Introducing Informatics in Primary Education: Curriculum and Teachers' Perspectives

Valentina Dagienė[1], Tatjana Jevsikova[2](✉), and Gabrielė Stupurienė[2]

[1] Vilnius University Institute of Educational Sciences, Universiteto 9, 01513 Vilnius, Lithuania
valentina.dagiene@mif.vu.lt

[2] Vilnius University Institute of Data Science and Digital Technologies, Vilnius, Lithuania
{tatjana.jevsikova,gabriele.stupuriene}@mif.vu.lt

Abstract. Informatics and especially its nowadays leading part, computational thinking, becomes an important and universal competence within the debate on 21st century skills and addresses the concepts and learning goals of Informatics (Computing or Computer Science). There are initiatives appearing worldwide that tend to include Informatics into early education. In this paper, we analyze implementation of Informatics as well as developing computational thinking competence on a primary school level. We survey the situation on Informatics in primary education in different countries (52 countries included), discuss the structure of draft curriculum for Informatics in primary education developed in Lithuania, and study primary teachers' readiness to integrate Informatics into primary education.

Keywords: Computational thinking in primary school · Computing in primary school · Informatics curriculum · Informatics in primary school · Primary education

1 Introduction

Computational thinking has been actively promoted through K-12 curriculum as a part of Informatics (Computing or Computer Science) subject or in an integrated way, as it addresses the concepts and learning goals of Informatics. Interest to teaching Informatics in primary school has increased during the last decade. Informatics education in Europe report, released in 2016, provides a recommendation: "All students must have access to ongoing education in Informatics in the school system. Informatics teaching should preferably start in primary school…" [1]. Basing on the findings of this report, an initiative of Informatics for all has been started and the strategy has been released [2] which states: "With its capacity to precisely describe how information can be automatically managed and processed, Informatics provides cognitive insights and a useful common language for all subjects and professions" [2].

Computational thinking encompasses a set of concepts and thought processes from Informatics that aid in formulating problems and their solutions in different fields. As Jeannette Wing defined, "computational thinking represents a universally applicable

The original version of this chapter was revised: Second and third author's affiliation has been modified. The correction to this chapter is available at https://doi.org/10.1007/978-3-030-33759-9_24

S. N. Pozdniakov and V. Dagienė (Eds.): ISSEP 2019, LNCS 11913, pp. 83–94, 2019.
https://doi.org/10.1007/978-3-030-33759-9_7

attitude and skill set everyone, not just computer scientists, would be eager to learn and use" [3]. It is considered as a universal skill for all and one of the important 21st century skills. J. Wing later gave a more concrete definition, stating that computational thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts of computational thinking [4]. It includes a range of mental tools that reflect the breadth of the field of Informatics.

Unless we can notice the separation of terms Informatics and Digital Literacy in e.g. [1, 2], some international initiatives, e.g. DigComp, include elements of Informatics (programming) into the digital competence area "Digital content creation" [5]. Terms of Informatics, Computing and Computer Science, used in this paper, refer to more or less the same thing, that is, the entire discipline.

"K-12 Computer Science framework", released in 2016, defines the main concepts that should be addressed in school Informatics education: computing systems, networks and the Internet, data and analysis, algorithms and programming, impacts of Computing [6]. Research on education in the early years has moved forward in the last few decades, informed by an understanding of the multimodality of young children's learning, as well as socio-political changes that emphasize the need to respect young children's views. As a result, it has been increasingly important to encourage children to reflect upon the world around them and to be engaged in real-world problems and solutions [7]. Visual gaming environments and tangible interfaces provide tools to learn Computing in early years [8], computer science unplugged activities [9] and Bebras international challenge task activities [10] for primary school provide possibilities to develop computational thinking without computer.

