Computational Thinking – Forces Shaping Curriculum and Policy in Finland, Sweden and the Baltic Countries

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Abstract. Through an increased focus on computing and computational concepts in the school curriculum the Nordic and Baltic countries are preparing to equip themselves to explore the opportunities that Industry 4.0 and beyond can offer. Realising this vision has inevitable consequences for the curriculum in compulsory schooling (preschool to year 9) as new scaffolding for the development of new competencies is needed, and adapting to technological change involves also integrating Computational Thinking topics and skills, as well as elements of programming and digital literacy into existing curricula. The Nordic countries (Finland and Sweden) have chosen not to create a new school subject, advocating the integration of these skills and competencies into existing subjects such as Arts and Crafts, Language, Mathematics and Technology. In contrast, the Baltic countries emphasise introduction of a subject called Informatics in which programming and Computational Thinking skills and competencies are intended to be developed. This paper provides an analysis of approaches taken to scaffolding access to Computational Thinking in the Nordic and Baltic countries.

Keywords: computational thinking, digital skills, technological fluency

1 Introduction

Programming and Computational Thinking (CT) have emerged as a hot topic in the redesign of national school curricula over the last decade. Driving this debate is a belief that the increasing presence of digital computing systems in all sectors places demands on compulsory education to respond by adjusting curricula to equip citizens to both understand and contribute to this new world.

The Nordic and Baltic countries responded rapidly in terms of the integration of computing in their school curriculum, however, they have adopted rather different approaches. This paper contributes to the debate by exploring the power factors and positioning of CT in the national educational political debate in Estonia, Finland, Lithuania and Sweden.

In the European context, the Nordic and Baltic countries have spearheaded the integration of computing in their school curriculum. The vision has been to realise competitive benefit from small size, unified culture, advanced infrastructure, digitalisation, and well-established, centralised national curricula. These benefits result in three driving forces acting to produce nation-wide changes to the curriculum, and in consequence the development of computing and digital literature addressing the sector. The refinement of the computing syllabus is necessary to ensure a consistent learning trajectory, as well as the establishment of this new subject among other subjects with a longer history. Similarly to mathematics, computing would fit as an entry criteria for Computer Science (CS) studies, and to a lesser extent also for natural sciences. This adds to the relevance of the subject, and makes it a reasoned choice for intentional students orienting toward these domains.

The main contribution of the current paper is to chart and analyse curricular developments in the Nordic and Baltic region with a focus on how curricular pressure can be understood and traced over time. This study benchmarks the current situation of CT in curricula of Nordic and Baltic countries, and targets the following questions:

- RQ1: What is the current status of Computational Thinking in K-9 education in Nordic and Baltic countries?
- RQ2: What factors influence national priorities in digital skills curricula for all citizens?

2 Computational thinking in compulsory education

Curricula are one of the central instruments through which policy makers set strategic direction and establish common goals at the national level in the context of compulsory schooling. By “compulsory schooling” we mean education provided by the state to all citizens in the school years from preschool to year 9, thus comprising the first 10 years of a citizen’s engagement with formal education.

The concept of compulsory schooling as a means to equip people for a productive life in human society can be traced back to educational policy makers in the early 19th century [1]. By examining existing and past curricula, it is possible to deduce the values, ideals, and how these are shaped by the societal and political agenda. We argue that the evolution of technology places civilisation on the cusp, and that radical change in education, especially in regard to reforming the curriculum is underway.

An example of a similar situation can be found in the Soviet technological accomplishments resulting in Sputnik I and II in 1957, which prompted much of the Western world to examine their technological capabilities, research programs and education systems [2]. In a similar vein international comparisons, such as PISA and TIMMS, have provoked both reflection and redesign of curricula in multiple countries [3]. A common theme is the desire to ensure technological competitiveness, which is also one of the aspects behind the move to address computing topics in national curricula [4]. Other aspects of the debate include promoting democracy and gender equality, using the argument that every child has a right and opportunity to learn digital skills, and that these are comparable to the more established civic skills to which we have become used. In Nordic and Baltic countries, curricula are state-run and centralised to ensure the equality of students and schools regardless of their resources or location, whether in rural or urban environments.

