# Computing Education Research in Baltic Countries

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## 1 Introduction

Very similar school systems were built in all three Baltic countries during the Soviet occupation (1940–1991), where the dominating school type was 8- or 9-year basic school and the remaining one-third of schools taught children from age 7 up to 19. Also, computing education was strictly standardized in all Soviet republics. After the breakdown of Soviet Union in 1991, the three Baltic countries followed slightly different paths, both in regard to modernizing their school system and their computing education. Despite the low status of computer science as an elective subject in Estonian schools today, successful tertiary education in computing has allowed Estonia to become a leading country in digitalization. A strong foundation to computing education on tertiary level has been laid by high quality mathematics and science education in schools. In 2018, Estonia ranked number one in Europe in all three domains of assessment in PISA: Reading, Science, and Mathematics. Latvia has its own unique developmental trajectory of Computing education, focusing on local job market needs. Compared to the two other countries, research on computing education has been significantly more extensive in Lithuania, which is demonstrated by the establishment of the international research journal "Informatics in Education" by Vilnius University in 2002. Lithuania has initiated and coordinated

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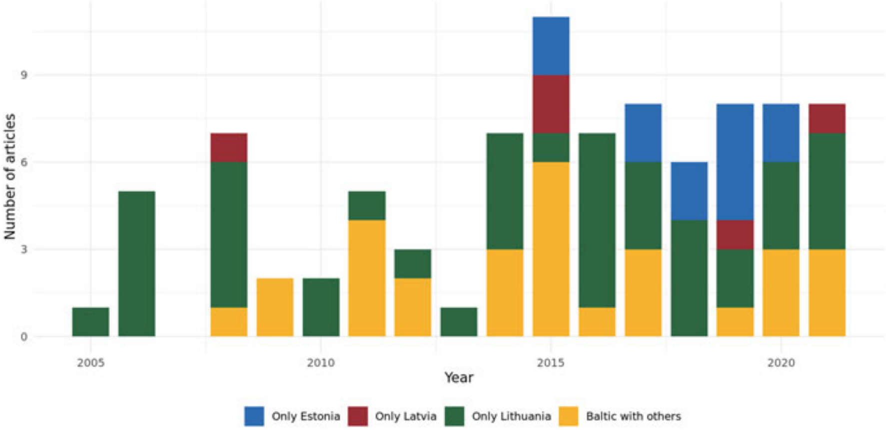


**Fig. 1** Distribution of CER papers where the publications are either by a single Baltic country author or include also authors from outside, but apparently they never include authors from multiple Baltic countries and no outside ones

the Doctoral Consortium on CER in schools, as well as the Bebras Challenge, a challenge on Informatics and Computational Thinking, attracting millions of school students globally every year [1]. A lot of research publications have been published with the data collected by Bebras.

A scientometric analysis revealed 89 papers that contained at least one author from Baltic countries (Fig. 1). The bibliometric dataset employed was a subset of the computing education research dataset described in chapter 'Scientometrics: A Concise Introduction and a Detailed Methodology for Mapping the Scientific Field of Computing Education Research' of this book [2], including only those articles with at least one author affiliated to a Baltic institution at the moment of publication.

According to scientometric analysis, most cited papers with at least one author from Baltic countries are presented in Table 1 and ten most cited authors in Fig. 2.

But let us begin this chapter with something that has been in common for Computing Education Research in Estonia, Latvia and Lithuania, namely: the emergence of Computing Education in 1986–1991, and the Baltic Olympiads in Informatics.

### *1.1 Computing Education in Three Baltic Countries: Prehistory*

Tertiary education on computing started in Estonia, Latvia and Lithuania in 1960. The movement was led by local enthusiasts who have been studying the emerging discipline in the best universities of St. Petersburg (former Leningrad) and Moscow. While there were attempts in all three countries to build local computer hardware

**Table 1** The top cited papers where at least one author is from Baltic countries

| Title of paper | Authors | Authors' countries | Year | Cit. index |
|---|---|---|---|---|
| Educational Data Mining and Learning Analytics in Programming: Literature Review and Case Studies [3] | Ihantola P; Vihavainen A; Ahadi A; Butler M; Börstler J; Edwards S; Isohanni E; Korhonen A; Petersen A; Rivers K; Rubio Ma; Sheard J; **Skupas B**; Spacco J; Szabo C; Toll D | Australia; Canada; Finland; **Lithuania**; Spain; Sweden; US | 2015 | 147 |
| Computational Thinking in K-9 Education [4] | Mannila L; **Dagiene V**; Demo B; Grgurina N; Mirolo C; Rolandsson L; Settle A | Finland; Italy; **Lithuania**; Netherlands; Sweden; US | 2014 | 125 |
| Bebras International Contest on Informatics and Computer Literacy: Criteria for Good Tasks [5] | **Dagiene V**; Futschek G | Austria; **Lithuania** | 2008 | 94 |
| A Global Snapshot of Computer Science Education in K-12 Schools [6] | Hubwieser P; Giannakos Mn; Berges M; Brinda T; Diethelm I; Magenheim J; Pal Y; Jackova J; **Jasute E** | Germany; India; **Lithuania**; Norway; Slovakia | 2015 | 68 |
| Bebras – A Sustainable Community Building Model for the Concept Based Learning of Informatics and Computational Thinking [7] | **Dagiene V; Stupuriene G** | **Lithuania** | 2016 | 66 |

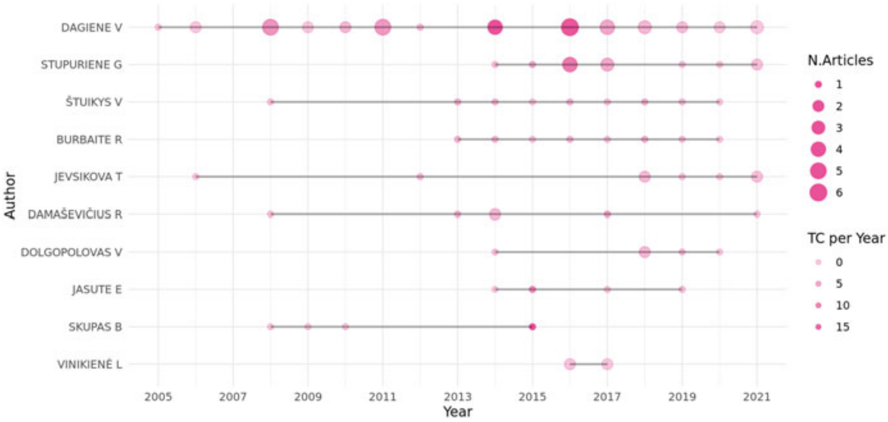


**Fig. 2** The most productive authors from the Baltic countries (actually all of them are from Lithuania), TC means "Total Cites"

and software, the first programming courses ran on Soviet factory-built machines (Minsk, Ural, *Edinaja Sistema* – ES). Computing was taught mainly as a part of applied mathematics and engineering study programs, later also in economics.

The starting point for introducing Computing Education in secondary schools in all three Baltic republics was Mikhail Gorbachev's talk on the 27th Congress of the Communist Party of the Soviet Union (March 1986), where the new leader made a radical call for "acceleration of the scientific-technological process" through the computerization of the Soviet economy. He saw this as the only chance for competing with "capitalism of the age of electronics and informatics, of computers and robots" [8]. Actually, M. Gorbachev had launched an ambitious computer literacy program a year before (ibid). Then, all three Baltic countries rushed to develop and produce their own local school computers [9]: Juku in Estonia (1986), VEF Mikro in Latvia (1985) and Sigma Poisk in Lithuania (1987). These locally-built computers were used in parallel with Russian-made school computers BK-0010SH, Agat and Korvet, but also imported Yamaha YIS-503IIIR machines. However, the new school subject called Informatics that was rolled out in all schools of the Soviet Union in 1986, did not assume the use of computers at all – the content was theoretical. The author of the first informatics textbook for secondary schools was the leading Soviet computer scientist, academician Andrei Ershov, who was invited by M. Gorbachev to lead the "informatization" of his perestroika project. Unfortunately, this progressive campaign for achieving universal computer literacy collapsed even before the Soviet Union and A. Ershov's difficult textbook remains in the memory of teachers and students of that era as an example of "Soviet absurdity" [8]. Already from the beginning of the 1990s, all three Baltic countries redirected their school informatics towards using Western IBM PC compatible computers for teaching more practical computing skills.