There are well known initiatives of Informatics implementation in primary education. For example, the Australian Curriculum: Digital Technologies is a new national subject within the Technologies learning area since 2016. The subject is mandatory from Foundation (Kindergarten in New South Wales) to year 8, with elective offerings following for year 9/10 students. The digital technologies curriculum includes fundamental ideas from the academic disciplines of Computer Science, information systems and informatics [11]. Media arts, online safety are integrated correspondingly into arts and health and physical education, while ICT is integrated across all subjects. The UK introduced new subject of Computing in 2014 that replaced IT, and guide for primary school teachers has been released [12]. The review of Informatics in K-12 education in Australia, England, Estonia, Finland, New Zealand, Norway, Sweden, South Korea, Poland and the USA provide information on initiatives, taking part in primary education as for year 2016 [13].

However, when introducing Informatics in primary education, we face many challenges. As Hubwieser et al. (2014) conclude in their research on Informatics education vision in primary and secondary education: (1) proper teacher education in substantial extent and depth seems to be one of the most critical factors for the success of rigorous Computer Science education on the one hand and also one of the hardest goals to achieve on the other; (2) there is a convergence towards computational thinking as a core idea of the K-12 curricula; (3) programming in one form or another, seems to be absolutely necessary for a future-oriented Computer Science education [14].

This paper aims to look at the tendencies of Informatics education in primary school, to analyze and share Lithuanian experience on introducing a primary school Informatics curriculum and teacher preparation.

Our main research questions we address in this paper are:

1. What is the up-to-date picture of introduction of Informatics in primary education in various countries?
2. What are the general differences in big topics (areas) of primary Informatics education curriculum?
3. How Lithuanian teachers are prepared for introduction of the new Informatics curriculum on the national level?

In order to answer Research Question 1, we survey the situation on Informatics in primary education in different countries (52 countries included) and present results of quantitative analysis (Sect. 2), discuss the structure of draft curriculum for Informatics in primary education developed in Lithuania (Sect. 3), and examinate primary teacher readiness to integrate Informatics into primary education (Sect. 4). Finally, we present a conclusion and discussion.

2 Informatics in Primary Education

2.1 Research Methodology and Respondents

In order to learn the most up-to-date information about the practice and situation of introduction of Informatics in primary education in different countries, a study of expert answers has been conducted during spring-summer period in 2019 instead of just literature review. In total, 52 experts representing different countries took part in this survey. It should be mentioned that requirements for the respondents (experts) of the study were very high: an expert was the one involved in the creation of national education system, curriculum and methodological material development in Informatics (Computer Science area), knowing the situation on primary education level. If expert could not answer all the questions by himself, the questions were redirected to another expert. In addition, we asked to self-evaluate the level of confidence of expert's answers on the scale from 1 (low) to 5 (high). General confidence level is evaluated as high (median: 5, mean: 4.6). List of countries, represented by experts, includes 34 countries of European region (Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, Ukraine), and 18 non-European countries (Algeria, Australia, Cyprus, Cuba, India, Indonesia, Iran, Japan, Malaysia, Palestine, Philippines, Singapore, South Africa, South Korea, Thailand, Tunisia, Turkey, Uzbekistan).

The experts were asked the following questions:

- Students' age group, corresponding to primary education in your country.
- Is (Informatics, Computing or Computer Science) taught in primary school in your country? (Yes, as a separate subject; Yes, in an integrated way; No; Other).
- Is there a curriculum for the Informatics (Computing, Computer Science) in primary education? (Yes; No; It is being developed at the moment).

- If Informatics (Computing, Computer Science) is introduced in primary education, in which grade does it starts? (Please write grade number, e.g. 1st).
- Is Informatics included into primary teacher education programs? (Yes; Yes, mostly limited to common digital literacy; Yes, mostly limited to programming; No).
- If Informatics (Computing, Computer Science) is introduced in primary education, please mark areas of competence that are addressed: (Please mark one or more of the following answers that suite at least partly.) The six areas of primary Informatics education that were included into the Lithuanian curriculum were listed with general content explanation: Digital Content, Algorithms and Programming, Problem solving, Data and Information, Virtual communication, Safety and Copyright (see Sect. 3).

