Towards a Compulsory Computing Curriculum at Primary and Lower-Secondary Schools: The Case of Czechia

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Abstract. A new national curriculum in informatics for primary and lower secondary education has been in force in the Czech Republic since September 2021. This curriculum introduces a compulsory subject, which systematically focuses on computing from the age of 9. This paper shows the path we have taken, the visions and principles on which the reform has been built, and the milestones that have lined the way from a user-led approach to computers to development of computational thinking and understanding the world of computers as a major educational objective**.**

This paper is structured as follows. We start with an introduction to the Czech educational context and some terminology. In Sect. 2, we describe the initial situation and the first steps towards the reform of school informatics. In Sect. 3, we explain the main concept and describe a project preparing new educational content and the conception of teacher education. An outline of the contents of the curriculum and teachers' first reactions are shown in Sect. 4.

Keywords: Education · Informatics · Computing · Innovation · National curricula · Country report

1 Introduction, Terminology

The paper focuses on the practical implementation of the paradigm shift in computer education in schools from a user-oriented approach to the mandatory inclusion of informatics into the curriculum. The process is shown on the specific situation of the Czech Republic, a Central European country with several hundred years of common history of the school system with other countries of the former Austrian Empire, and several decades in the 20th century under the influence of communist totalitarian ideas and experiments and limited sovereignty. It is a country that has been trying to return to full democracy and individual freedom for the last 30 years. In the paper we describe the initial situation, the ideas that appealed to us, the sources of inspiration and the changes in the system of informatics education.

The author of the paper participated in the innovation of informatics education described in the paper both as a member of the expert group that developed the national curriculum for primary and lower-secondary schools and as the leader of the strategic

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PRIM project, which created the conditions for implementation of the proposed changes in practice by, among other, developing teaching materials, innovating undergraduate teacher education and popularization of computing. He was thus present at a number of activities and decisions and can provide "first hand" information.

The paper describes changes in Czech elementary schools, i.e. on ISCED1 and ISCED2 levels. The levels of education in Czechia are organized as follows:

- Primary (ISCED1, 5 years, age 6–11)
- Lower-secondary (ISCED2, 4 years, age 11–15)
- Upper-secondary (ISCED3, 4 years, age 15–19)

In the paper, the following terms are used with the following meaning:

- information and communication technology (ICT) in the sense of user approach to (consumption of) digital technology; the area for development of digital literacy and use of computers as a learning tool. The paper also uses the acronym ICT for the name of the educational area Information and communication technology, as this compulsory subject has been known until today.
- informatics – in the sense of computer science, computing; the basis of the discipline analogical to other scientific disciplines that are included in the STEM disciplines; authorial approach to technology, the field for understanding systems and for development of computational thinking. Informatics is also new name of the subject.

Our conception is close to the terminology used by Sysło [1, p. 144], for whom informatics deals mainly with creating 'new products' related to computers (such as hardware, programmes, software ...) and ICT mainly uses 'informatics (computer related) products'. Similarly to Blaho [2] we perceive the area of ICT as the forerunner of informatics, which builds on ICT skills.

2 The Starting Point

2.1 Situation in Informatics Since 2006

Although ICT and informatics were taught in Czech secondary and primary schools since the early 1990s (it was perceived as "teaching computers"), these were selective subjects or topics included in other educational areas such as mathematics or technology. When Czechia joined the EU in 2004, a new Education Act was adopted, which formally brought Czech education closer to European practices, for example in defining the expected outcomes in the form of competencies or in defining educational areas [3]. A brand-new element in the system was the creation of School Education Programmes, which were binding for the school and had to include the mandatory core defined by the state Framework Education Programme (FEP). The development of School Education Programme was handed over to the schools.

When this Act came in force in 2006, the compulsory educational area of ICT was introduced for the first time at primary and lower secondary levels, where the main topics were searching, processing and use of information and communication [4]. The gradual

introduction of this subject resulted in the situation when, since 2011, the subject of ICT was taught on a compulsory basis in all schools in the extent of 1 lesson per week in one grade of primary and 1 lesson per week in one grade of lower-secondary level. The basis of teaching this subject was the use of office software. The subject did not include any informatics topic, its focus corresponded to the UNESCO model of ICT development in the curriculum of 2002 [5]. A certain autonomy of schools in developing the curriculum made it possible to include extra ICT lessons from the so called disponible lessons, which was eventually the case of almost half of the schools. Schools could also include the basics of computer science in their school education programme, most often in the form of a programming course in the so-called children's programming languages such as SuperLogo or the original Czech iconic language Baltie. However, schools more often included additional ICT topics in these extra lessons, such as digital photo and video editing. The support provided by textbooks and teaching materials, teacher training in the field and investment in school hardware has been weak and unsystematic until today.