The first traces of discourse of CT date back to the late 60’s - early 70’s. Seymour Papert was a significant influence in the international discourse. His Logo programming language made its debut in 1967 with an apt pedagogical rationale derived from the theory of constructivism [5]. The CT idea was popularised by Jeannette Wing in her 2006 paper [6] and the definition of the concept and what is included has been hotly debated over the last decade [7–9] During the ensuing decades, digitalisation has accelerated and brought digital devices within the reach of nearly every citizen, and transformed a significant segment of the workplace, further strengthening the ideas behind the goal to equip all citizens for future agency in society through the teaching of digital skills. In 2014, Mannila [10] summarised the situation of CT in education of multiple European countries and USA Mannila’s study pinpoints the lack of qualified teachers as a crucial bottleneck, the impact of which cannot be underestimated in terms of the importance of the teaching of computing to a broader segment of the population.

However, it is clear that at primary school, teaching the basics of CT via unplugged activities is not particularly demanding on either teacher or pupil, thus, achieving low level goals in relation to CT should be achievable without an extensive CS education. In terms of enhancing teachers’ knowledge to achieve higher levels of computing education, we observe that universities and teacher associations provide courses, material and even certificates to support this process in the Nordic and Baltic regions, however more needs to be done [11]. In-service teacher training is provided by a range of organisations. In Finland the Association of mathematics teachers - MAOL, offers a variety of courses, and in Sweden similar courses are offered by universities through the government agency Skolverket [12]. In Lithuania, a variety of courses is offered by Vilnius University [13], while in Estonia similar initiatives are provided through the Lifelong Learning Strategy (2014-2020) that also targets the provision of open material for school use [14]. In addition, there are a number of European funded projects, for instance, the TeaEdu4CT ERASMUS+ initiative[1] that provide extensive teaching resources for teacher education programmes, and practising teachers.

At secondary school, CS/CT is provided either as a separate subject, or integrated within other subjects, mainly mathematics. For instance, Baltic countries have been swinging between separation and integration since late 60’s, see Fig 2. In PISA, mathematics is the closest counterpart to CS/CT if not the very subject where the CT has been integrated.

[1] https://www.fsf.vu.lt/mokslas/projektai/tarptautiniai-projektai/erasmus?layout=edit&id=2720=future-teachers-education-computational-thinking-and-steam

2.1 Nordic Countries

Computational Thinking education in the Finnish and Swedish systems have a common ground based on the idea that CT should be integrated into subjects such as Language, Mathematics, Arts and Crafts, and Technology, rather than introduced as a separate subject. This approach differs from that adopted in the UK, USA, Germany, New Zealand and Australia, where computing and informatics were introduced into the curriculum as a new subject to address these educational challenges. The Nordic approach has assumed that courses in languages will be able to handle the relevant aspects of digital literacy, in particular those that aim to develop critical thinking and reflective learning capabilities. This content is increasingly emphasised in the national curricula for Swedish language and literature over the past couple of decades, culminating in the current version [15]. The language curriculum emphasises the influence of digitalisation on the curation of information, including internet media, and a focus on large scale systems operating on big data to derive modern data-driven platforms, primarily Google and Facebook, which have significant impact on information provision.

The political discourse underlying this strategy is that it will be necessary to enhance awareness of the data these systems collect about users, and the impact of algorithms and machine learning on social media experience. Examples include social bubbles of like-minded people, emotion engineering [16], targeted advertising based on our preferences, and even manipulating users' political views, which has been reported in the much debated Brexit process [17] and the 2016 USA presidential election [18].

Computational Thinking in Finland through Language, Craft and Mathematics. After introducing programming as an elective course in 1984, the 2014 Finnish National Curriculum (FNC-2014) established general goals for teaching programming in compulsory education [19]. FNC-2014 introduces hands-on experimentation (e.g., programmable robots) as a precursor to CT, emphasising using robots, and following stepwise commands. At the secondary level, CT is integrated into mathematics, the motivation for this approach is that aspects of mathematical thinking applied in problem solving are analogous with CT. There are also expected benefits for mathematics education, in particular in the area of algebra where CT is expected to improve outcomes due to transfer effect [20].