We posed the simplicity requirement for our questionnaire. However, experts could not only select suggested option of answer, but add their free-text comments as well. Most of respondents commented their answers due to the considerable differences within the country, no possibility to select between answer option, actuality of the problem, activities taking place in Informatics early education right now, etc. In this paper, we concentrate more on quantitative aspects of the study. But due to the active comments and information sharing by the experts, the study can be extended to qualitative research, what is positioned as future work. The study aims at answering Research Questions 1 and 2 of this paper (see Introduction).

2.2 Study Results and Discussion

It is important to know what students' age different primary education systems embrace. Age of students in primary education in surveyed countries ranges from 3 to 16. Most frequent lower and upper age boundaries are 6 and 11.

52% of surveyed countries (27 countries) have already introduced Informatics curriculum for primary education (Fig. 1). 56% of European region countries and 44% of surveyed non-European countries. There is no curriculum for Informatics in primary education in 27% of all surveyed countries, and the curriculum is being developed at the moment in 21% of all surveyed countries. Active development of new curriculum can be noticed in the surveyed countries of European region (91% of all respondents who stated that curriculum is under development).

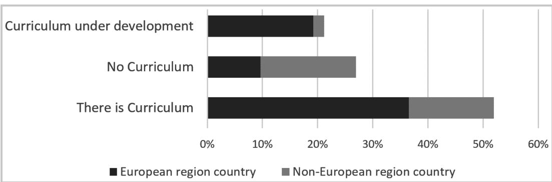

Fig. 1. Existence of Informatics curriculum for primary education in the surveyed countries, N = 52

The majority of surveyed countries introduces Informatics in the first year of primary school (44%), 22% of respondent countries introduces Informatics in grade 3, the same number (22%) in grade 5, and correspondingly 3% and 6% of countries introduce in grade 2 and grade 6 (Fig. 2).

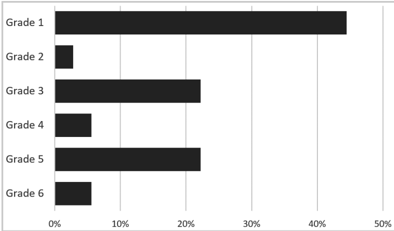

Fig. 2. Starting grade (school year) of Informatics introduction in primary education, N = 37

However, only 17 (33% out of all surveyed countries, or 46% out of countries with Informatics in primary education) introduce Informatics in grades 1 or 2 (Australia, Belarus, Bosnia and Herzegovina, Cuba, Denmark, Estonia, Greece, Indonesia, Norway, Poland, Romania, Russia, Sweden, Switzerland, Thailand, UK, Ukraine). All these countries (except for Thailand) reported to have/being developed Informatics curriculum for primary school at the moment of survey.

The vast majority of surveyed countries (83%) teach Informatics elements in primary education. However, there are a lot of differences in the level of Informatics implementation. Out of the countries who teach elements of Informatics, 26% have either non-compulsory (elective) Informatics subject in primary education, or the level of introduction of Informatics in primary education differs depending on the region, school type (e.g. private), choice done by school, etc.

Out of respondent countries who either have curriculum or undergo curriculum development process at the moment, 50% of countries introduce Informatics as a separate subject in primary education (Fig. 3), that is called differently across the countries, e.g. Computer modeling, ICT, Computing, Computer Science, Digital Technologies, Media education, etc. 21% of countries include basics of Informatics in primary education in an integrated way. Some countries introduce both as separate and as integrated either due to pilot study taking part at the moment (e.g. in Denmark), due to differences in school years (e.g. in Switzerland, for grade 1–2 the subject is integrated, for grade 3–4 the subject is separated), or due to possibility to select on a school level (e.g. Czechia).

