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Teaching Computational Thinking in Primary Schools: Worldwide Trends and Teachers' Attitudes*

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Abstract. Computational thinking (CT) as one of the 21st century skills enters early years education. This paper aims to study the worldwide tendencies of teaching CT through computing in primary education and primary school teachers' understanding of CT. A survey of 52 countries has been performed and complemented by a qualitative study of 15 countries. In order to identify teachers' understanding-level of CT and its integration approach in the class activities, a case study of 110 in-service teachers from 6 countries has been performed. The implications of the research results may be useful for primary school educators, educational initiatives, government authorities, policy makers, e-learning system and content developers dealing with support for teachers aiming to improve their CT professional development qualification.

Keywords: informatics education; computational thinking development; early years' education; 21st century skills; teacher professional development.

1. Introduction

In the 2000s, education policy makers of many countries started to bring computer science into school curricula as a response to demands of 21st century learning skills. Instead of the term "computer science" many countries especially in multilingual Europe use other names (e.g., computing or informatics) or enrich with technology-based components (e.g., digital fluency, digital competence). The terms "informatics", "computing" and "computer science", used in this paper, refer to more or less the same subject, that is, the entire discipline.

In European countries it is common to use informatics or its similar translations. Several documents have declared a strong separation between informatics and digital literacy [9, 7], whereas other international initiatives, like DigComp, has included

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elements of informatics (e.g., programming) into the digital competence area "Digital content creation" [16].

A decade ago the term "computational thinking" [33, 34] started to flourish in the United States, and Europe recognized the importance of an appropriate informatics education in schools.

Computational thinking (CT) has been actively promoted in schools in an integrative way or as a part of informatics subject, as it addresses concepts and learning goals of informatics. We may notice that interest in teaching informatics in primary school has increased during the last decade [24]. As recommended for informatics education in the report by the Committee on European Computing Education, "All students must have access to ongoing education in informatics in the school system. Informatics teaching should preferably start in primary school…" [9, p. 3].

Recognizing the importance of introduction of CT in primary school, the path towards this goal has many challenges, e. g. curriculum design and implementation, in-service and pre-service teacher training [23] due to novelty and possible misconceptions of CT, e.g. [18].

The **aim** of this paper is two-fold: to study worldwide informatics curriculum tendencies in primary education and determine primary school teachers' understanding of CT.

The main **Research Questions** we aim to answer via this study are:

1. What are the latest tendencies in introducing informatics and computational thinking through informatics in primary education in various countries and what are the recommendations based on the experts' experiences?
2. What is primary school teachers' understanding (or their possible misconceptions) of computational thinking?

In the next Section we discuss CT and existing practices of its implementation in primary school. In Section 3, we present research methodology. The results of quantitative and qualitative studies hold with experts, representing countries, and in-service teachers are discussed in the Results section. Finally, we discuss limitations, provide conclusions, discussion and recommendations.

2. Computational Thinking and Informatics in Primary Education

Computational thinking became popular after Jeannette Wing published a paper declaring that "computational thinking represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" [33, p. 33] and that the U.S. National Science Foundation included this idea in a funding call in 2007. Despite S. Papert's initiatives in computing education and publication of his 1980 book "Mindstorms" [29], many educators and other people heard arguments about the value of informatics (computer science) in education for the first time. Seymour Papert coined the concept of "computational thinking" in "Mindstorms" and used it for teaching procedural thinking to children.

Later J. Wing gave a more concrete definition, stating that CT involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts of CT [34]. It includes naturally a range of mental tools that reflect the breadth of the field of informatics. So computational thinking became a new wave in the movement to provide students with powerful tools for solving real world problems. The rapid growth of newcomers in this area led to considerable confusion about learning objectives and the essence of CT [13].

CT is a term applied to describe the increasing attention on students' knowledge development about designing computational solutions to problems, algorithmic thinking, and coding. Based on a systematic literature review the dimensions of CT are discussed and a three-stage model for developing computational thinking is proposed [28].

