Integrating Computational Thinking in a computing subject: Three case studies

Computer Science (CS) concepts to develop Computational Thinking (CT) skills are usually integrated in a separate computing subject (e.g. Informatics), within other subjects (e.g. Mathematics) and/or as a cross-curricular theme in all subjects. This issue presents findings from a multiple case study on how CT skills are integrated as a separate subject in Croatia, Poland, and UK-England. European Schoolnet conducted this case study for the recently published JRC study ‘Reviewing Computational Thinking in Compulsory Education’ (see p.113 ff).

In UK-England, the subject is referred to as ‘Computing’, in Poland as ‘Computer Science’ and in Croatia as ‘Informatics’. Both Poland and Croatia have a long-standing tradition of Computer Science Education, unlike the UK-England. In recent years, however, UK-England has been in the vanguard, being one of the first countries in Europe to mandate CT in primary and secondary schools. The new Computing curriculum was introduced in 2014 and established an entirely new subject in schools. Croatia and Poland started to implement their current CS curricula in 2017/18. One hypothesis was that their CS curricula might be implemented differently due to their long tradition of teaching CS. This tradition seems to indeed have eased the transition since no new subject had to be created and initial teacher training and CS teachers were available. In UK-England, preparing teachers for the new Computing subject was a huge challenge, as many teachers of the previous ICT subject were language or math teachers by training. Nonetheless, also in Poland and Croatia, introducing the new CS curricula remained challenging, since CS was integrated at all education levels and its focus was adjusted. Hence, the new curricula necessitated large scale training also for CS teachers.

Background information

The April 2017 issue already focused on integrating CT in school curricula across Europe, based on the 2016 JRC study that described CT as a promising concept. The recently published JRC study concludes that CT is more than the promising new trend it was in 2016. Out of the 29 analyzed European countries, 17 countries have introduced basic computer science concepts as compulsory for study in both primary and lower secondary schools (Austria, Greece, Finland, France, Hungary, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Russia, Serbia, Sweden, Slovakia, Switzerland, UK-England).

One of European Schoolnet’s key aims is to broker educational research findings and other evidence to our key stakeholders: Ministries of Education, schools, teachers, and industry partners. The European Schoolnet Perspectives series is one way through which we achieve this.

The issues aim to:

1. Summarize research evidence from key studies on innovation in education;
2. Translate this evidence into concrete ideas for policy action;
3. Conclude with the implications of the evidence for using technology in teaching and learning.

All issues can be accessed online:
www.europeanschoolnet.org/resources/perspectives
Comments and suggestions on European Schoolnet Perspective are welcome: info@eun.org.
Curricula in Croatia and Poland both put a focus on developing students’ problem-solving skills. The Polish CS curriculum aims to motivate students to apply CT to engage in problem solving in other school subjects. The purpose of Computing Education in UK-England is to equip students to use CT and creativity to understand and change the world. Students should learn about the principles of information and computation; how digital systems work and how to put this knowledge to use through programming. Students should also become digitally literate. All three CS curricula effectively combine elements of digital literacy and CS Concepts. The Croatian curriculum, for instance, also aims for students to learn how to use technology in an effective, reasonable, and respectful manner and consists of four domains: CT and programming, Information & Digital Technologies, Digital Literacy & Communication, and e-Society (see Figure 1).

Since CS is usually taught 1 or 2 hours per week, time can be short to address all subject areas. In Poland, one hour of CS as a separate subject is compulsory at all grades in K-12 Education, while in Croatia, two hours are compulsory in grades 5 and 6. As a matter of principle, the National Curriculum in England does not specify the number of hours taught per week. In the Croatian curriculum activities related to CT take up to 20-30% of teaching time in early grades, and up to 70% in secondary education. Similarly, in UK-England, the amount of time dedicated to CS concepts increases at higher grade levels.

How much do Computer Science subjects focus on Computational Thinking skills, and why?

With their open formulation and focus on fostering problem-solving and logical thinking skills, CS curricula lend themselves to teachers implementing pedagogical approaches that promote student autonomy. Examples of such approaches are personalized learning, project-based learning approaches and collaborative learning. Curricula usually do not prescribe which tools teachers need to use. Curricula in Poland and Croatia suggest teachers to start with visual languages with young students and gradually progress to text-based languages. Games-based approaches are usually favored with younger students. The case study teachers in Poland and Croatia start their teaching by identifying their students’ interests and needs. What seems to be at the core of successful CS education is to enable students to work on real-life problems or create something on their own and let them find and correct errors in that process. The Croatian case study teacher provides tasks like turning on and off lights on micro:bit, which helps students to realize that everything around them is essentially CT and has been created by someone. Most students have the desire to create something new, according to the teacher. As a result, students get the chance to be proud of their achievements, and teachers become guides on the sides that provide guidance and feedback. Implementing CS curricula in that way probably requires a lot of courage to try out new things and potentially make mistakes and open-mindedness about learning processes and their results from teachers and their students. For a combination of flexible curricula combined with additional guidance to be successful, an environment needs to be fostered that allows teachers to make mistakes so that they feel comfortable to experiment and innovate, the Polish case study teacher commented.

Ideas for policy action:

- Piloting a new curriculum with a limited number of schools to test guidelines, recommended pedagogical approaches and teaching resources can prepare a smoother roll-out of the actual curriculum. Such piloting took place in Poland and Croatia.
- Combining rather open curricula with detailed guidance and high-quality resources seems to cater for the needs both of experienced and less experienced teachers.
- CS curricula need to provide sufficient space for including foundational CS concepts (entailing algorithms and programming) to develop CT skills. Clear guidelines on the amount of time teachers should devote to teaching basic CS contents are necessary.
- CS curricula that aim to foster problem-solving and logic thinking skills should be accompanied with focused research and guidance on how to design learning activities that effectively foster such thinking order skills.