We must point out here that the model did not impose any obligation to use digital technology in other school subjects. Thus, computers were often used only in the subject ICT, which resulted in its isolation. This model did not change until 2021.

2.2 First Occurence of Computing: Bebras Challenge

The first opportunities for ordinary Czech schools to get in touch with informatics content other than programming were informatics tasks from the Bebras challenge [6] contest, in which Czechia has been participating since 2008 and which is designed for pupils aged 9 to 19. The fact that Bebras contest was first full-service electronically implemented competition at Czech schools with hitherto unseen tasks including interactive ones allowing participants to solve them by clicking on or dragging objects on the screen contributed to its popularity. The interest of schools and the number of participants gradually grew to 90,000 participants and the involvement of 16 % of all schools in 2019.

Despite the initial misunderstanding of some teachers to whom the tasks looked mathematical or logical as they were not about computers [7, p. 22], Bebras tasks were in fact the first mass introduction to informatics tasks, moreover embedded in real-word problem situations. The tasks from the contest were soon used by some schools in lessons. Teachers were introduced to the tasks in the professional teacher publications in the form of a series [8]. Some of the tasks are included in informatics textbooks [9]. The Bebras tasks were also used for new teachers preparation, they changed a point of view to informatics which was perceived as a discipline about programming and computers.

2.3 INICT Panel. Models of Inspiration

The INICT panel, an expert group of about 15 people, informatics educators from universities, ICT teachers and headmasters of secondary and primary schools, representatives of the school inspectorate and other education experts has been active for more than 10 years at the National Pedagogical Institute. Its goal is innovation in the ICT curriculum. This group was aware of the insufficient number of lessons, the isolation of lessons with computers from other subjects and the absence of computing content. Being aware of the fact that, unlike in the case of other subjects, upper secondary schools do not

show informatics and computer science as an interesting field of study at university led to the belief that computing should become an integral part of general education. It is this group that was at the background of the gradually created concept of innovation. Later, it created the new National Curriculum for Computing.

When developing ideas on how to innovate teaching in this area in Czechia, we naturally looked for inspiration in the world. We studied the situation in Slovakia, a country that has more than 300 years in common with Czechia and a virtually identical system of education. In 2008, Slovakia introduced computing as a compulsory subject from the 2nd grade of primary school with a much larger number of lessons (1 lesson per week in each grade starting in the third grade), focusing on areas with algorithmic thinking, procedures, problem solving, principles of digital technologies [10]. Thanks to the linguistic closeness and personal relationships, we could be present in the process of creation of the new school subject in a country that was 13 years ahead of us. Slovakia showed us the way not only in the form of a model national curriculum, but especially in the form of the content of teaching, textbooks and pedagogical research as well as by creating a community of teachers and educators around the conference DidInfo, which has been held alternately in Czechia and Slovakia since 2017 [11].

An important source inspiration for how to organize the teaching of computing was the model implemented in the United Kingdom, which was started by publishing the study Shut down or restart? [12] and led to the creation of the subject Computing. This document states that "ICT and informatics, which is a scientific discipline similar to mathematics and physics, are two different subjects in school education with different mission and functions, although they have common areas of synergy" [12, p. 10]. Instead of the term ICT, the term digital literacy was introduced.

2.4 Strategy of Digital Education

In 2014, after expert discussions of computer specialists, educators and teachers, the public, schools, employers and IT companies, the Czech government adopted the strategic document *Strategy for Digital Education until 2020* [13]. This document was binding primarily for the Ministry of Education to bring about innovation in education in this area.

Three main goals were the development of computational thinking, the development of digital literacy and the opening of education to new methods and ways of learning through digital technologies. Computational thinking is mentioned as a relatively new phenomenon and its introduction is justified not only by the need for new IT professionals, but also to enable students to acquire skills related to solving a wide range of problems associated with, for example, automation. The development of digital literacy and computational thinking of pupils and teachers was among the seven main directions of intervention.

This document triggered work that in the following six years prepared the transition to a completely new concept of school informatics and computer-assisted education, at the beginning of which we are now. The nature and extent of these preparations will be described below.