Peter J. Denning and Matti Tedre have in their book [14] portrayed CT in all aspects, its richness and deepness, and presented a long history of computing and connected to current practical challenges. “There has never been a consensus about what computational thinking “really” is. <...> We should embrace the lack of a fixed definition as a sign of the vitality of the field rather than our own failure to understand an eternal truth.” [14, p. 217].

Many countries have brought informatics into secondary school curricula with the intention to teach students important skills that no other subject does (e.g. computing design, programming). Until the early 2000s informatics was part of the upper secondary school curriculum (grades 10–12). Teaching fundamental computational thinking skills such as computer modeling or programming is much harder than introducing pupils to text processing or other application tools. Because of the shortage of qualified teachers, teaching informatics was replaced by focusing more and more on application of information and communication technologies (ICT). This resulted in a heavy focus on using computers and tools instead of informatics concepts, as teachers were not used to or trained in the latter [4].

Several countries have included informatics as a part of digital literacy or information technologies curricula for secondary schools. For example, the Netherlands published the report “Digital Literacy in Secondary Education - Skills and Attitudes for the 21st Century” and included the elective informatics subject in the upper grades [20]. Furthermore, in that report, CT is considered to be an integral part of digital literacy. Lithuania renamed informatics as information technologies and developed new curricula for grades 5 to 12 in 2005 [10, 11].

Research on education in the early years has shown that it is important to encourage children to reflect upon the modern world around them and focus on real-world problems using various technologies [27]. Primary schools have recognized the importance of including elements of CT in their teaching and started to incorporate them in lessons [1]. However, there are difficulties with teacher training and professional development in the computing discipline. Extensive and detailed methodological support should be provided to ensure that the relevant competences would be achieved [32].

International organizations like Computer Science Teacher Association (CSTA), the British Computing at School (CAS), Australian Curriculum Assessment, and Reporting Authority (ACARA) developed frameworks for computational thinking education in schools starting from elementary or primary schools to upper secondary schools. The CAS introduced a new subject of computing that replaced information technology in UK schools [6]. Australia has developed a curriculum called Digital Technologies: this is a new national subject within the Technologies learning area since 2016 [2, 3]. The subject is mandatory from kindergarten to year 8, with elective choice for pupils in year 9 and 10. The digital technologies curriculum includes fundamental ideas from the academic disciplines of computer science, information systems and informatics. Media arts and online safety are integrated correspondingly into arts, health and physical education, while ICT is integrated across all subjects. CSTA developed detailed K-12 Computer Science standards that delineate a core set of learning objectives designed to provide the foundation for a complete informatics curriculum and its implementation at schools [8]. These three curricula have been analyzed and notable insights have been provided [15]. One of the important conclusions is that introducing informatics at an early age can broaden the pupils' perception of computing and create their interest in technological disciplines. The review of informatics education in Australia, England, Estonia, Finland, New Zealand, Norway, Poland, South Korea, and Sweden the US provide information on initiatives taking part in primary education [21, 22].

When introducing informatics in primary education, we face several challenges. Peter Hubwieser et al. [23] have concluded in their research on informatics education: 1) proper teacher education in substantial extent and depth seems to be one of the most critical factors for the success of rigorous informatics 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 to introduce to the students. So pre-service teacher education and in-service teacher training are the crucial points when introducing CT to primary schools. In order to motivate teachers to learn about CT, they have to see positive benefits for both them and their pupils. Having access to high-quality training courses and engaging educational resources is hence crucial [25, 26].

A detailed study on coding in primary schools was conducted by Rich et al. [30]. Some international trends in teaching informatics at primary-school level were drawn. More than 55% of 310 teachers (from 23 countries) had no or very little training with computing/coding prior to deciding to teach it in the classroom. Average experience of teaching computing/coding is 4.6 years (although such experience varies greatly by country). Teachers revealed that they don't necessarily have a high confidence in their computing/coding ability, but that seems not to be impeding them from teaching it as a subject (even though this was their most prevalent apprehension and challenge).

An instrument to survey teachers about their implementation of informatics curriculum to understand pedagogy, practice, resources and experiences in classrooms around the world was developed and implemented [17]. The researchers reviewed and analyzed pilot data from 244 teachers across seven countries (Australia, England, Ireland, Italy, Malta, Scotland and the United States). The resulting instrument combines a country-level report template and a teacher survey that will provide teachers with a means to communicate their experience enacting informatics curricula.