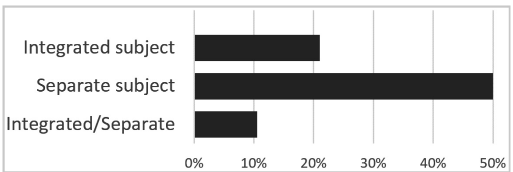

Fig. 3. Informatics elements introduction in primary education (integrated or separate subject) in the countries which have/develop Informatics curriculum, N = 38

A key question in quality of Informatics teaching in primary education is teacher training. In general (N = 52), 77% of surveyed countries have included elements of Informatics into primary teacher education programs (data for one non-European country is not available) (Fig. 4). 27% of countries include all main aspects of computational thinking in primary teacher training programs (answer "Yes"). However, almost in half of surveyed countries (46%) teacher training is mostly limited to digital literacy. In 2 countries (4%, Finland and Czechia) primary teacher training in Informatics mostly include programming.

It should be noticed that all countries who answered "Yes" to the question on teacher training, have Informatics curriculum in primary education.

Training in primary teacher education programs is limited mostly to digital literacy, dominates among all countries and even those who have introduced Informatics-related curriculum in primary education, or such curriculum is being developed.

Three experts, representing countries with Informatics-related curriculum in primary education but without teacher training included into primary teacher training programs, commented that it is planned to be introduced soon (Denmark), some programs do (Poland), or informatics teachers are teaching Informatics elements in primary education (Latvia).

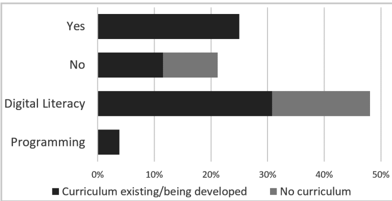

Fig. 4. Informatics inclusion in primary teacher education programs (N = 52)

Results on the main Informatics topics, being taught in primary education, are discussed and compared in the next section. Informatics content areas for primary education has been selected, corresponding to the curriculum main areas in the Lithuanian curriculum being developed, in order to compare implementation across countries.

3 Informatics Curriculum for Primary Education: Prospective Framework in Lithuania

Lithuania has experienced more than 30-year way of teaching Informatics in schools. Informatics in Lithuanian schools has been introduced as a compulsory subject since 1986. Since 1995, national exam in informatics has been introduced. The way of teaching informatics has been changing from theoretical aspects of Informatics in the first decade to more information technology-oriented subject in the second decade, and during the last decade we are moving to computational thinking oriented skills development. Since 2005, a compulsory subject, called Information Technology, has been introduced in schools since grade 5 (first year of basic education). It should be noticed that grade 5 in many countries at the moment of writing this paper is assigned to primary education level.

In 2016, working group of education experts, including Informatics teachers and primary school teachers, scientists, teacher trainers, educational policy-makers, business sector representatives, has developed a draft version of informatics curriculum framework for primary schools (grade 1–4). Lithuanian primary education typically embraces ages 7–11, i.e. 4 grades (now we are in a transformation phase to ages 6–11). As a result, six areas of Informatics have been identified [15] (Table 1).

Table 1. Lithuanian primary school informatics curriculum areas and basic skills

Area	Essential skills
1. Digital content	1. Familiarize with digital content diversity 2. Use digital content to learn in various subjects 3. Create digital content, using various technologies 4. Evaluate and improve digital content
2. Algorithms and programming	1. Understand an importance of algorithm and program for problem solving 2. Perform actions of algorithm/program 3. Identify sequencing, branching, loop actions and express them by commands, apply logical operations 4. Create and run programs using gamified programming tools and environments 5. Test, debug and enhance programs
3. Problem solving	1. Identify problems occurring when using digital technologies 2. Creatively use digital technologies learning various subjects 3. Select and apply appropriate digital technologies to solve tasks 4. Evaluate own digital skills
4. Data and information	1. Understand purpose and benefit of data and information management by digital technologies 2. Search information purposefully using digital technologies 3. Collect, store, manage data 4. Discuss and evaluate information relevance and reliability
5. Virtual communication	1. Understand purpose and importance of virtual communication 2. Communicate by the means of digital technologies 3. Collaborate by the means of digital technologies, share found/created digital resources 4. Discuss and evaluate possibilities and risks of virtual communication
6. Safety and copyright	1. Perceive the necessity to protect digital devices from malicious software 2. Protect personal data 3. Discuss copyright and piracy issues 4. Protect health while using digital technologies 5. Protect environment while using digital technologies

Correspondence of the designed curriculum areas and skills to the DigComp competence areas [5] can be found (Fig. 5). Probably the main difference is that Algorithms and programming which are most promoting computational thinking skills in Lithuanian curriculum is a separate area, while in “DigComp” it is included into Digital content creation competence area.