However, the FNC-2014 programming content is painted with a broad brush: logical and algorithmic thinking are mentioned, as well as problem-solving through decomposition. These goals are the integral parts of "computational thinking" yet the CT term does not appear in the FNC-2014 text. Concrete guidance for teachers is largely lacking, and the targeted computer science concepts and skills are left undefined. Indeed, the clarification of the learning goals for CT has largely been delegated to book publishers in Finland. The biggest publishers (SanomaPro, Otava and Edita) seem to have reached consensus to publish texts promoting Scratch at primary and Python at secondary level [21].

Finnish PISA results have been falling since 2006, especially in mathematics. Male students and minorities are over-represented at the lower end of the results [22, 23] see Fig.1, and the gap between native and immigrant students is the largest [24]. Too open and unstructured learning environments provide no support. Instead of the anticipated empowerment, students may be left overwhelmed and clueless about how to study. [25] also points to a correlation between increased online and digital learning and deteriorating learning outcomes, e.g., in PISA-2015 [26]. To counter this trend the Ministry of Education provides new support through the "Right to Learn" initiative [27], in particular the New Literacies [28] sub-program. New Literacies highlights source criticism, critical thinking and a thread of programming and CT as an integral part of new literacies. During the next few years, New Literacy pilots are scheduled in 100 schools to gather evidence, and create CC-licensed material for other schools, including material for CT.

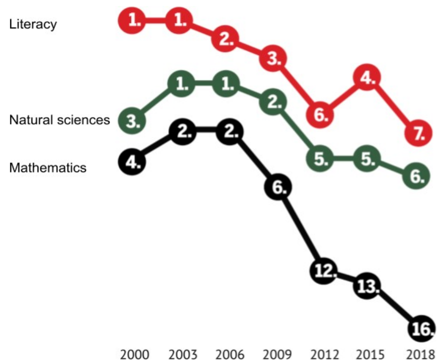

Fig. 1. The drop of PISA results in Finland, retrieved from the Ministry of Education

Computational Thinking in Sweden, Integration with Mathematics and Technology. Despite early forays into computing in schools in the 1980's[2], the subsequent Swedish education policy has emerged as more conservative than the Finnish model. Programming was ensconced in the national curriculum for the second time in 2016. However, the educational act for compulsory education (SWEA) [29] did not include computing or programming prior to 2017 [30]. The subject of Technology and the corresponding upper secondary school programme, an elective programme, (teknik programmet) provided access to similar content, also including courses covering various aspects of computing.

In 2012, the Swedish government established a committee with the task of giving recommendations and guidelines for how Sweden can, and should, benefit from digitalisation. In a report published in March 2014 [31], the committee emphasises the need for an additional focus on digital competences in national curricula. One concrete recommendation is for programming to be introduced as a cross-curricular element in already existing subjects. This ultimately resulted in programming being included into the compulsory school subjects Mathematics and Technology. The associated political discourse also emphasised the need to enhance technological fluency. The assumption is that technology is a transverse skill, can be applied to all subjects, and that the necessary computing skill set can be partially addressed in the digital literature curriculum.

[2] https://undervisningshistoria.se/programmering-i-skolan

In 2015, the government commissioned the Swedish National Agency for Education to propose content in the national strategy for digitalisation. As a result, the curriculum for compulsory school was revised and digital competence was added. The revised curriculum has been in operation since 2018 and describes digital competence as follows: a) to understand the impact of digitalisation on human society; b) to be able to use and comprehend digital tools and media; c) to adopt a critical and responsible attitude to change; d) to be able to solve problems/challenges and implement theoretical solutions in practice. After considerable consultation with the academic and industry sectors the revised compulsory curriculum was released in 2017, and became mandatory from August 2018 for all schools in Sweden.