### 1.2 Baltic Olympiads in Informatics

The Baltic Olympiad in Informatics was established as a joint initiative of Estonia, Latvia, and Lithuania in 1995. A few years later, it grew to include seven more countries around the Baltic Sea: Denmark, Finland, Germany, Iceland, Norway, Poland, and Sweden [10]. In addition, teams from other countries may be invited as guests. The main goals concentrate on providing the participating students with experience of an international Olympiad, encouraging communication and exchange of ideas between the developers of national contests in informatics, as well as assisting delegation leaders in selecting participants for the international Olympiad.

The Baltic Olympiad in Informatics (BOI) is a programming contest for secondary school students from countries around or close to the Baltic Sea. Each year approximately 60 school students from 10 countries compete against each other, solving difficult problems of algorithmic nature. Each participating country sends 6 contestants from their national Olympiads organized beforehand.

BOI shares its competition format with the International Olympiad in Informatics (IOI), which is the most prestigious annual world programming competition for secondary school students established in 1989 (see chapter 'Computing Education Research in Schools', section 'Extracurricular Activities'). On each of two contest days, the contestants participate in a 5-h exam. They are given a number of algorithmic problems and are required to solve these by writing computer programs. Their programs are then evaluated and scored based on both efficiency and correctness. Usually, the participating countries take BOI results into account when selecting their teams for IOI.

The BOI is a short-term (lasting 3–4 days) and inexpensive event. It can be distinguished for cozy and good neighboring atmosphere, which is highly important when motivating students for self-help. Even though the BOI is a mini model of the IOI, it has significant differences from the cultural and learning perspectives. The organization of the scientific part of BOIs is based on mutual trust of the participating countries. The leaders of all the participating countries offer problems for the nearest BOI. At first draft task texts are offered, then the ideas are exchanged via e-mail and discussed, and some problems are rejected, while other problems are suggested to be modified and later are accepted.

Most of the problems are translated to the native languages by the leaders before going to the Olympiad. This is a unique possibility for country representatives to gain experience in organizing the scientific part of a relatively small international Olympiad as well as to raise their qualifications in algorithms.

The organizers of BOIs try to follow as close as possible the newest IOI trends in problem types, compilers, platforms, and contest systems. Even though all the tasks are of an algorithmic nature, they represent cultural and methodical differences. Since in the BOI most of the preparatory work has been done in advance, team leaders can discuss the tasks, possible solutions, and technical issues, and the BOI can be considered as a prearranged international way of learning.

The Baltic Olympiad in informatics has a long and interesting history. There are many activities in connection to BOI: countries have been preparing brochures of the used problems with detailed programming solutions, write papers about interesting task cases or testing environments, provide discussion on programming languages or testing innovations, and conduct various studies on programming education [10]. BOI has brought a message to society that informatics and programming are important for young people, and that they can be smart. There are many people involved in hosting Olympiads: companies, startups, researchers, professors, teachers, students, and policy makers.

List of venues and dates of the Baltic Olympiads in Informatics:

Lübeck, Germany, April 2022
Lübeck, Germany, April 2021 online
Ventspils, Latvia, July 2020 online
Tartu, Estonia, April 2019
Stockholm, Sweden, April 2018
Bergen, Norway, April 2017
Helsinki, Finland, May 2016
Warsaw, Poland, March 2015
Palanga, Lithuania, April 2014
Rostock, Germany, April 2013
Ventspils, Latvia, May 2012
Lyngby, Denmark, April 2011
Tartu, Estonia, April 2010
Stockholm, Sweden, April 2009
Gdynia, Poland, April 2008
Güstrow, Germany, April 2007
Heinola, Finland, May 2006
Pasvalys, Lithuania, May 2005
Ventspils, Latvia, April 2004
Tartu, Estonia, April 2003
Vilnius, Lithuania, April 2002
Sopot, Poland, June 2001
Haninge, Sweden, July 2000
Riga, Latvia, April 1999
Tartu, Estonia, June 1998
Vilnius, Lithuania, April 1997
Riga, Latvia, April 1996
Tartu, Estonia, April 1995

In 1996–1998, the Baltic School of Algorithmization, a distance teaching project for school students was initiated by the Institute of Mathematics and Informatics of Lithuania. School students from Estonia, Latvia and Lithuania participated in it. The purpose of this project was to teach high school students of the three countries competitive programming skills, and to compete and compare their skills with those of the students from other countries. Over one hundred school students participated in the Baltic School of Algorithmization.

All learning took place through e-mail. Each country picked one topic (non-overlapping), prepared the learning material, and created five tasks from the topic, e.g. recursion, backtracking, combinatorics, or big numbers. Each country translated the learning material and the tasks to their own language. Student submissions were evaluated by the country which created the task. After testing the solutions, the task authors prepared an overview of the received submissions and sent them out together with sample solutions and data sets. The School was completed with a competitive programming competition by email. Each country prepared one task for the competition. During the project, the students mainly communicated in their native languages through project coordinators in their countries.

## 2 CER in Estonia

### 2.1 Prehistory

The first computer that was used for educational purposes in Estonia was switched on in the University of Tartu in 1959: it was Soviet-made Ural 1. The first students of computational mathematics with programming skills graduated a year later, their teachers had studied computer science in Leningrad and Moscow [11]. Six years later, the same Ural 1 computer was moved to the nearby Nõo Secondary School, where it became the first school computer in the whole Soviet Union. For the next 20 years, it remained the only school computer in Estonia. Nõo Secondary School was not an ordinary one: it was a boarding school for mathematically gifted children who have excelled in math competitions and invited to take part in an experimental study program focusing on math, computing and science.

In Estonia, the M. Gorbachev’s call for providing universal computer literacy resulted in the development of the locally designed school computer Juku, whose mass production of which started in 1988 [9]. The last computer lab with 20 functioning Juku computers remained functional at Nõo Secondary School until 1997. The informatization campaign resulted in the preparation of qualified informatics teachers that first started in Tallinn Pedagogical Institute (from 1987, the first cohort graduated in 1989) and a few years later also in the University of Tartu.

However, there was almost no research conducted on computing education within these first three decades (1960–1990). The only computer scientist interested also in educational aspects of teaching with and about computers was Ustus Agur in Tallinn Polytechnical Institute, who co-authored with Inge Unt and Kalju Toim (educational scientists) an extensive book on Programming Learning [12]. The first Estonian who pursued a doctoral degree specifically in Computing Education Research was Mati Maksing from Tallinn Pedagogical University, but he did not remain in academia after his PhD studies in Germany in mid-1990s. At the same time in Tartu, Eno

Tõnisson was leading a group of teachers experimenting with Turtle Logo in primary schools. Since 1994, when internet arrived in first 5–10 schools in Estonia, Anne Villems was organizing in the University of Tartu several online simulation games for upper-secondary school students [13].