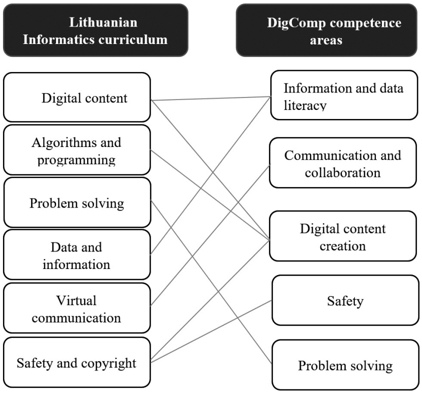

Fig. 5. Lithuanian prospective framework of Informatics curriculum area and DigComp competence area mapping

During the countries survey, discussed in Sect. 2 of this paper, we asked experts whether six areas of primary Informatics education are being developed in their primary education (each area had explanations on the content included into it). The reason of selecting such areas was to compare to the Lithuanian curriculum. The results are presented in Fig. 6.

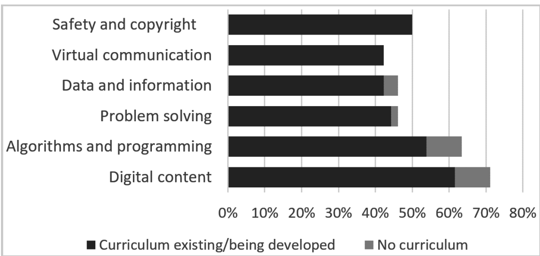

Fig. 6. Informatics content areas in primary education in surveyed countries (N = 52)

All of the areas are addressed in most surveyed countries in primary Informatics education. More often, Digital content (62%), Algorithms and programming (54%), Safety and copyright (50%) are taught. Digital content and Algorithms and programming are even taught in some countries that have not introduced Informatics curriculum.

However, only 33% of surveyed countries start Informatics from grade 1 or 2. In Lithuania, the Informatics is going to be introduced starting from grade 1 (before the reform to start primary education from age 6, Informatics is introduced starting from pre-school, i.e. one year before current grade 1). Out of these countries, 94% introduce Digital content skills, 71% introduce Algorithms and programming, Problem solving, Data and information Safety and copyright, 76% introduce Virtual communication topics.

4 Primary School Teachers Readiness for Informatics Curriculum Implementation

Introducing a new subject in primary education is a long process of discussions, pilot implementations, sharing best practices, teacher training, etc. Therefore, in 2017 Ministry of education, science and sport in Lithuania has launched project called "Informatics in primary schools". The goal of this project was to become ready for nation-wide Informatics implementation in primary schools. By competition means, 10 schools were selected, where primary teachers in school year 2017/2018 implemented practically draft Informatics curriculum, provided suggestions to curriculum correction, prepared various integrated activities to teach Informatics, closely collaborated with researchers who consulted them. A year later, 90 more schools have been selected for pilot implementation of Informatics curriculum. The finalized curriculum is planned to be implemented in all schools since 2020. But before activities with 100 schools have started, in the beginning of school year 2018/2019, a study [16] on teacher readiness to implement the new Informatics curriculum in primary schools has been run.

4.1 Research Methodology and Respondents

The participants of this study were 1342 primary school teachers (this makes up about 21% of all primary teachers in Lithuania) working in primary schools of different municipalities across all Lithuania (87% of all municipalities are covered).

The main research question of this study was "How Lithuanian teachers are prepared for introduction of the new Informatics curriculum on the national level?" (this is Research Question 3 of this paper).