The revised 2018 curriculum stipulates the following four main goals for students' digital competence:

- to learn to put one's own creative ideas into action and learn how to solve problems,
- to be able to use digital tools and media,
- to understand the digital transformation of society and how it affects us,
- to be critical and develop a responsible approach to digital technology.

The Swedish interpretation of digital competence includes aspects of digital literacy, such as the importance of critical thinking, source criticism, fact checking, and safe use of the internet by being aware of security threats, as well as attempts at information manipulation. The key areas are considered as critical components of the strategy to establish Sweden as a strong democracy in alignment with Swedish policy in the 21st century.

2.2 The Baltic countries

The Baltic countries started to reform informatics education, and ever since it was introduced, it has been swinging between integrated and separated subjects, as illustrated in the Fig.2. The swing started from an independent optional subject and currently, in 2021, has almost returned to the starting point.

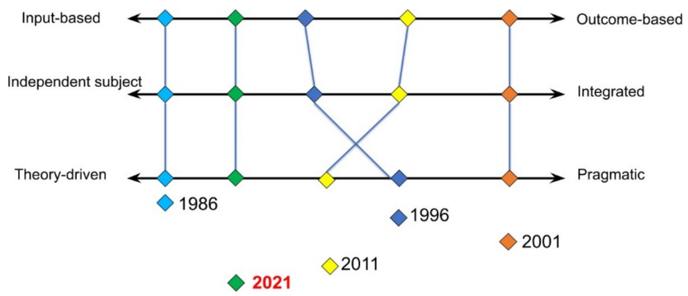

Fig. 2. The swing of informatics curriculum between integration and separation.

Computational Thinking in Lithuania focuses on Informatics. Lithuania has taught informatics at schools for almost 40 years [32]. In 1986, informatics was first introduced as a school subject, and it focused on logical principles of computers, information transmission, storage and processing, and algorithms, particularly data types and basic control structures of programming (based on Logo and Pascal). Before that, Lithuania had already established the Young Programmers' School, a Correspondence school, and one of the first programming schools for pupils in the world. The School triggered a number of research articles, books, contests and competitions [33]. In 1981-83, lessons in programming for beginners were even published in one of the biggest daily newspapers in Lithuania.

The most significant influence on the status of informatics education was the introduction of the informatics maturity exam in 1995. Those who pass the informatics exam have enhanced opportunities to enter CS-related studies in higher education. The test also provides a reliable indication as to whether a student has the aptitude to study informatics. The informatics exam consists of two parts: one part (over 50% of the full exam) is allocated to programming, while the rest concerns computer literacy and applications.

A revision of the informatics core curriculum was initiated in 2005, expanding the scope from two to four years' teaching time (in total 136 hours) with more focus on developing algorithmic thinking and applications. The teachers were formally qualified, usually with a bachelor's or master's degree in informatics, combined with mathematics. 5th and 6th grade pupils are introduced to the basics of informatics based on Logo or Scratch. In grades 9 to 10, more advanced students are recommended to enrol in the optional module of algorithm design and coding.

In 2019, the Lithuanian Ministry of Education, Science and Sport developed new guidelines for pre-school, primary, basic and secondary education[3]. The general curriculum framework is a document governing the content of national level education, which helps teachers to scaffold performance in relation to learning goals, and the levels required to attain them.

The Ministry and the National Agency of Education manage all update efforts within the framework, documents under consideration and planned events are published online (www.mokykla2030.lt). In 2020, one hundred primary schools started to pilot the proposed informatics curriculum. The pilot targets the development of learning resources and textbooks, as well as teacher training. The full-scale implementation commences in 2022.

The revised curriculum includes fundamental CS topics such as programming, problem solving and algorithms, data mining, data representation and information, networks and communication, digital technology and human computer interaction, security, and privacy and ethical considerations. Attention is given to the key concepts in the field, and the constructive aspect of the discipline. Figure 3 illustrates six areas of informatics education with main focus on four core areas: 1) Data mining and information, 2) Algorithms and programming, 3) Technological problem solving, and 4) Digital content creation.