Fessakis and Prantsoudi [18] presented the research of the perceptions, attitudes and beliefs on CT of informatics teachers (N=136) who teach in various types of schools (primary, secondary, higher education) in Greece. Results show that for successful integration of CT in classroom lessons, teachers need to have clarified the practices and dimensions of the concepts. Also, an appropriate knowledge of informatics didactics is needed. Concerning the relation between CT and informatics, misconceptions also occur, as most teachers mistakenly consider informatics as a subset of CT or as a totally different field. Only ¼ of them perceive that CT and informatics intersect and are not totally different cognitive fields. These misconceptions need to be treated with proper in-service professional development and/or pre-service education.

3. Research Methodology and Respondents

3.1. Research Design

This research study employs a mixed method approach in order to investigate the current situation in informatics education in primary schools and teachers' understanding of CT in different countries, i.e., both quantitative and qualitative approaches are used in order to collect and analyze data. From the methodological viewpoint, our research was designed as a survey. Detailed composed questionnaires were used for the data collection processes.

Our research consisted of two studies and three phases as presented in Table 1.

Table 1. Studies and phases of the present research

First study: experts' opinions		Second study: in-service teachers' opinions
Phase I Quantitative research	Phase II Qualitative research	Phase III Quantitative and Qualitative research
Survey on experts' opinions about the most up-to-date information about the practice and situation of introduction of informatics in primary education in 52 countries.	Continuous survey on selected experts' from 15 countries that have informatics curriculum introduced or where it is being developed at the moment.	A case study on primary and pre-primary teachers' understanding about CT and its integration in the class activities in 6 different countries.

In order to answer Research Question 1, we survey the situation on informatics in primary education in different countries (52 countries included, phase I of the first study). Our quantitative data are supported with qualitative data collected from the countries that have implemented informatics curriculum or undergo its development process (phase II of the first study). In order to answer Research Question 2, the survey of 110 in-service teachers (a case study) has been conducted (phase III, the second study).

3.2. The First Study: Experts' Opinions

The Phase I of the first study included the quantitative analysis of answers provided by experts from 52 countries. This study was conducted during the spring-summer period of 2019, and the first results were presented to the international community during the ISSEP 2019 (Informatics in Secondary Schools: Evolution and Perspectives) conference [12]. The study of experts' opinions let access the most up-to-date and generalized information about the practice and situation of introduction of informatics in primary education in different countries.

The requirements for the respondents (experts), participating in the study were very high: an expert was involved in the creation of the national education system, developed curriculum and methodological material in informatics (or similar discipline depending on how it is called in respondent's country), and was knowledgeable of the situation at the primary education level. If an expert could not answer all the questions, the expert suggested another expert to whom the questions were redirected.

In addition, we asked each expert to self-evaluate the level of confidence of their answers on the scale from 1 (low) to 5 (high). General confidence level was evaluated by the experts as high (median: 5, mean: 4.6). The list of countries, represented by the experts, includes 34 countries from the 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, Ukraine, United Kingdom), 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 phase II of the first study was aimed at extending the study to qualitative research. For this purpose, only countries that have an informatics curriculum introduced or where it is being developed were selected. The questionnaire was completed by experts from the following 15 countries: Australia, Belarus, Bosnia and Herzegovina, Estonia, Greece, Indonesia, Malta, Netherlands, Poland, Romania, Russia, Sweden, Switzerland, Ukraine, and the UK. The goal of this phase was to gain a deeper understanding of the background for the answers given by the closed-type questions in the quantitative study in phase I, by probing the knowledge and recommendation from the experts in these countries. Usually, there is considerable variation between schools and districts in a country. Therefore, we selected as much as possible experts who were considered as national experts and presented recommendations based on their experience. We note that the comments provided by the experts reflect their personal opinion and do not reflect those of the organization they are representing. This study has been conducted during the summer-autumn period in 2019.