2.5 The Monograph Subject Didactics

In 2015, the first significant scientific monograph focusing on subject didactics entitled Subject Didactics: Development – Status – Perspectives [14] was published in Czechia. Representatives of 15 subject didactics describe the state, direction, resources, successes and problems of subject didactics in their field. Representatives of didactics of informatics were also invited to contribute to this monograph. Their chapter was named Didactics of Informatics at the Starting Line. Didactics of informatics in Czechia is characterized as emerging, not fully defined and established, with a number of problems of which the unsettled state of the maternal discipline, weak empirical research, narrow base and weak position of didactics at professional departments educating teachers are stressed out. The monograph defines the fields of informatics, ICT and technology in education. The term computational thinking is introduced. The chapter also describes the situation in Czech schools with problems of a low number of lessons, of one-sided focus of the curriculum towards user approach to technology, of poor quality of teacher education without a nationwide concept of in-service education and of the fact that the goal of teaching ICT is conceived as mastering a tool without any attempt at mastery of a deeper conceptual level.

The monograph was published in Czech; the main ideas from the chapter on didactics of informatics from the point of view of the international audience were presented in the paper [15].

3 Conception and Preparation of Changes

3.1 Computational Thinking and Digital Literacy

The use of the existing terms ICT and informatics ceased to be satisfactory because these terms were perceived as semantically equivalent in the general and pedagogical public and also they paid too much attention on the content aspect of education. New terms that emphasize the goals of education and development of the individual began to be used: computational thinking and digital literacy. With the help of these concepts, a model of change was developed, which eventually led to a complete change in the compulsory subject, it turned from a digital literacy-oriented to computational thinking-oriented subject.

The Table 1 illustrates these changes. The upper row shows the situation until 2021, the bottom row shows the situation the coming changes should bring about. Second column represents the compulsory subject focusing on “teaching computers”. Third column represents individual school subjects. The text describe the areas of educational objectives for whose fulfilment the different subjects will be responsible. extracurricular often means organized education outside the school or rarely non-compulsory added part of school education.

3.2 PRIM and DigiGram Projects

The creation of conditions for innovation of education and development of computational thinking and digital literacy was the aim of two major strategic projects in the

Table 1. The educational content of individual subjects with respect to informatics content before and after the planned innovation

Years	Informatics (ICT)	Other subjects	Extracurricular
before 2021	digital literacy	---	computing
after 2021	computing, digital literacy	digital literacy	

years 2017–2020. They were implemented by a consortium of all 9 Faculties of Education in Czechia. It is important for necessary changes in pre-service primary and lower secondary informatics teacher education. Both of these projects were funded by the EU.

Main goal of the PRIM project (Podpora rozvoje informatického myšlení – Support of Development of Computational Thinking) was to prepare changes that will be made in the subject informatics. This project reacted to the increasing necessity both of IT expert and general education of population in the area of computing [16].

3.3 Development and Piloting of a New Set of Textbooks

The main goal of the PRIM project was the creation of a new set of textbooks of computing that would cover teaching at all school levels from ISCED0 to ISCED3. The following demands on the textbooks were formulated:

- They must be targeted at teachers who have never taught or studied computer science – they must, therefore, among other things, present a detailed methodology that will fully support the teacher in self-study.
- As it is not certain that all schools will have the funds needed to purchase robotic aids, the set of textbooks as a whole must lead to the achievement of all FEP outputs without the need to buy any equipment.
- They must teach computing in a modern way, i.e. without long explanations, definitions, memorization. The pupils is expected to work actively and to build their knowledge by discovering, experimenting, creating, discussing, solving problems, cooperating, working on projects.
- They must be piloted in schools by beginner teachers.
- They must be available free of charge. This has been fulfilled by uploading them on the website https://imysleni.cz/ucebnice with the possibility of a free download or access to online materials with a CC-BY-SA license [17].

The total of 14 textbooks of computing were created by teams of university educators and teachers. Their content is divided into three major thematic areas:

- Programming and algorithmizing (in Scratch and in Python on upper secondary level)
- Other topics from informatics (work with data, coding, modelling, information systems), including Computer science unplugged activities
- Robotics (using Lego WeDo on primary level, Lego Mindstorms or Micro: bit on lower secondary level and Arduino on upper-secondary level)

These three areas evolved naturally. Before this set of textbooks there were no textbooks for primary and lower secondary schools in Czechia that would teach computer science topics. While there was some experience with programming in primary education, and some earlier ICT textbooks contained programming passages, other computer science topics were not covered at all. Therefore, the area of algorithms and programming was singled out. It was the experience with writing programming textbooks that made it possible to develop new textbooks with a more modern vision, based on building concepts [18]. Programming is perceived here as a training ground for the development of components of computational thinking, such as algorithmizing, abstraction, decomposition, evaluation or generalization. The textbook for the 5th grade of primary school, which was taken over and localized from the outputs of the English project Scratchmaths [19], emphasized the connection between programming and the teaching of mathematical skills [20].