The study has been run using internet-based questionnaire teachers had to fill in. We aimed to determine whether the skills, indicated in the draft Informatics curriculum, are already been addressed during regular primary school lessons (while Informatics is not compulsory subject yet) and how often. Another aspect of the study has been teachers' competence to teach Informatics in primary schools according to the new curriculum self-evaluation and comparison between those teachers who had digital competence training during the past 3 years and who had not.

4.2 Results and Discussion

The teachers, participating in the study, indicated for each Informatics curriculum area and its essential skill (see Table 1), how often do they include this skill into their regular lessons (almost every day, once or twice per week, one to three times per month, two to three times per half a year, very rarely or never).

The format of this paper does not allows us to present the detailed results for each curriculum area skills, therefore we generalize results by introducing numeric scale from 5 to 1: 5 – almost every day, 4 – once or twice per week, 3 – one to three times per month, 2 – two to three times per half a year, 1 – very rarely or never. Median values has been counted for each curriculum area and general result has been derived (Fig. 7).

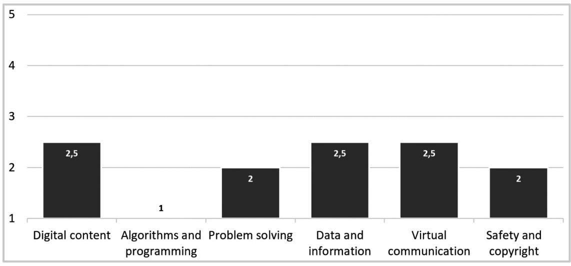

Fig. 7. Students' Informatics skills development during the lessons (generalized results), N = 1342

We see that for Digital content, Data and information and Virtual communication, appropriate skill training during the lessons is done almost one to three times per month. Approximately two or three times per half a year teachers include in their lessons Problem solving and Safety and copyright skills development. Unless, there are individual initiatives to develop Algorithms and programming skills, but generalized national results show that these area skills are almost not included into regular lessons.

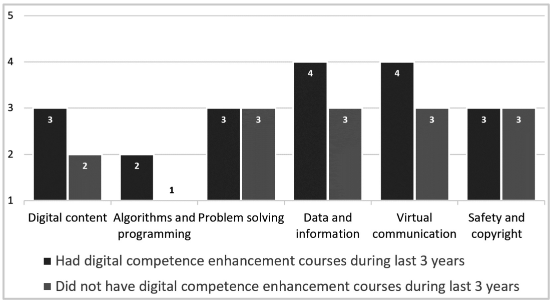

Fig. 8. Primary school teachers' competence self-evaluation to teach Informatics skills, N = 1342

In order to know how primary school teachers self-evaluate their competence to teach curriculum defined areas of Informatics, we asked them to use evaluation scale point from 5 to 1 corresponding to their preparation (5 – very good, 4 – good, 3 – moderate, 2 – weak, 1 – not prepared). The results (Fig. 8) show that teachers feel most prepared to teach Data and information as well as Virtual communication skills, has moderate preparation to teach Problem solving and Safety and Copyright skills. Less prepared teachers are to teach Digital content. And almost not prepared to teach Algorithms and programming.

We can also see the difference between self-evaluation of these teachers who had had digital competence training during the last 3 years and who had not. The difference per 1 scale point is seen in Digital content, Algorithms and programming, Data and information, and Virtual communication areas.

5 Discussion and Conclusion

We face three main challenges when introducing Informatics in primary school: (1) curriculum development; (2) teacher preparation; (3) research of implementation process and what should be taught [1]. In this paper, we addressed all of them and presented Lithuanian experience of Informatics introduction in primary school (grade 1–4).

Active participation of experts representing 52 countries in the study we run, indicates the importance of the problem. In 21% of surveyed countries (91% of these countries belong to the European region) Informatics for primary education curriculum is under active development at the moment.

Collected data has shown that Informatics in one or another way is taught in the majority of surveyed countries (83%) in primary education. However, there are a lot of differences in the level of Informatics implementation. It is quite a challenging task to compare implementation of Informatics in different countries due to the difference of education system. For instance, only 17 out of 52 surveyed countries (33%) introduce Informatics in grades 1 or 2. 19% of countries start teaching Informatics in grades 5 or 6 while in some countries (including Lithuania), grade 5 is a start of basic level of secondary school.