The most pressing current challenge is to redesign an existing informatics course in upper secondary school (grades 11-12) so that it would also introduce some new technologies such as artificial intelligence, machine learning, and big data. The renewed

[3] https://www.e-tar.lt/portal/lt/legalAct/e3e9269009e511ea9d279ea27696ab7b

informatics curriculum at upper secondary school is expected to be ready for incorporation into the new national curriculum in 2023.

Fig. 3. The areas of informatics curriculum

Computational Thinking and Estonia's Commitment to Digitalisation. The national curriculum for a newly independent Estonia was introduced in 1996. In this process, a new elective school subject called informatics was introduced that comprised four 35-hour modules for grades 10-12. The new informatics curriculum contained no coding, algorithms or other abstract elements of CT, as opposed to the theoretical CS course that was forcibly introduced into the curricula of all Soviet Union's republics in 1986. Instead, the focus was on everyday use of computers: word processing, spreadsheets, computer graphics, and internet. The next version, National Curriculum 2001, dismissed informatics completely, which resulted in a sharp decline in teaching popularity. While removing informatics, the 2001 curriculum introduced instead a set of compulsory ICT skills that were assessed by the National Exam Centre at the end of basic school, in the ninth grade.

The current renewed national curriculum came into force in 2011. One of the four prioritised elective subjects is informatics, and it is recommended by the policy makers. This informatics curriculum outlines syllabi for two 35-hour courses in basic school:

- Y5/6 working with computer: word processing, file management, digital presentations, spreadsheets, internet search, citations, plagiarism, evaluation of online information, cyber-threats, digital identity;
- Y8/9 information society technologies: online communities, blog and wiki usage for digital content creation, metadata and annotations (tags, bookmarks), online content aggregation (e.g., RSS), collaborative digital project, digital safety.

The high school curriculum (grades 10 - 12) does not mention informatics as a subject, but describes a set of new technological elective courses under Natural Sciences domain, each accompanied by a textbook, e-course in Moodle, tests and educational videos. Elective courses are: 1) inquiry-based learning (data collection, data analysis and visualisation in Excel, presenting the research results); 2) introduction to programming and software development; 3) robotics and mechatronics; 4) 3D-modelling; 5) Geoinformatics.

As in the Nordic system, there is a tension in the Estonian national curriculum and educational practice between the content of informatics and generic digital competence. Are these the same subject, partly overlapping, or completely different things? In 2014, a minor update to the national curriculum introduced digital competence as one of the eight compulsory key competences (e.g. the DigComp model). An online test of digital competence has been conducted in grades 9 and 12 since 2017 by HARNO, an agency responsible for exams. In some schools, teaching digital competence is the responsibility of the informatics teacher, whereas schools without informatics teachers have integrated the teaching of digital competence into other subjects. The third group of schools tries to offer both: informatics as a separate subject focusing on development of CT and digital competence nurtured by other subject teachers.

The development of a radically changed informatics curriculum for primary and upper secondary schools was led by the HITSA agency 2016-2019. This curriculum is still classified as an “unofficial document”, but the majority of primary schools already apply it to some extent in grades 1-6, thanks to the corresponding online textbook for informatics (digiopik.it.ee). The new informatics curriculum for high schools was introduced in 2019, but its uptake is significantly poorer compared to primary school, with less than 10% of high schools offering it. The Figure 4 illustrates the new elective courses for grades 1-6 and 10-12. The most complicated stage is grades 7-9, due to no “free space” in the national curriculum.