Unlike in the case of programming, it was difficult to find international models for those textbook sections focusing on work with data, modelling or information systems. For example the Swiss textbook Lösungen finden by Hromkovič and Lacher [21], which focuses on these topics, was published later. Our textbooks introduce teachers to and guide them through a brand new, in Czechia not previously taught topics [22].

The area of robotics is conceived as non-compulsory as it requires the purchase of hardware by schools. Textbooks, especially for older pupils, work with the previously acquired programming competences and can thus focus on designing a robot and solving problems by programming it [23].

The textbooks were piloted in the years 2018–2020 in three stages. The first stage of piloting was conducted by very experienced teachers simultaneously with the creation of the first version of the textbooks. The authors were present in the lessons and received immediate feedback. The second and the third stages took place all over the country under supervision of individual pedagogical faculties. In total, the textbooks were piloted by over 130 teachers who had never taught computing. The feedback was provided through software into which the teachers entered comments and suggestions for adjustments after each lesson. These comments were assessed by the authors of the textbook for their potential incorporation into the next version. The fourth version of the textbooks was the final one.

It must be stated here that use of these textbooks is not binding for teachers. Every teacher has the freedom and responsibility to choose the methods, environment and aids they want. The same applies to programming languages, which are not prescribed.

3.4 Preservice and In-Service Teacher Education

The PRIM project created a model of comprehensive training of all teachers of computing on lower secondary level and also of all primary school teachers. All faculties of education introduced compulsory subjects in which pre-service teachers of computing focus on didactics of programming and school robotics and pre-service primary teachers learn basics of programming and also study methodology of teaching this subject. For some faculties this was the first time when such courses were given. Introduction of these subjects means, among other, that all graduates of pre-service primary school teacher education will be able to teach computing.

As far as in-service teachers are concerned, the project prepared a nationwide system of informatics training in two variants for primary and lower secondary levels of elementary school. This training in the scope of 24 lessons of presence learning supplemented by e-learning is intended to acquaint teachers with informatics content in the new textbooks. Piloting showed that it is necessary to teach them the basics of programming and to equip them methodologically to be able to teach using the textbooks and teachers' methodological guides. The system of in-service training is organized in two stages: dozens of certified lecturers train teachers in their region using the national methodological network of school support. These lecturers have been trained centrally by the authors of the textbooks. The lecturers draw attention to key passages of the textbooks and show teachers how to implement their lessons. These trainings are currently underway.

4 New National Informatics Curriculum

In January 2021, the Ministry of Education published the new Framework Education Programme for Elementary Education [24] This document defines the national curriculum which includes the new conception of computing. Its approval and its putting in pracitce were motivated by two facts. Experience from the time of COVID pandemic and long period of distance online education, which Czech teachers were able to cope with, boosted their confidence in the area and improved their attitude to the computer as a teaching aid. The other cause was the preparedness for the shift to new conception of computing, i.e. the existence of the piloted textbooks, of in-service teacher training and availability of finances to purchase of robotic and other teaching aids. The new national curriculum is at this point in force for levels ISCED1 and 2. The approval of the innovated curriculum for general upper secondary education (so-called gymnasium, level ISCED3) is planned for the end of the year 2021, the finalization of it is in progress now. Is necessary to add that new national curriculum for all levels was prepared together by the same group of experts and is interconnected. At secondary vocational schools, this innovation process was interrupted and postponed to the general revision of the Czech national curricula planned for 2023.

We concentrate our description to levels ISCED1 and 2 because informatic content is completely new there. Topics of algorithmization and programming are already included in current edition of the national curricula for some types of upper-secondary schools including gymnasium. The education area of ICT has been renamed as Computing in the new national curriculum. The compulsory minimum number of lessons is 1 lesson a week in each of the 4^{th} to 9^{th} grades, which is 300 % of the previous time allocation.

The content of the subject has been changed completely. It is now divided into four areas (which we illustrate by selected expected outcomes when finishing lower secondary education in the 9^{th} grade):

- Data, information and modelling

  The pupil
  – defines a problem and determines what information will be needed for its solution
  – finds mistakes in other people's interpretation of data
  – proposes and compares different ways of coding data
  – models a situation using graphs and schemas, finds and corrects a mistake in a model.

- Algorithmizing and programming

  The pupil
  – having read individual steps finds the problem which is solved by a given algorithm
  – breaks a problem into individually solvable parts
  – adapts a given algorithm for other problems, proposes various algorithms for the solution of a problem
  – creates a programme in a block-oriented programming language, tests it and corrects any errors in it
  – uses cycles, branching, variables.