The third period of computing education in Estonia started in 1996 after launching the new national curriculum and also the national school computerization program “Tiger Leap”. While the latter resulted with equipping all schools with modern computer labs, internet connectivity and teacher training by year 2000, the former redefined completely the goals and content of the computing education in the country. The new concept of computing education did not include any flowcharts, programming, algorithms or data structures that were the core of A. Ershov’s textbook. Instead, the new subject called Informatics was focusing on generic ICT skills: word processing, spreadsheets, presentations, internet. Another major difference from A. Ershov’s concept was that the new Informatics could not be taught without computers. As a few schools had full-size computer labs at the time, the subject remained elective and marginal. By 2001, when the Tiger Leap program had modernized the computing infrastructure in all schools, the new version of national curriculum was published without mentioning any computing-related subjects or topics. To compensate this loss, there was a recommendation to integrate development of ICT skills into other subjects [14]. From 2003 until 2005, the national test of ICT skills was conducted by the National Examination Centre, the results were researched by A. Villems and L.-M. Tooding (2006) [15]. The test did not include any programming tasks. Within the next decade, the universities adjusted their computer science study programs and related entry requirements in line with an assumption that the majority of students enter university without any knowledge or skills of programming. For instance, Tallinn University of Technology introduced the introductory coding course based on MS Visual Basic in 1998 [16].

In 2011, the next major curriculum reform took place and informatics made its way back as an elective subject in primary and lower secondary school, still excluding coding, algorithms and other elements of traditional computing education. Although upper-secondary school curriculum did not mention informatics, it introduced several new elective courses that were related to computing: “Using computers for inquiry”, “Basics of programming and software engineering”, “Robotics and mechatronics”, “3D-modeling”, “Geoinformatics”. Each of these new elective courses was accompanied by an original textbook, online courseware, videos and other digital learning resources. However, uptake of these new courses remained limited due to lack of teachers – less than 20% of upper-secondary schools offered these courses to their students in 2017 [17]. The only exception was the data analysis course (“Using computers for inquiry”, taught in more than 80% of schools), as it appeared to be a necessary preparation for compulsory inquiry project every high school graduate has to defend before graduation.

Another round of curriculum innovation is currently (2022) being finalized, introducing significantly the renewed, widened and deepened concept of school informatics. This concept is balancing Design Thinking and Computational Thinking, as it introduces coding with educational robots already from Grade 1. From

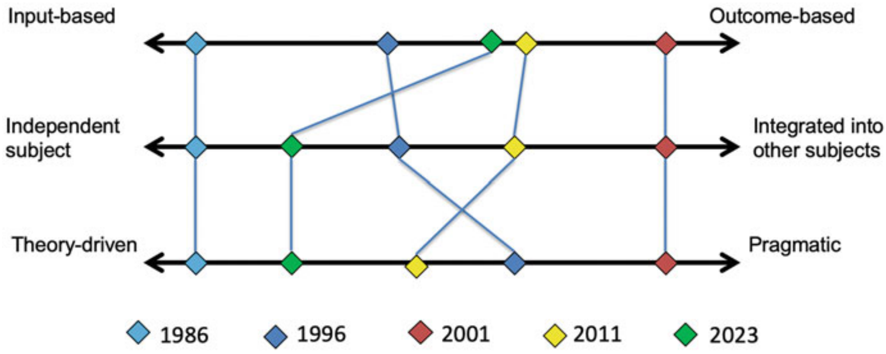


**Fig. 3** The pendulum effect in Estonian school informatics curriculum

Grade 4 onwards, it recommends switching to coding with Scratch and Kodu, while also addressing digital safety topics. In Grade 7, the students are expected to learn about information society technology: digital signature, information systems, online communities, Internet of Things, Virtual/Augmented Reality, Robotics, Big Data, Cyber Security. All students are expected to complete a Creative Project in Grade 8, which can be conducted in a new format: a Digital Prototyping Project that applies above mentioned new technologies. The e-textbooks matching the new informatics curriculum for Grades 1–6 and 10–12 are already available, Grades 7–8 are still waiting for it. Radical changes in Estonian informatics curriculum between 1986 and 2022 created a pendulum effect (Fig. 3).

The swift departure from Soviet-style input-based, theoretical curriculum resulted with replacing informatics as a school subject with integrated teaching of ICT usage skills through other subjects in 2001. Then, dissatisfaction of various stakeholders with this situation pushed the pendulum back towards restoring the informatics subject and re-introducing coding and computational thinking as its core in 2022. Unfortunately, this latest curriculum change process has been only briefly captured by research, specifically by K. Salum et al. [18] and P. Niemelä et al. [19].

## 2.2 *Informal Computing Education*

Increasing availability of personal computers in schools and informal education centers enabled the growth of coding clubs across Estonia at the end the 1980s and the beginning of the 1990s. Fidonet was launched in Estonia in 1989, from 1991 this network attracted a rapidly growing community of computing enthusiasts who also met physically for so-called informal BBSummer events. BBSummer'93 was attended by 140 participants. Fidonet Bulletin Board Systems remained hubs of informal computing education until the Internet replaced it from 1994 onwards.

A very important role in promoting informal, but systematic computing education was played by the Science School of the University of Tartu, where the department of school informatics was established by Rein Prank in 1993. Printed computing tasks were mailed to registered secondary school students, who then returned their solutions for review. The first online course "Java Programming" was launched by Tartu Science School in 2003. Today, 98% of their courses are delivered online. It is difficult to estimate the effect of correspondence courses delivered by Tartu Science School to the promotion of computing education and careers among secondary school students within the last three decades. Unfortunately, these important developments in computing education were not addressed by Estonian researchers.

While informatics and coding disappeared from the national curriculum by the turn of the century, computing activities remained active in 10–15% of Estonian schools through informal education. Extracurricular activities were supported financially by Estonian IT and banking industry through Look@World Foundation (e.g., the "SmartLabs" programme involved more than 600 students annually in 2012–2018), but also by the National Agency of IT in Education (HITSA) who conducted the "ProgeTiger" programme in 2014–2021 [20]. More than half of Estonian primary and lower secondary schools participated in the "SmartLabs" and "ProgeTiger" programs.

## 2.3 Research on School Informatics

The first Estonian academic journal that addressed the issues of computing education research was "Arvutustehnika ja andmetöötlus" (Computing Technology and Data Processing) that was published by Estonian Institute of Information from 1987 till 1992, then by Mainor Ltd. between 1992 and 1997. From 1998 till 2009 this journal was published by Tallinn University of Technology under the name A&A, chief editor was prof. Paul Leis. The section editor and most active contributor in the computing education section of this journal was prof. Leo Võhandu from Tallinn University of Technology, who discussed approaches to teaching coding based on various languages, but also interdisciplinary applications of computing education: computational linguistics, data visualization, geoinformatics, mathematics of computation, etc. The Estonian computing education research community is very small and has not been able to set up a new local journal that would address computing education topics. Rather, Estonian computing education researchers tend to publish in international journals, less frequently in the Baltic Journal of Modern Computing (published in Latvia) or Informatics in Education (published in Lithuania).

In the early years, the research on computing in general was conducted in four locations:

- Electrotechnical Research Institute (est. 1958) and,

- Institute of Cybernetics (est. 1960), both belonging to Estonian Academy of Sciences.
- Tallinn Polytechnical Institute, where the department of computing technology was established in 1964 by lecturer Kaarel Allik.
- University of Tartu, where the department of statistics and programming was opened in 1969 by prof. Ülo Kaasik.

In 1980, the computing center was established also in Tallinn Pedagogical Institute, contributing to development of educational computing tasks and learning resources.

Today, there are three research groups in the Computing Education field in Estonia. The largest and oldest one is led by associate professor of didactics of informatics Piret Luik in the Institute of Computer Science, University of Tartu. Their research focuses mainly on motivation and dropout of students taking a MOOC on programming [21], assessment of Computational Thinking [22], and automated assessment of programming tasks [23].

Another research group is led by Mart Laanpere, professor of mathematics and computing education in the Centre for Educational Technology, Tallinn University. Their research addresses mainly modelling and assessment of digital competence [24], digital transformation in schools [25], learning design, and learning analytics [26].

