evaluation of curricular implementation (e.g. impact of CT skills within other subjects)
- develop a long-term research agenda for computing education in schools.

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https://op.europa.eu/en/publication-detail/-/publication/bbf875ec-a5a2-11ec-83e1-01aa75ed71a1/language-en