At the moment of research, countries pay priority to separate subject of Informatics in primary education rather than integrated. In Lithuania, we select integrated way of teaching Informatics. The results have shown that still more attention should be payed to primary teacher education. Training in primary teacher education programs, mostly limited to digital literacy, dominates among all countries and even those who have introduced an Informatics-related curriculum in primary education, or such a curriculum is being developed. Ongoing initiatives and experience in Lithuania (Informatics curriculum for primary school, pilot implementation in 10, then in 100 schools, collaboration with scientists, business representatives, teacher training activities and research) can serve as one of the possible models for countries who are going to implement Informatics in primary education.

Evaluation of teacher readiness to implement Informatics curriculum is an important element in the transformation phase. If there are initiatives of integration of Informatics elements into regular lessons nation-wide, even when there are no compulsory Informatics subject, this is a good indicator for launching Informatics as a new subject.

The future steps of the research include qualitative analysis of experience of difference countries.

Acknowledgement. We would like to express gratitude to the all international experts who took part in the survey on Informatics in primary education for active participation and collaboration. We also thank Education Development Center of Lithuania for the support of the research on primary teacher readiness to introduce Informatics in primary school.

References

1. Informatics Education in Europe: Are We All in the Same Boat. Report by The Committee on European Computing Education (CECE) Jointly established by Informatics Europe & ACM Europe (2016)
2. Informatics for All: The strategy. ACM Europe & Informatics Europe (2018). https://europe.acm.org/binaries/content/assets/public-policy/acm-europe-ie-i4all-strategy-2018.pdf
3. Wing, J.M.: Computational thinking. Commun. ACM **49**(3), 33–35 (2006)
4. Wing, J.M.: Computational Thinking: What and Why (2011). http://www.cs.cmu.edu/link/researchnotebook-computational-thinking-what-and-why
5. European Commission: DigComp into Action. Get inspired, make it happen. A user quide to the European digital competence framework. European Union (2018)
6. K–12 Computer Science Framework. ACM (2016). http://www.k12cs.org
7. Manches, A., Plowman, L.: Computing education in children's early years: a call for debate. Br. J. Educ. Technol. **48**(1), 191–201 (2017)
8. Garneli, V., Giannakos, M., Chorianopoulos, K.: Computing Education in K-12 schools: a review of the literature. In: IEEE Global Engineering Education Conference (EDUCON), pp. 543–551 (2015)
9. CS Unplugged: Computer Science without Computer (2019). https://csunplugged.org/en/
10. Dagiene, V., Stupuriene, G.: Bebras – a sustainable community building model for the concept based learning of informatics and computational thinking. Inform. Educ. **15**(1), 25–44 (2016)
11. Australian Computing Academy: Coding and Computational Thinking. What is the Evidence? https://education.nsw.gov.au
12. CAS: Computing in the National Curriculum. A Guide for Primary Teachers (2013)
13. Heintz, F., Mannila, L., Färnqvist, T.: A review of models for introducing computational thinking, computer science and computing in K-12 education. In: 2016 IEEE Frontiers in Education Conference (FIE) (2016)
14. Hubwieser, P., Armoni, M., Giannakos, M., Mittermeir, R.T.: Perspectives and visions of computer science education in primary and secondary (K-12) schools. ACM Trans. Comput. Educ. **14**(2), Article 7 (2014)
15. Education Development Center: Lithuanian Informatics Curriculum Outline. Preschool and Primary Education. Draft, 2019-06-30 (2019). https://informatika.ugdome.lt/lt/biblioteka/dokumentai/. [In Lithuanian]
16. Jevsikova, T.: School Potential and Readiness to Implement an Integrated Informatics Curriculum in Primary Education. Study Report. Education Development Center (2019). https://informatika.ugdome.lt/lt/tyrimas/ [In Lithuanian]