The third research group is led by senior researcher Birgy Lorenz in the Centre for Digital Forensics and Cyber Security at TalTech. Their research interests are related to cyber security education and contests, and gender issues in computing education [27].

These research groups have hosted a few conferences related to CER in Estonia: ICALT 2019, EC-TEL 2017, ISSEP 2020. For the last 4 years, the National Agency of Education and Youth has financially supported the development of informatics teacher education in Tallinn and Tartu, informatics teachers' summer schools and winter conferences, a MOOC on programming for secondary school students and the publishing of seven new e-textbooks of school informatics.

# 3 CER in Latvia

## *3.1 Prehistory*

The beginning of the computer era in Latvia is considered to be 1957, when the Latvian State University docent Eižens Āriņš raised the need for an electronic digital computing machine for scientific and technical development in Latvia. In November of 1959, the Computing Centre of the State University of Latvia was founded, with E. Āriņš as its director. The first serial computer in Latvia БЭСМ-2 was launched in a Computing Centre in 24-h mode in April 1961.

In the meantime, computer construction was also developing in Latvia. In 1960, under the leadership of Jānis Daube, a computer LM-3 was built. LM-3 was commissioned in July 1960, the first computer in the Baltic States. However, this direction did not gain further development and constructors of the LM-3 moved to the University of Latvia's Computer Centre or to the newly established Institute of Electronics and Computing Engineering of the Latvian SSR Academy of Sciences. LM-3 was dismantled in 1964.

The first programming textbook for computing machines (in Russian) was published by Ilze Irēna Ilziņa in 1962. On 16 May 1963, the first programming textbook in Latvian was published by E. Āriņš, S. Hozioskis and V. Līnis. In 1968, БЭСМ-2 was used to teach programming in machine code as no programming language for this machine existed yet, and the teacher had to learn to program simultaneously with the students.

The teaching of programming was also launched in 1961 by the Faculty of the Riga Polytechnic Institute (now Riga Technical University) in Automatics and Computing Engineering study program.

Research into how to systematically teach and learn usage of computers was not considered at the time.

## *3.2 Computer Education Research Chronology in Latvia*

The terms computing (*datorika* in Latvian) and informatics (*informātika* in Latvian) are often used as synonyms (e.g., https://www.informatics-europe.org/). In the Latvian education system, it is well established that informātika covers high-quality usage skills of an existing software product (e.g., MS Word, Excel, Drive), while *datorika* in addition contains software development theory and practice. Thus, *informātika* mainly refers to primary and secondary education, while *datorika* refers to professional secondary and higher education. Of course, some elements of the *datorika* can also appear in secondary and even primary education.

Then, the computing education research should be understood both as how to teach *informātika* and how to study/teach *datorika*. These studies are inevitably based on and depend on the technical basis of the period concerned (Table 2).

In the context of CER, these activities were crowned in several doctoral theses: "Software to Support Some Topics in Basic Course of Informatics at General Secondary Schools" of M. Vītiņš in 1993, "Informatics at School" of V. Vēzis in 2005, and "Competencies based school computing education content" of O. Krūmiņš in 2022.

### 3.2.1 Decades of Ershov-Monachov-Vītiņš

The informatics subject was introduced in secondary educational establishments in the USSR in the school year 1985–1986 [28]. The objective of the course was to develop computing skills without using computers, due to a limited availability of hardware in schools at that time. When the supply of computers to schools

**Table 2** CER chronology in Latvia

| Year | Technology | Users | Domain | Education | CER |
|---|---|---|---|---|---|
| 1950–1965 | Few computers, small series | Professionals – University graduates | Military, science, economics | Universities: *datorika* | Prehistory |
| 1965–1995 | Serial computers for professional usage | Mass usage in professional fields, university graduates | Military, science, economics | Universities and some secondary schools: *datorika* | Decades of Ershov-Monachov-Vītiņš |
| 1995–2005 | Personal computers for professional usage | Mass usage in professional fields, university graduates | Military, science, economics, household | Universities and some secondary schools: *datorika* | |
| 2005–2015 | Global web and personal computers for professional and home usage | Mass usage in professional fields, secondary/tertiary education | All fields of economics, majority of households | Higher education: *datorika, informātika*; secondary schools: *informātika* | Decade of Vītiņš-Borzovs-Vēzis |
| Since 2015 | Global web and dominance of social networks | Mass usage in all sectors and households; non-ICT professionals | All fields of economics, majority of households | Higher education: *datorika, informātika*; all schools: *informātika* | Decade of Vēzis-Krūmiņš |

improved by the end of decade, the course was gradually transformed to make use of computers. The course syllabus was expanded and more lessons were allocated for the subject. Programming elements and working with office software still remained a part of the course. Latvia was the first from the former republics of the USSR to introduce a computer-based version of A. Ershov's informatics course in all secondary educational establishments.

### 3.2.2 Decade of Vītiņš-Vēzis

All Latvian schools had received at least one computer class around 2000 that enabled them to react constructively to the rapid spread of the global web. There was an objective need to train both adults and students to use the most common software products (Word, Excel, e-mail, etc.) qualitatively. It was organized by M. Vītiņš and J. Borzovs through the Latvian Information and Communication Technology Association (LIKTA) by introducing European Computer Driver License (ECDL) certification in Latvia [29]. A set of educators lead by V. Vēzis developed and published textbooks for preparing for ECDL exams. These initiatives launched a major campaign for the acquisition of informatics skills in Latvia. Latvia was the first country in the world to introduce the ECDL curriculum in both secondary and primary schools. These changes did not affect programming training, leaving it to the few schools that already practiced such a subject.

### 3.2.3 Decade of Vēzis-Krūmiņš

In the second decade of the twenty-first century, an acute shortage of computer-system developers appeared to be continuing. There was an objective need to teach not only informatics in schools, but also computer literacy. The pressure of the ICT industry lobby on the government resulted in a state-funded project designing new subjects in informatics and computing. This was done by the Working Group under the leadership of V. Vēzis and O. Krūmiņš [30]. They based on Association for Computing Machinery's recommendations, especially:

- digital literacy should be taught to anyone under 12 years of age, including not basic skills only, but also aspects of effectiveness, ethics and security;
- all students should study computing as a separate field of science, including by using it in other fields of study.

More detailed analysis for teaching informatics and computing at Latvian schools are provided in [31].

### 3.3 CER in Other Latvian Universities

Although, due to historical circumstances, the part of the research aimed at creating informatics curricula for primary and secondary schools was carried out at the University of Latvia (see Sects. 3.2.1, 3.2.2, and 3.2.3), a number of other Latvian institutions of higher education also conducted CER.

At Riga Technical University since 1997, there is the Distance Education study Centre, led by Atis Kapenieks, where ecosystems for distance learning are explored and developed (collaborators I. Daugule, A. Gorbunovs, M. Jirgenson, K. Kapenieks, J. Kapenieks Jr. I Kudina, G. Stale, Z. Timsans, I. Vitolina, V. Zagorsky, B. Zuga and others).

Led by Anita Jansone at the University of Liepaja, D. Barute, I. Konarev, K. Mackare, I. Magazeina, R. Nacheva, L. Ulmane-Ozolina, M. Zigunov have studied guidelines for designing e-study materials and higher education e-learning frameworks.

In cooperation between the University of Latvia and the University of Daugavpils, under the guidance of Laila Niedrite, V. Vagale, S. Ignatjeva et al. have focused on development of a personalized e-learning. Independently, S. Cakula and M. Sedleniece carried out similar research at the University College of Vidzeme.

L. Niedrite, D. Solodovnikova, N. Kozmina and J. Borzovs conducted a series of studies in an attempt to find the human properties for successful information technology studies.