Background information:

Curricula in UK-England and Poland are rather open to leave autonomy to teachers in how to implement them. The 3 pages English Computing curriculum only specifies what teachers should teach. The Informatics curriculum in Croatia describes learning outcomes and level of achievement in great detail, which helps teachers to create content for all students, including gifted ones and those with special needs. The curricula are accompanied by additional support, such as guidelines (in Croatia, England, Poland), model school curricula (e.g. in Poland), lesson plan examples (e.g. in England) and training materials (e.g. in Poland).
Background information:

In Poland, the subject is compulsory at all education levels, in UK-England from key stages 1 to 3 and in Croatia in grades 5 and 6. Additional optional subjects and extra-curricular activities continue to play a key role in allowing those with a particular interest in CS to go further. In Poland, students interested can take six additional hours of CS. In Croatia students could attend Informatics for all 12 years in primary and secondary schools.

Ideas for policy action:

- **Teacher training needs** to prepare teachers to identify students’ needs and interests and to cater for students of different abilities.

- **Teacher training** could also promote active pedagogical approaches such as collaborative learning as well as formative assessment approaches that have been highlighted as important in the context of teaching and assessing CT skills by the 2022 JRC report. The importance of formative assessment approaches has been emphasized by periods of remote and hybrid teaching due to Covid-19, as the EUN report The future of schools beyond Covid-19 highlights. The results of the Assess@Learning project on digital formative assessment practices will be published in February 2023.

How to tackle the lack of qualified CS teachers?

The lack of qualified teachers emerged as the key barrier to quality CS education in Croatia, Poland, and UK-England. In UK-England and to some extend also in Poland, the new curriculum was implemented before teachers were fully trained at scale. In UK-England, generating demand for training from teachers beyond the most interested ones proves still challenging. Several lessons on teacher training emerged from the case study. Quality teacher training and teaching resources and communities of practice are needed.

Such communities of practice can foster teachers’ readiness to experiment, fail and learn from it, and help them feel at ease with teaching students that may at times know more than them. In UK-England, school-based hubs connect different schools to enable them to support each other in carrying out quality Computing education. At those hubs teachers get together to learn how to teach CS. In Croatia, large scale online training was offered prior to the start of the curriculum. Key features were learning communities with participants also being experts and mentors, training on new topics every few weeks, and continuous support. Teachers tried out different methods of teaching and assessment in the roles of students and created a shared base of learning resources. Participants actively participated four to ten hours weekly and their progress and involvement were recorded. These trainings were organised in 31 topics with total of 244 hours of professional development for 1781 Informatics teachers. In UK-England, in response to the 2017 Royal Society report calling for more teacher training, the government provided 80 million pounds over four years to the National Computing Centre. The center developed over two years a complete program of study Teach the Computing Curriculum, containing 500 hours of lesson plans, assessment exercises, practical exercises, student interaction, progression charts, concept charts and teacher guidelines. The guidelines were produced by a team of ten people, working with focus groups of teachers that continuously provided feedback.

Ideas for policy action:

- **Communities of practice have the potential to foster teachers’ readiness to experiment**, fail and learn from it, as the examples of Croatia and UK-England show.

- **Coherent and systemic provision of teaching support** should be established that offers methodological assistance, guidelines, good quality lesson plans, and appropriate scaffolding for reusing effective practices already tested in classrooms. Support should be provided to help teachers carry out both formative and summative assessment of students’ CT skills.

- **Approaching the teacher upskilling challenge from a more long-term perspective**, efforts should be devoted right now to including basic computing in pre-service education for compulsory school trainee-teachers.
Conclusion

The 2022 JRC report shows that the teaching of CS concepts and underpinning CT skills has become an integral part of school curricula across Europe at an impressive scale and speed.

1 Teach CS as a separate and part of other subjects

The multiple case study on Croatia, Poland and UK-England suggests that there is a rationale for teaching CS concepts and underpinning CT skills as a separate subject, but also as part of other subjects. Case study experts deem a separate CS subject necessary to cover proficient subject knowledge and the underlying foundations of CS education (e.g., concepts behind the internet or the limitations of what computers can do). That is not to say that CS concepts and underpinning CT skills should only be taught as part of a separate subject. On the contrary, all three countries also aim for students to apply CT skills acquired in CS education in other subjects in a way that fosters their learning of those subjects.

2 Combine compulsory, elective, and extra-curricular elements

CS education usually aims to cater to all students to provide them with a basic understanding of the digital world but also to students with further interest in CS. In a context of often already crowded curricula, a combination of compulsory, elective, and extra-curricular elements with particular attention to synergies between those elements can cater to these different goals.

3 Invest in monitoring and research of CS education

Teachers seem to overall respond rather well to relatively open curricula that allow for some flexibility in their implementation, in combination with detailed guidance and high-quality teaching examples. The question if we really need to think computationally to understand the world around us and whether the current teaching of CS curricula effectively caters to this goal, has, however, not been finally answered yet. For CS to earn its place as an established subject in education, more evidence is needed to substantiate that teaching of CS concepts and underpinning CT skills does indeed cater to general curricular goals. This is true for Croatia, Poland, and UK-England but also other European countries.