The qualitative questionnaire included the following questions to the experts representing the countries:

- What are the main areas of competence (content topics), included in the newest version of primary school informatics curriculum?
- What learning theories and methodologies are most usually used in primary school informatics in your country?

– What tools are most usually used in informatics primary education?
– What best practices and failures in informatics integration in primary education do you notice in your country? If there were just a start of informatics integration in primary education right now, what would you have done differently? Consider the following aspects: informatics as a separate/integrated subject; Age of students; Pre-service and in-service primary school teacher training and teacher support; Curriculum development and update; Research; Organizational aspects.

The preliminary results of the first study have shown that there is a lack of teacher training activities. Therefore, we decided to study the situation with focus on the primary education in-service teachers' level. At this phase we decided not to limit to informatics as a subject concept, but use CT as a universal way of addressing skills of informatics and other related subjects, no matter if the country has introduced an informatics curriculum or not. The study was aimed at examining the understanding of CT by the in-service teachers (the second study, phase III).

3.3. The Second Study: In-Service Teachers' Opinions

This study corresponds to phase III (Table 1). 110 pre-primary and primary teachers from 6 countries answered the questionnaire about their own understanding of computational thinking and its integration approach in the class activities. The distribution of teachers by their teaching type is as follows: class teachers (70.91%), STEM subject teachers (mainly mathematics, science, and technology teachers) (11.82%), special education teachers (4.55%), and others (e.g., administration) (12.73%). By a class teacher we consider a primary school teacher who usually teaches all subjects from preschool through fourth to sixth grade in most cases. In the study, there were teachers from 6 countries: Belgium (43 respondents), Finland (11 respondents), Lithuania (23 respondents), Portugal (6 respondents), Spain (20 respondents), and Sweden (7 respondents). This study has been conducted during autumn 2019.

As not all surveyed countries at the time of the survey had officially approved the curriculum of informatics as a subject in primary school, we used the computational thinking concept in order to identify the level of its integration in primary education based on teachers' perspective. We included pre-primary teachers due to the differences in the students' age in primary education and in order to examine preparation for informatics in primary education.

The online questionnaire, which took 15–20 minutes to answer, consisted of 14 questions that included eleven five-level Likert-scale questions (see the list of questions in Table 2) and three open-ended questions as follows: Describe what you understand by CT; If you already work on CT in class, describe how; Describe your needs to work on CT in class.

4. Results I. Study of Experts' Opinions

4.1. General Implementation

The vast majority of surveyed countries (83%) teach at least some elements of informatics in primary education. However, there are many differences in the level of informatics implementation. Out of the countries who teach at least some elements of informatics, 26% have either a 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, and other factors.

It is important to know which age groups different primary education systems embrace. Most frequent lower and upper age boundaries are 6 and 11, and in general, the age of pupils in primary education in surveyed countries ranges from 3 to 16. According to experts' opinion, informatics education should start already at an early age, using playful approaches (more unplugged activities) and not forcing children to repeat formal tasks like steps or commands. In Lithuania, informatics is going to be introduced starting from pre-school (one year before grade 1).

Out of the countries who teach informatics in primary education (N = 37), 44% introduce it in the first year of primary school, 3% in the second year, 22% introduce informatics in grade 3, the same number (22%) in grade 5, and correspondingly 3% and 6% introduce it in grade 2 and grade 6.

Of the 17 countries who introduce informatics in grades 1 or 2 (47% out of countries with teaching of informatics in primary education; these 17 countries being Australia, Belarus, Bosnia and Herzegovina, Cuba, Denmark, Estonia, Greece, Indonesia, Norway, Poland, Romania, Russia, Sweden, Switzerland, Thailand, Ukraine and the UK), all (except Thailand) reported to have informatics curriculum for primary school or it is being developed at the moment of the survey.

4.2. Curriculum Issues

27 countries, that is 52% of the surveyed countries, have already introduced an informatics curriculum for primary education: 56% among them are countries of the European region (Fig. 1). There is no informatics curriculum 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 from the European region (91% of all respondents who stated that curriculum is under development). However, when presenting generalized results, we should be aware of the factors described in the Limitations section.

