REVIEWING COMPUTATIONAL THINKING IN COMPULSORY EDUCATION IN EUROPE

State of play and recommendations

Panagiotis Kampylis, PhD
National Documentation Centre, Greece
Greek music teacher, primary school teacher, school head, teacher trainer, author of textbooks, father of two…


2012-2020: Researcher and project manager at the Commission’s Joint Research Centre

2012-2020: Supporting policy making in Learning and Skills at EU level

2021: Senior research fellow at the Italian National Research Council

Policy Analyst, National Documentation Centre, Adjunct Lecturer, University of Piraeus
We live in the digital age...
…but how ready are we?

“My teacher told me to read for an hour a day. Do Facebook and text messages count?”

Does use of technology imply digital competence?
Exposure to technology is **NOT** enough to make people digitally competent!

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Exposure to technology does not make young people digital natives. Credit: Thomas Nast/JetPhotos/Alamy

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

Digital is one of the eight key competences
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...

Holistic approach

Ecosystem
Regional, national, international level

Capacity building of key stakeholders
Self-assessment/reflection tools, courses…
How to fulfil your [school’s] potential

Outside school’s capacity or control

School’s digital potential

Where school stands

SELFIE-based action plan

Collective reflection

Lev Vygotsky
Zone of proximal development

@pankampylis

https://selfieptk.eu
Brings together different perspectives
(school leaders, teachers, students)
SELFIE for schools
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*

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

Panagiotis Kampylis1, Valentina Dagiene2, Stefania Bocconi3, Augusto Chiocciariello1, Katja Engelhardt1, Gabrielle Stupuriene2, Vaida Masilionyte-Dagiené2, Egle Jasute3, Chiara Malagoli1, Milena Horvath4 and Jeffrey Earp1

1National Research Council, Italy // 2Vilnius University, Lithuania // 3European Schoolnet, Belgium // panagiotis.kampylis@std.cnr.it // valentina.dagien@smf.vu.lt // stefania.bocconi@std.cnr.it // augusto.chiocciariello@std.cnr.it // katja.engelhardt@outlook.com // gabriele.stupuriene@smf.vu.lt // vaida.masilionyte-dagiene@smf.vu.lt // egle.jasute@ffv.vu.lt // chiara.malagoli@std.cnr.it // milena.horvath@eun.org // jeffrey.earp@std.cnr.it

Corresponding author

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

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https://computhink2study.eu
**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 a validation workshop
  - Policymakers, researchers, school leaders and teachers from 23 countries

**CASE STUDIES**
- 3 multiple-case studies
  - FI, FR, HR, LT, PL, SE, SK, NO, UK-ENG
- 9 countries
- 38 semi-structured interviews with experts, policymakers, school leaders, teachers
- 10 focus groups
  - with 50 students

Timeline:
- April 2021
- December 2021
### Multiple-case study methodology (Yin, 2014)

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

- **3** multiple-case studies
- **9** countries
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- **38** semi-structured interviews with experts, policymakers, school leaders, teachers
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**CT SKILLS AS CROSS-CURRICULAR THEME**
[Primary Education - ISCED 1]

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

**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
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...

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

(image from CompuThink report 2016)
Great variety of terms still used by stakeholders...

**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)

(image from CompuThink report 2016)
CS CONCEPTS SUPPORTING CT SKILLS
FROM 9 CASE-CURRICULA

ALGORITHMS
- Notion of algorithms
- Algorithmic problem solving
- Logical reasoning
- Searching algorithms
- Sorting algorithms
- * Evaluation

PROGRAMMING
- Notion of programming
- Variable
- Conditional
- Loops
- Sequence
- Create a programme
- Debugging
- Data structure
- Procedures
- Boolean logic
- * Event
- Functions

Programme development in response to a given problem
Decomposition
Design
Pattern recognition (Generalization)
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)
Arms: 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.

Arms: to develop students’ technical expertise and technical awareness so that they can orient themselves and act in a technology-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**.

Arms: 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.
Digital Competence/Literacy contents
#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:
  1. overall *time allocated* to the subjects involved (e.g. Math), and
  2. *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, programs and interfaces

CT Test item included in the French Diplôme National du Brevet for Mathematics (2018 session)
Integration of CT skills in summative and final assessment

CT conceptualisation and strands in ICILS CT 2018 framework

CT Test item included in the French Diplome National du Brevet for Mathematics (2018 session)
#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.
pkampylis@ekt.gr