University of Latvia in cooperation with Vilnius University and other Latvian universities and institutes conducts the Baltic Journal of Modern Computing (established in 2008) where the Computing Didactics, led by V. Dagienė from Vilnius University and M. Vītiņš from University of Latvia, is one of the nine journal's content areas. The topics in the area of Computing Didactics are quite broad. The research is more related to use of digital technologies in education than to computer science education, but few papers are devoted to CER, for example [30, 32].

## 4 CER in Lithuania

Teaching informatics (computing/computer science) in secondary schools in Lithuania was implemented in 1986. On occasion of the 20th anniversary of informatics in schools, the second international conference ISSEP (Informatics in Schools: Situation, Evolution, and Perspectives) was arranged in Vilnius, and the book "The Road of Informatics" [33] was published in both Lithuanian and English, which provides an overview of the teaching of computing over the past 20 years. Before the official introduction of informatics in schools, all school students had the opportunity to learn programming elements remotely 5 years earlier, starting in 1981. This was the School of Young Programmers by correspondence. At the same time, researchers in the Institute of Mathematics and Informatics (now Institute of Data Science and Digital Technologies) began discussions on how to teach programming to secondary school students.

## *4.1 Prehistory: School of Young Programmers by Correspondence*

In 1979, an experimental School of Young Programmers by correspondence was conducted. Two years later, the nationwide School of Young Programmers named JPM (acronym for Lithuanian *Jaunųjų programuotojų mokykla*) was established.

Ministry of Education of Lithuania approved the teaching materials and tasks for publication in the most popular youth daily newspaper at that time (*Komjaunimo tiesa*). Ordinary postal service was used for communication between teachers and school students. In the early 1980s, this school was the only educational institution enabling to get a primary acquaintance with algorithms and computer programming for most students in Lithuania, especially for those living in provinces. The JPM provided an excellent opportunity for CER. Many papers, especially those focused on methodology of teaching programming for young people, were published in local publications [34–36].

### 4.1.1 Main Curriculum of the School of Young Programmers

In order to convey the foundations of contemporary programming methodology to the students of the JPM, theoretical knowledge is necessary as well. However, for most children, the theory is less attractive than practical activities. Thus, the basic principles of the theory were delivered in an indirect way through problem solving. The set of programming problems was chosen in accordance with the requirements dictated by appropriate programming style and creativity [37].

All the teaching materials of JPM till 1993 consisted of several teaching chapters, for example: (1) Names, variables, values, assignment statement and sequence of statements; (2) Branches of actions; (3) Repetitions of actions; (4) Program and its running by computer; (5) Logical values; (6) Functions and procedures; (7) Recursion; (8) Discrete data types; (9) Real numbers and records; (10) Arrays; (11) Programming methodology (i.e. style); (12) Program design.

Many tasks were small and simple (e.g., to find the perfect numbers, friendly numbers, etc.), though their solutions without a computer is cumbersome. The benefit of a computer for solving such tasks may be demonstrated too. A special attention was given to the Boolean type and recursion. Logic is a base of the programming as a whole and the recursion may be considered as a bridge between two programming paradigms, the procedural and nonprocedural programming.

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CIKLAI CIKLE

menų sumos. 2) Imti visas galimas skaitmenų poras. Iš jų sudaryti dviženklį skaičių ir tikrinti, ar šis skaičius dalosi iš skaitmenų sumos. Spręsime antruoju būdu.

```
kiek:=0;
for a:=1 to 9 do
   for b:=0 to 9 do
     begin
       sk:=a*10+b;
       s:=a+b;
       if sk mod s=0 then
         kiek:=kiek+1
     end
```

Čia dviženklis skaičius pažymėtas vardu sk, jo skaitmenys — vardais a ir b, skaitmenų suma — s, o rezultatas — vardu kiek. Išoriniu ciklu perrenkami visi skaitmenys nuo 1 iki 9 — tai pirmasis dviženklio skaičiaus skaitmuo. Vidiniu ciklu perrenkami visi skaitmenys nuo 0 iki 9 (antrasis dviženklio skaičiaus skaitmuo gali būti ir nulis). Taigi išorinis ciklas atliekamas 9 kartus, o vidinis 9×10=90 kartų.

**Fig. 4** The fragment of the newspaper with lesson in programming. In the upper left corner appears the logo of JPM – letters J (for "Young"), P (for "Programming"), and M (for "School") combined together

### 4.1.2 The Growth of the School of Young Programmers

Since 1981 until 2014, there have been many changes in the teaching of informatics in general and in programming in particular due to the increase in the number of computers in educational institutions and introduction of informatics as compulsory discipline in secondary schools. These changes had a considerable effect on the teaching in the JPM [38–40]. The changes can be characterized by five periods:

1. Universal (general) programming teaching (1981–1986).
2. Learning effectively: differentiation by students' abilities (1986–1993).
3. Intensive teaching of gifted students (1993–1999).
4. Preparing students for the Olympiads (1999–2005).
5. Using new media while learning algorithms (2005–2014).

The primary course of programming used to be published in the daily newspaper (Fig. 4), one lesson per week (1981 January – May, 1983 September – December and 1985 September – December). The lessons covered all the material in programming needed for beginners: text and tasks for self-control as well as certification tests. The JPM lessons in newspaper were the only possible way to get primary acquaintance with computers and programming for many youngsters at that time.

The primary course of programming covered only four chapters of the JPM curriculum: all operations with integer numbers, assignment statements, a sequence of statements, conditional and loop statements. Program execution by computer was discussed as well. Students were taught to solve interesting and attractive problems by algorithmic approach [41]. Tests were presented about once per month, so that the students studying the primary course could carry out four or five tests per year.

The second course of the JPM was more difficult and lasted a bit longer – from a year and a half to two years. There were considerably less students studying this part than the first one. During 1993–1994 the JPM was reorganized because of increasing numbers of computers in schools and growing participation in national Olympiads in informatics [41]. The studies were divided into two parts (courses): (1) constructs of algorithms and programming, and (2) methods of algorithms.

Reading (analyzing) tasks made up to a quarter of each student's homework. All the tasks were attractive and developed reasonable thinking. The first part of the course covered the whole curriculum of JPM and consisted of five training chapters and a test: (1). An algorithm. Variables. Assignment statement. (2). Control structures: conditional, compound and loop statements. (3). Functions and procedures. Recursion. (4). Scalar (simple) data types. (5). Data structures.

The second part of the course consisted of five tasks classified according to the nature of the algorithms' methods. There were usually five topics (they could be slightly different each year), i. e.: (1) the big numbers, (2) units of measurement (regular and irregular), number systems, calendars, (3) searching for solutions, backtracking method, puzzles, (4) coding and ciphering, finding and correcting mistakes in data, (5) data sorting, (6) dynamic programming, (7) graph algorithms.

During the period 1999–2001, the JPM was reorganized again. The main reason for the reorganization was the changes in curriculum of informatics in schools and the spread of new communication technologies, i. e., an electronic mail system [38, 42]. The goal of the changes at that period was to differentiate the learning course by adding one year. Fundamental principles of programming and developing of algorithms were the basis for teaching. The second year was devoted to the learning of various algorithms, e.g., data sorting and searching, recursion, backtracking, and graph algorithms. The third year was intended to analyze more advanced tasks of informatics (similar to tasks of Olympiads in informatics).

In 2005–2006, a virtual learning environment, developed by Lithuanian Olympiad student A. Paltanavičius, started to be used at JPM [43] and all students get tasks and deliver solutions using the virtual environment. The JPM curriculum has not been changed.

### 4.1.3 Training Approaches and Research

A specialized Pascal translator (compiler) for schools for the soviet computer EC ЭВМ (a clone of IBM System/360) was developed by young researchers V. Dagienė and A. Petrauskienė led by Dr. Gintautas Grigas. The translator had an error-detection module that allowed students to receive useful feedback, and even corrected part of errors in beginner's programs, and reported on what and how it changed. This was a very important feature since access to the computer was limited. Several studies were conducted and research papers published [44].