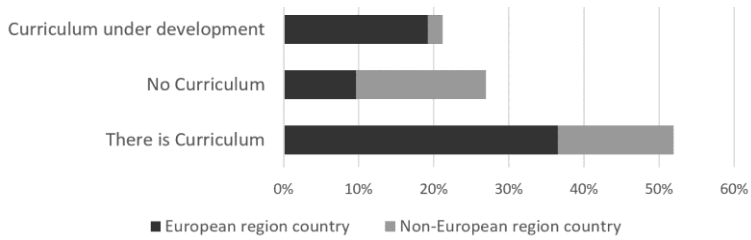

Fig. 1. Existence of informatics curriculum for primary education in the surveyed countries, N=52

During the first stage of the survey 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). It is not a surprise that informatics content areas in primary education are similar from country to country, but that the naming and assigning to the particular category differs. For this reason, we selected a model to compare with. The model for the selected topics corresponds to the Lithuanian informatics curriculum for primary and pre-primary education, which is in the implementation process:

– *Digital content*. Essential skills of working with digital devices; managing textual, graphical, numeric, visual, audial information; information visualization and presentation; digital content creation.
– *Algorithms and programming*. Solving problems: algorithm, action control commands (sequencing, branching, looping), programming in a visual programming environment for children.
– *Problem solving*. Essential technical and technological skills of working with digital devices: solving technical problems, evaluating and identifying suitable technologies for the selected problem, creative use of technologies.
– *Data and information*. Working with data skills: problem analysis, data collection, sorting, search and data management, content quality evaluation.
– *Virtual communication*. Social skills in a virtual environment: continuous learning, e-learning, communication via email, chats, social networks, sharing, collaboration, reflection.
– *Safety*. Digital safety, safe work with digital devices; ethics and copyright issues of information processing and usage; safety, ethics and copyright issues in virtual communication.

The areas are being addressed in primary informatics education of up to 72% of countries. From 42% to 62% of the addressing countries are the countries who have implemented informatics curriculum or being developed it at the moment of the survey, and up to 10% are those countries with no curriculum (Fig. 2).

In the countries with existing informatics curriculum or curriculum under development, the following three content areas - Digital content (62% out of all 52 respondents), Algorithms and programming (54% of all surveyed countries), Safety (50% of all respondents) - are taught more often. Digital content and Algorithms and programming are even taught in some countries that have not introduced an informatics curriculum.

As it was mentioned before, 17 countries introduce informatics in grades 1 or 2. Almost all of them teach Digital content skills, and more than 70% of these countries introduce all other areas.

Further communication with experts from 15 countries that are either in a stage of active development of informatics curriculum in primary education, or already have introduced it, has shown that mostly just the naming of content topics differs between countries. For example, from the curriculum in Greece: 1. I know, create and express myself with ICT; 2. I communicate and collaborate using ICT; 3. I inquire-explore, discover, and solve problems using ICT; 4. ICT as a phenomenon in society. Bosnia and Herzegovina uses: Introduction to ICT; Components of computer systems; Treatment of data; Digital and virtual world; Algorithms and data structures. In Estonia: Key stage 1: Digital art, (playful) coding and digital safety. Key stage 2: Digital media, (visual) programming and digital hygiene. In the Netherlands the new curriculum has started to be implemented in 2020. The domains of digital literacy are discussed in these areas: information skills, media literacy, basic ICT skills and CT (solving issues or problems using digital technology). In primary education, pupils learn to use digital resources consciously in their own context and level of learning.

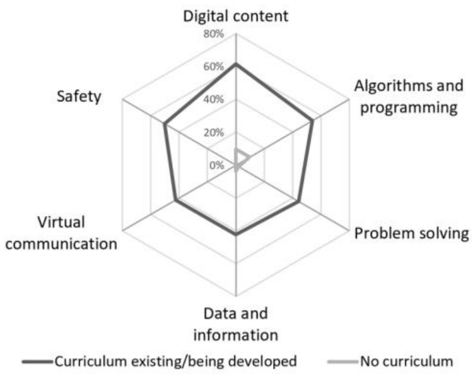

Fig. 2. Informatics content areas in primary education in surveyed countries (N=52)

In Switzerland the subject “Media education & informatics” consists of the competence areas defined by: 1. Pupils can present, structure and evaluate data from their environment; 2. Pupils can analyze simple problems, describe possible solution methods and implement them in programs; 3. Pupils understand the structure and operation of information processing systems and can apply concepts of secure computing.