- Information systems

  The pupil
  – identifies elements of an information system and the relationships among them
  – defines a problem and determines how they will use data records to solve it
  – designs a table for recording data
  – sets sorting and filtering of data in the table.

- Digital technology

  The pupil
  – describes how a computer works in terms of both hardware and operating system
  – stores and manages their data in a suitable format
  – selects the most appropriate way to connect digital devices to a computer network
  – handles typical computer faults and error conditions
  – can manage their activities to minimize the risk of data loss or misuse [24].

The subject Computing was characterized as a subject helping pupils understand the computer and the world around us from the informatic perspective and developing the pupil's computational thinking. In terms of the organization of teaching, it was emphasized, for example, that the pupil should actively construct their knowledge by discovering, discussing, solving problems, etc. Recommended are group activities. There is no emphasis on reproduction of knowledge and memorizing.

Since the new teaching standards were developed parallelly with the new textbooks, the authors of the textbooks were often in an uncomfortable situation, as they had to react

to changes in the developed curriculum while writing. They did not even know how many lessons a week in each grade the innovated subject would be allotted. In consequence, the authors did not manage to write new textbooks for topics perceived as traditional, which had previously been taught, such as data processing using spreadsheets or digital technology.

The other innovated area, digital literacy, has become a so-called key competence in state documents, which means it has been implemented in other educational areas. All other subjects are responsible for achieving this competence. Thus, there is no specific responsibility defined for achieving goals in digital literacy such as implementation of measurement and research in science, typewriting in Czech language, safety and interpersonal relationships on the Internet in social sciences, etc. On the other hand, it is obligatory for all subjects to use the computer as a teaching aid to fulfil their subject educational goals. Digital technologies can be expected to change teachers' working methods.

4.1 Introducing Innovation at Schools

It has been stipulated that from September 1st 2021, schools may start transition to new computing curriculum, with the proviso that from 2024 all grades must be taught according to this new national curriculum. In other words, schools have been given time within which the teaching can be innovated by gradually adding new topics to the original curriculum.

In order for schools to be able to develop their school curriculum, so-called model school educational programmes in computing were designed within the PRIM project. This was not without discussions, as the school curriculum is meant to be created in discussions among the school's teachers, not taken over from somewhere. In the end, the opinion prevailed that it would be too difficult for teachers to define the content of an essentially brand-new subject that few people understand. This allowed creation of four variants of model school programmes, from which schools can choose with respect to their situation and interest: whether the school wants to profile itself as a school supporting informatics, whether it has the needed technical equipment and staff, whether it is rather conservative in its approach to changes and whether it wants to develop its own curriculum and let itself be only inspired. The model school programmes were developed to make maximum use of the new set of textbooks [25].

The publication of the new national curriculum triggered a massive discussion in the professional community, which was taken by surprise by the changes in consequence to insufficient communication from the side of the Ministry of Education before the publication of the changes. The Ministry found itself under pressure from professional teachers' associations in those areas of education whose number of lessons was shortened at the expense of computing. On the other hand, some schools welcomed the changes as a confirmation of their long-term efforts to innovate teaching.

In addition to questions that schools were expected to ask in the discussions (what to teach, who should teach it, who will pay for the changes), ICT teachers asked where to cover the traditional topics such as use of computer, office applications or Internet search. Currently, these topics are not compulsory in computing and it is up to the school whether it will include them in some educational area. Many teachers perceive the teaching of

office applications as the core of informatics and are likely to perceive it in this way some time longer.

5 Perspectives

The first stage of the long journey to the emancipation of computing as a standard area of general education of the citizen of the 21st century seems to have been successfully completed in the Czech Republic. Now, however, the following stage is beginning, in which the prepared changes will be implemented. If this stage is to be successful, a change in the teachers' attitudes and also their willingness to learn are essential. For many of them the change means learning how to teach a completely new subject. Also, a change in the thinking of school headmasters is necessary. They will, for example, have to allow class teachers or practitioners to teach informatics at primary school level instead of specialists in informatics who teach older pupils.

It is also imperative to set a standard for teachers, to develop new textbooks, to use new forms of teacher training, including personal assistance and sharing experience, to engage in research that evaluates the changes and points out their weaknesses as well as looks for new ways to teach informatics. Only a proper completion of innovation with quality feedback, with constant interest of the general public and the support of the ministry and last but not least with a massive training of new informatics teachers at universities will lead to the perception of informatics as a common school subject whose existence springs not only from the current situation but also because it can develop individuals in a modern way.

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