Studying in JPM was voluntary and individual. Training and evaluation approaches had been changing during the time. At the beginning (1981–1986) the difficulty of each task and different maximum points for different tasks given were estimated. However, it appeared that often JPM participants could not solve rather easy tasks and sometimes surprisingly solved tasks which were estimated to be hard and high points were given for them.

During the whole period of JPM's participating students were receiving advice and guidance although their work was evaluated strictly enough. This circumstance as well as proving of the characteristics required for a programmer (e.g., algorithmical thinking, creativity, diligence, accuracy, and attention) and the difference of the extramural studies from the usual ones at school determine that just a part of students who have tried themselves at JPM are awarded with its certificate.

During 34 years of JPM's existence, over 7000 school students were introduced to programming basics. The JPM was one of the long-existing school on programming by correspondence available for all school students all over world. Main issues can be highlighted following the long experiences in teaching programming:

- Attention to the programming and algorithmic style as a part of information culture. Meaningful names of variables, procedures and other objects are selected, and commented.
- Introducing the reading's tasks. Analyzing algorithms is proved important while learning programming. By reading a task, more complicated algorithm can be introduced.
- Priority is given to tasks which requires creativity in programming. Teaching programming rather than programming language.

The JPM triggered a number of scientific and methodological articles, books (however, all of them are in Lithuanian and only printed versions), contests, and other activities. The team was enthusiastically inspired by the idea to contribute to computing education at schools despite lacking even the most elementary resources, e.g., there was only one typewriter in the entire institute.

## *4.2 Compulsory Informatics in Schools: From 1986 Until Now*

A significant role in the history of designing informatics education in secondary schools was played by the scientists of the Institute of Mathematics and Informatics. Comprehensive materials were prepared including tasks, tests and didactical explanations for teaching computing with main focus programming. Just like in Estonia and Latvia, informatics subject was introduced in Lithuanian schools in 1986, under the slogan by Soviet academician A. Ershov: "*Programming is the second literacy*" [45]. This quote is used even today, often without any reference to the original author. These were not empty words: in order to reach this objective, the Soviet Union invested significant resources and efforts.

### 4.2.1 Teaching Algorithms: From Logo to Pascal

In 2006, when Lithuania celebrated 20 years of informatics in schools, the book "The Road of Informatics" was published and it was written: "*At the beginning there was Logo. Then everything happened*" [33]. Teaching informatics started with Logo developed by Seymour Papert, the "father of Logo".

The book "Mindstorms: Children, Machines, and Powerful Ideas" by S. Papert [46] was translated into the Lithuanian language. Educators throughout the world became excited by the intellectual and creative potential of Logo. Their enthusiasm fueled the Logo boom of the early 1980s. The book begins with an affirmation of the importance of making a personal connection with one's own learning and ends with an examination of the social context in which learning occurs.

In 1985, the Logo Computer Systems corporation developed an interpreter "LogoWriter", which was localized into Lithuanian and used in schools for many years. "Mindstorms" (1980) [46] and "Logo Writer" were tools that helped teachers to grow up combining computing and innovative pedagogy such like constructionism. Teachers were influenced by S. Papert's ideas that learning to communicate with a computer (to program the computer) may change the way other learning takes place.

Later a "Comenius Logo" for Windows was purchased for all schools in Lithuania and localized. It had fascinated graphics, an easy animation capability, but teachers and students needed to be creative and willing to do something new. That's about innovative pedagogy [47]. Many exercises for learning Logo were developed, and many books published on Logo-inspired ideas to introduce children to programming [48]. The ideas from Logo reoccur time after time; through development of learning tools in many countries and in several companies when new educational products are developed. For many years, Vilnius University has been cooperating with the CER group of ETH Zurich, Switzerland led by Juraj Hromkovič.

There has been many important events in connection with teaching Logo and algorithms all over the world, a detailed Logo Tree Project is provided by P. Boytchev [49].

Pascal, the great programming language that served in education for many years, was designed in 1968 by Nicklaus Wirth, with the goal to encourage good programming practices to novices by using structuring programming and data structuring. Pascal had big influence in programming education in many countries. In Lithuania, Pascal was chosen as language to communicate to big machines and express algorithms especially for secondary school students. It was a way to algorithmical thinking. Pascal was backbone for Young Programmers School [43].

Informatics education in Lithuanian schools (grades 10–12) was based on Pascal, the language that fit perfectly to think of and develop algorithms. Pascal's advantage was its simple syntax and logical structures. Pascal was used also to develop algorithms on paper and pencil and run them later on a computer, which was an important aspect in the early eighties when schools had very limited access to machines.

### 4.2.2 Informatics Curriculum Developments

In 1991, the second year of Lithuanian independence, a first original textbook for grades 10 and 11 was published. Attention was drawn to main concepts of informatics rather than to the particular technical details of computing techniques and programming. The authors V. Dagienė and G. Grigas [50] emphasized the design of algorithms and of algorithmics style. An innovative approach was the reading of well-prepared algorithms (reading tasks) and answering challenging questions. Thousands of such "reading tasks" for learning algorithms were published in a series of books.

The course in informatics started to be taught in Lithuanian comprehensive schools 35 years ago. The contents of the course, evaluation, and even the name were changed several times. Nevertheless, informatics has remained as a separate subject in schools of Lithuania. In 2002, informatics subject was renamed as information technologies (IT) in grades 11th and 12th while it was still called informatics in grades 9 and 10 [38]. The objective was to teach both, information technologies skills and computer science concepts including programming.

A revision of the informatics core curriculum was initiated in 2005, expanding the scope from 2 to 4 years teaching time (in total 136 h) with more focus on developing algorithmic thinking and applications [51]. The teachers were formally qualified, usually with a bachelor or master degree in informatics combined with mathematics. Fifth and sixth 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 enroll in the optional module of algorithm design and coding.

During years, the main aim of teaching informatics in general education is to develop students' information culture (digital literacy) in a broad sense. The information culture is a wide concept, considerably wider than information skills or abilities to work by computer. The conception of information culture covers various abilities and skills [52]. The content of information culture's notion is constantly changing and is reliant on technological transformations, it embraces a broad range of students' cognitive and other abilities and attitudes.

Concerning informatics curriculum development and implementation in schools there were many studies also comparison with other countries done for example [53–55] and recommendations taken into account for further developments [38, 51, 56–58].

In 2019, the Lithuanian Ministry of Education, Science and Sport approved new guidelines for pre-school, primary, basic and secondary education [59]. Informatics is included in primary school level as well (Fig. 5). In 2020, one hundred primary schools started to pilot the new developed informatics curriculum (www.mokykla2030.lt). The pilot targeted to develop learning resources and textbooks, as well as teacher training. The full-scale implementation of the new informatics curriculum for all grades commences in 2023.