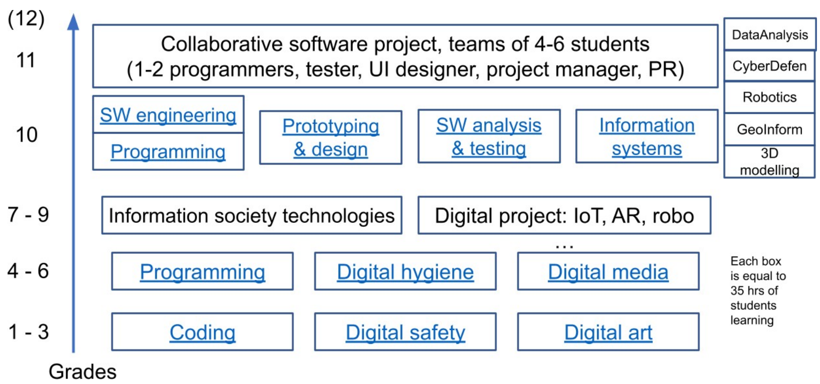

Fig. 4. The proposed K-12 informatics curriculum

The new task force group has been formed to design a solution for this grade level by 2022. The key idea is to redesign an existing informatics course “Information Society Technologies” to introduce new technologies such as artificial intelligence, augmented reality and big data analytics in grade 7. The school renewal has been successful, which manifests in international comparisons, such as PISA, see Table 1. The new additions to informatics curricula, such as artificial intelligence and machine learning, are intended to be incorporated into the new national curriculum in 2024.

3 Discussion

As Figure 2 illustrates, the Baltic countries have acted in a more synchronised manner. Estonia has taken the lead, for instance in open e-textbooks that are prepared together with academia, and its advancements are well disseminated within other Baltic countries. Adoption among policy makers is promoted by the results reached in Estonia, such as a constant improvement in national PISA results of mathematics (Table 1) [34].

Table 1. Math PISA results of 2006-2018

	2006	**2009**	**2012**	**2015**	**2018**
Finland	548(1)	541(2)	519(12)	511(13)	507(16)
Sweden	502	494	478	494	502
Lithuania	486	477	479	478	481
Estonia	-	512(11)	521(11)	520(10)	523(8)

Finland and Sweden have adopted integrative approaches to the introduction of CT to an already full curriculum, through the subjects mathematics, craft and (in Sweden) technology. Efforts in the Nordic countries are not as coordinated as the Baltic approach, but they have considerable similarities, and face common challenges. Educators and policy makers are faced with the necessity to establish priorities between existing subjects and the new demands of the digital transformation of society.

The problem with integrating CT is, however, that teachers of the target disciplines (languages, craft, technology and mathematics) should be knowledgeable enough to teach programming basics. In addition, the learning goals should be defined in detail and adhered to. The current situation of vaguely specified, broad brush descriptions of the CT goals and content to be included in the curriculum; such as “digital fluency” or “computational thinking” tends to frustrate teachers. Leaving aside the issue of poor definitions of CT, acquiring the required knowledge to teach CT has also been largely left to the teachers alone.

The selection of the programming paradigm has also been largely left to teachers and book publishers. However, the prevailing CT definitions provide a strong impetus towards the imperative programming paradigm represented by languages such as Python and Scratch. While some arguments have been advanced for adopting a functional approach, this is a marginalised area [35, 36]. The rationale for adopting a functional paradigm is the close conceptual correspondence with mathematics, and the absence of contradicting concepts, such as mutable data. However, this argument has gained little traction among policy makers. To establish its position, CT/CS should consider following the lead of mathematics. A more concise definition for CT should be developed, and that definition should be linked to a consistent learning trajectory. Ideally elements of the CT learning outcomes would be added to the matriculation exam.

4 Conclusions

This paper summarises the state of play in the introduction of CT concepts and competencies into compulsory education in two Nordic and two Baltic countries. We conclude that while much progress has been made into incorporating CT into the Nordic and Baltic school curricula, there is still a considerable way to go. The major dilemma facing policy makers and curriculum designers is whether computational thinking and digital skills should be integrated into other subjects, or provided as a separate subject. Since then, various CT teaching experiments have ranged from optional to compulsory, and from a separate subject to wholly integrated into one or more existing subjects.

The trend we see from our analysis is that this integration has focused most often on mathematics or handicrafts in Finland, with Sweden also making efforts to include some content in language and technology subjects. Our observation is that integrating CT into other subjects makes the coordination of content and learning outcomes considerably more complex, while offering the advantage of enhancing the relevance of CT in familiar contexts.

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