The new informatics curriculum includes fundamental Informatics topics such as programming, problem solving and algorithms, data mining, data representation and information, networks and communication, digital technology and human computer

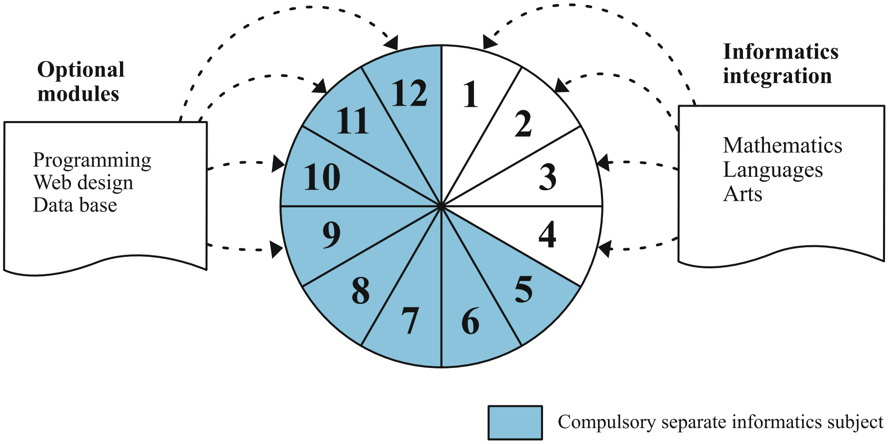


**Fig. 5** Informatics course in schools in Lithuania

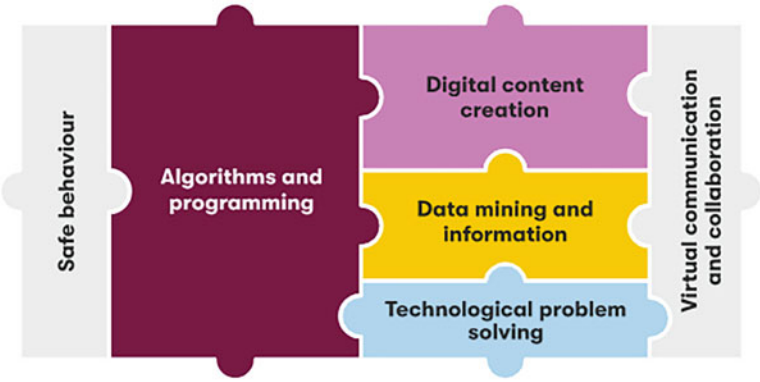


**Fig. 6** Informatics course in schools in Lithuania

interaction, security, and privacy, and ethical considerations. Six areas of informatics education with a main focus on the first four core areas were identified and used in the new curriculum in Lithuania (Fig. 6).

The six areas are applied to all levels of school education in Lithuania, starting from grade 1 of primary school (and even including pre-school education) all the way up to grade 12 of upper secondary school. In Table 3, the achievements of students and essential skills are briefly presented.

The challenge is to redesign an informatics course of upper secondary school (grades 11–12) so that it would be modern and cover new technologies such as artificial intelligence, machine learning, big data, and deep learning.

**Table 3** Six areas of a new established informatics curriculum in primary and secondary schools

| Area | Essential skills |
|---|---|
| Digital content creation | Familiarize with digital content diversity and forms, recognize computational thinking concepts<br>Use digital content to learn in various subjects<br>Create digital content using various technologies: draw, write, compose, record, film, make video, create mind maps, tables, graphs<br>Evaluate, improve and share digital content |
| Algorithms and programming | Understand the importance of algorithms and programs, provide samples from everyday life<br>Apply commands, logical operations and programming interfaces<br>Identify sequencing, branching, loop actions and express them by commands, apply logical operations<br>Create and run programs using programming tools and virtual environments<br>Test, debug and improve programs |
| Technological problem solving | Identify problems occurring when using digital technologies and devices<br>Creatively use digital technologies to learn various subjects<br>Select appropriate digital technologies to solve tasks<br>Self-educate and self-evaluate own digital skills |
| Data mining and information | Understand the importance of data and information, recognize computational thinking concepts<br>Search information purposefully using digital technologies<br>Perform various actions on data: collect, store, group, search, visualize<br>Evaluate relevance and reliability of information |
| Virtual communication and collaboration | Understand purpose and importance of virtual communication<br>Collaborate, share experiences and resources, communicate using digital technologies<br>Discuss possibilities and risks of virtual communication |
| Safe behavior | Perceive the necessity to protect digital devices from malicious software and spam<br>Discuss copyright and piracy issues<br>Protect health and environment while using digital technologies<br>Behave safety in virtual space |

### 4.2.3 National School Leaving Exam in Informatics

To meet the needs of higher education institutions and the economic development of the country, the nationwide maturity exam to evaluate students' skills in programming was established in 1995 [60]. Those who pass the informatics exam have enhanced opportunities to enter computing-related studies in higher education.

The main function of an exam is the evaluation of learning results [61, 62]. The content of the exam is closely related to the subject's curriculum. The proper selection of the exam's goals, and the emphasis (or lack thereof) on one or another aspect of the subject, have a strong impact on the quality and content of learning as well as on the students' motivation to learn the discipline. Lithuanian teachers and students pay attention to exams and therefore this situation should be exploited. By creating the content of the exam, a double goal could be achieved: to evaluate the students' knowledge and to encourage a student to cultivate his or her skills in the chosen discipline.

Students are acquainted with the formulation of topics in advance. The exam questions were formulated in a more concrete or constricted way, nevertheless their character was broad enough, requiring reasoning and a fair knowledge of the field. The topics embrace the compulsory course and the main conceptions associated with common human information activity. By answering the questions, students not only show their knowledge in a certain field but also have a chance to demonstrate their ability to express thoughts in a clear, logical and correct manner.

During the exam, students have to write programs of two tasks. The tasks consisted of several parts. The goals are to evaluate students' practical skills, the ability to choose and to create data types for the tasks, as well as to apply algorithms and tools for program structure in particular situations [63]. The content of the exam in informatics is based on the curriculum of grades 11–12. Since the course is quite modest, only 68 h, the exam is fairly compact.

## *4.3 Two International Journals on Informatics Education*

In 2002, Vilnius university established an international journal "Informatics in Education" (https://infedu.vu.lt/journal/INFEDU), a peer-reviewed journal that provides an international forum for presenting the latest original research results and developments in the fields of CER. At the beginning, the journal was promoting research among educators both in the Baltic countries and in Eastern and Central Europe, but now there are authors from all over the world. The topics range across diverse aspects of computing education research including empirical studies, statistical research on big data related to computing education, educational engineering focusing mainly on developing high quality original teaching sequences of different computer science topics that offer new, successful ways for knowledge transfer and development of CT, design of educational tools that apply technology in novel ways.

**Table 4** Submissions of papers in 2016–2021

| Number of papers/Years | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|
| Total submissions | 91 | 112 | 151 | 154 | 172 | 195 |
| Accepted and published | 16 | 15 | 20 | 20 | 30 | 30 |
| Rejected after peer review | 42 | 38 | 32 | 40 | 35 | 11 |
| Rejected before peer review | 35 | 61 | 90 | 86 | 101 | 154 |
| Rejection rate | 85% | 88% | 81% | 82% | 79% | 85% |

Recently “Informatics in Education” is published by Vilnius University Institute of Data Science and Digital Technologies in cooperation with Swiss Federal Institute of Technology (ETH), Zurich, Centre for Computer Science Education. The journal’s visibility is growing and well-written paper submissions are increased. In 2021, the journal received a total of 195 papers. The acceptance rate is quite low, less than 20% (Table 4).

The journal is indexed in many data bases including Web of Science Emerging List (176th place among 739 journals in Education & Educational Research category, 2022). The journal citation rate in Scopus is quite high (4.1 in CiteScore 2021). From 2021, the journal is indexed in the ICI Journals Master List database with Index Copernicus Value (ICV) = 128.60 (more information at https://journals.indexcopernicus.com/).

Another journal established by Vilnius university in 2007, is an international scholarly journal on Olympiads in informatics “Olympiads in Informatics”, it is described in chapter ‘Computing Education Research in Schools’ in section on Olympiads.

### *4.4 Hosting International Conferences of CER*

Several international CER conferences were arranged by Lithuanian researchers. The most important are: ISSEP, ITiCSE, Eurologo, named later by Constructionism, and specialized IFIP conferences. In 2006, on the occasion of the twentieth anniversary of teaching informatics in schools in Lithuania, ISSEP conference was organized. Researchers from 37 countries were participated. More than one hundred papers were selected and published: the best 29 papers were published in “Lecture Notes in Computer Science” by Springer, and 70 papers were published in the conference proceedings.

In 2018 in Vilnius, the Constructionism conference celebrated its fifth anniversary under this name, building on the 27-year tradition of biennial Eurologo conferences established by the European Logo community. S. Papert coined the term constructionism: in order to define its meaning, he started from the comparison with the term constructivism: “Constructionism shares constructivism’s connotation of learning as ‘building knowledge structures’ irrespective of the circumstances of the learning. He then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe" [65].

The Constructionism conference was truly international with about 150 submissions from 40 countries. The accepted submissions consisted of 18 keynotes talks, 57 research and practice papers, 3 panels, 7 working group proposals, and 27 proposals for posters, demonstrations, and workshops. In addition, a special Teachers' Day is organized before the conference. Selected research papers were published in the international peer-reviewed journals "Informatics in Education" and "Problemos". The best papers were selected and published in the "Constructivist Foundations" journal.

### *4.5 Doctoral Consortium*

Doctoral consortium is a yearly three-day event, shaped as an international version of the seminar, in which doctoral students meet and collaborate with peers, supervisors and scientific experts from other countries. Institute of Data Science and Digital Technologies of Vilnius University established international Doctoral Consortium on Informatics Education and Informatics Engineering Education Research in 2010 and organizes it each year on the first or second week of December in Druskininkai, Lithuania.

The Doctoral Consortium provides an opportunity for doctoral students to explore and develop their research interests in a workshop under the guidance of distinguished senior researchers.

The Consortium is designed as a student-cantered event and offers:

- A friendly forum for doctoral students to discuss their research topics, research questions and design in the field of their research;
- A supportive setting for feedback on students' current research and guidance on future research directions;
- Comments and fresh perspectives for each student on his/her work from researchers and students outside their own institution, as well as help with choosing suitable methodology and strategies for research;
- Support networking with other researchers in the informatics engineering education research field, and promote the development of a supportive community of scholars and a spirit of collaborative research;
- Support for a new generation of researchers with information and advice on research and academic career paths.

This event is attended annually by 12–18 doctoral students, and at least 6 senior researchers representing several countries who give lectures and work with small doctoral student groups. The methodology used in the Doctoral Consortium is project-based, going through methodological stages, students develop posters of their research project, share, and discuss their project with the Consortium's community.

The consortium was designed primarily for students who are currently enrolled in any stage of doctoral studies with a focus on CER and education research or with a focus on other areas of research in connection to globalization, modern technologies, and education. Senior researchers in the field provided feedback and suggestions for improvement of the research proposals. The Doctoral Consortium is a friendly forum for doctoral students to discuss their research topics, research questions and design in the field of education, to receive constructive feedback from their peers and senior researchers, to help with choosing suitable methodology and strategies for research.

In December 2021, the Doctoral Consortium was organized by two divisions of Vilnius University: Institute of Data Science and Digital Technologies and Institute of Educational Sciences. 29 doctoral students participated from 10 countries (Germany, Austria, Sweden, Estonia, Switzerland, Hungary, Netherlands, Finland, Slovenia, Lithuania) and 22 senior researchers from 12 countries (United Kingdom, Netherlands, Portugal, Italy, Slovenia, Ukraine, Austria, Hungary, Estonia, Macedonia, Switzerland, Lithuania). Senior researchers stressed that, despite deepening scientific knowledge, this consortium provided opportunities for intercultural exchange, both within the international student group and meeting local students and teacher.

### *4.6 Research on School Informatics*

Computing education research in Lithuania has started almost a half century ago. A significant role in designing methods for teaching programming was played by the scientists at the Institute of Mathematics and Informatics; more about history can be found on the website: https://www.mii.lt/en/about-the-institute/history. So, in 1978–1979, the institute scientists designed methods and resources for teaching programming at schools and conducted various small-scale studies.

In 1984, a Department of Programming Methodology was established led by G. Grigas, later in 2002, it was renamed to Department of Informatics Methodology and V. Dagienė became a chair. This small group of active scientists were among the first to create a programming learning environment where the teaching of informatics took shape. These scientists established the School of Young Programmers (see Sect. 4.1), designed and developed informatics curricula, teaching methodology, textbooks, and maturity exam (see Sect. 4.2), established two international research journals (see Sect. 4.3), hosted national and international conferences, seminars, workshops, the doctoral consortium (see Sects. 4.4 and 4.5) as well as conducted doctoral studies.

Since 2010, the Institute of Data Science and Digital Technologies has become part of Vilnius University, but informatics research continues within Education Systems Group led by V. Dagienė. The group conducts research on teaching and learning informatics at schools, approaches and methodology, informatics curriculum development for primary and secondary schools, teacher training with focus on informatics, also computing engineering education research especially in connection to educational software localization, and development of terminology.

More or less, the research on CER is taken care of by several other universities:

– Klaipėda University where several studies on informatics teacher education and educational software development were conducted led by Vitalijus Denisovas;
– Šiauliai University (became part of Vilnius University since 2021) participated in several studies on informatics teacher education led by Sigita Turskienė;
– Kaunas University of Technology has formed strong leadership in research on distance education mainly focusing on higher education (including informatics) led by Aleksandras Targamadzė.

Today the main research group in informatics education (CER) is the Education System group in Institute of Data Science and Digital Technologies of Vilnius University. One of the most important results of this group is the doctoral studies in the area of CER. More than 20 doctoral theses in connection to CER were supervised and defended, for example, “Concept-Driven Informatics Education: Extension of Computational Thinking Tasks and Educational Platform for Primary School” by G. Stupurienė in 2019, “Software learning objects for scientific computing education: teaching parallelization with recurrence based stochastic models” by V. Dolgopolovas in 2018, “Design of adaptive programming teaching tools” by J. Urbonienė in 2014, “A method for semi-automatic evaluation and testing programming assignments” by B. Skūpas in 2013.

## 5 Discussion and Conclusions

Computing education in schools of Estonia, Latvia, and Lithuania is entering the fifth decade of its existence. All three countries put a lot of effort in developing curricula, textbooks, and other activities in computing education and research. As the ongoing innovation is always in dialogue with today’s challenges as well as yesterday’s decisions, we explored in this chapter the historical perspectives on the development of computing education and related research in these three Baltic countries.

It is not easy to design curricular change that aims to shift the focus from acquisition of static content knowledge to integration of deeper procedural and conceptual knowledge, while considering local culture, language, etc. The impact of digital technologies on global and local contexts is forcing us to constantly redefine the forms of literacy and skills that are needed to survive in the world of tomorrow. These cognitive skills are based on higher-order thinking that might (or should?) involve computing. Hence, it is not surprising that computational thinking has been increasingly prioritized by policy makers around the world [66]. This is both a challenge as well as an opportunity for Computing Education Research today.

However, some lessons learned from the history of computing education in Baltic countries are valuable also today. Here are some conclusions we can draw from our experience:

- students benefit from developing a broad understanding of computing, as it prepares them better for adopting digital innovations in the future;
- instead of drilling the mechanic operations, the focus should be on problem solving and computational thinking including algorithmic thinking;
- to build deeper understanding, computing should be taught independently of application software, programming languages and environments;
- it helps if computing is taught using real-world problems while not avoiding computer science concepts and approaches;
- computing education should prepare students for the professional use of computing in other disciplines and fields;
- teaching and learning computing must encourage students to be creative.

Although including computing into formal education through curriculum as a separate school subject is very important, it is also important to support the informal education on computational thinking, especially for talented kids. Informatics curricula in all three countries are continuously being developed and updated according to recommendation of important interest groups and recommendations of international organizations such as ACM, CECE, CSTA, and UNESCO. Finally, we are glad that in the Baltic countries there is a strong involvement of computing education researchers in curriculum development and implementation, textbook publishing, teacher education and education policy development.

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