The government of Italy has recently approved the introduction of CT and coding in compulsory school curricula by 2022, clarifying that this will not imply the introduction of a new subject neither in primary school nor in lower secondary school [19]. This suggests that CT will be probably handled as a transversal subject in primary school and within the existing subjects of mathematics or technology (including information technology) in lower secondary school. This situation is not unique in Europe – consider, for example, France, Finland, Sweden, and Norway, which have recently completed a curricula reform following this path [5].

4.3. Subject Integration

When comparing informatics integration in primary education, we face the effect of different age groups in primary education in different countries (e.g., in some countries primary education embraces grades 5, 6, and only for these grades, separate subject is used, while in other countries these grades are included in basic education level), phenomenon of changing integration through different grades (e.g., integrated in grades 1 to 3, while separate in grade 4), region-level and school-level differences in primary education (school/region level choice). These issues affected the data that we collected using quantitative questionnaires (with closed-question options available). When analyzing the quantitative data, out of the respondent countries who either have curriculum or undergo curriculum development process at the moment (N = 38), 50% of countries introduce informatics as a separate subject in primary education.

As it was discussed in the introductory section, the name of the subject varies across the countries, e.g., computing, computer science, computer modeling, information technologies, ICT, digital technologies, media education, technology and design. 21% of the countries include the basics of informatics in primary education in an integrated way. Some countries introduce it both as a separate subject and as integrated to other subjects either due to pilot study taking part at the moment (e.g., 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).

Further communication with experts via qualitative questionnaire (Phase II) enabled us to obtain more information and recommendation on the subject integration.

In the fifteen additionally surveyed countries, three ways of teaching informatics are used: as a separate subject; as a subject integrated into other disciplines' activities; mixed approach when there are both separate subject and natural integration into other subjects, or there is integrated informatics up to some grade, and then separated subject, or there is a selection possibility.

As reported by the experts, informatics as a separate subject is taught in Australia, Bosnia and Herzegovina, Greece, and Ukraine. Some experts from these countries provided opinion based on their practice that "interdisciplinary approach for the integration to other subjects should be developed" (Greece).

Estonia, the Netherlands, Poland, Russia, and Switzerland, and reported to use both approaches: integrated and separated subjects. In other surveyed countries, an integrated approach is used.

For those countries, where informatics curriculum is being developed, or it is being integrated into other subjects, experts state that some part of informatics subject should be learnt separately: "After learning the basics of informatics it can be integrated in other subjects" (Estonia). "Students should be prepared in other literacies, like coding" (Malta). "Integrated subject has pros and cons. In a short time <...> it is the best. In the long term a separate subject may be better" (Sweden).

In Australia, the subject of Digital Technologies is introduced in a separate way [3]. Teachers are encouraged to teach digital technologies knowledge and understanding as a separate topic, but to teach the processes and production skills integrated in other subjects in parallel, for example by creating a quiz game to show how the human body works and using robotic toys in literacy and numeracy activities. This has been a challenge to trained teachers. Digital literacy, which comes closest to informatics, is introduced as both a separate subject and integrated into other fields. An expert proposed: “appointing a specialist for digital literacy in every school who can serve as an expert, helping out other teachers is recommended”.

One expert, representing the United Kingdom, provides an insight that “the cross-curricula element is a context in which an activity is set, e.g. Vikings as a context for making artwork, Math for a presentation. Whether we are really stretching pupils and differentiating effectively across subjects is very questionable. However, by setting computing in cross-curricular contexts then there is possibly more motivation for teachers to include the activities. English curricula are stated separately, and teachers find it hard to very effectively merge objectives in a single lesson. But they can do this over sequences and in themed topics. However, I have not seen research which proves this is effective”.

In primary schools of Poland, a stand-alone informatics subject is called Computer activities and runs through grades 1 to 6. In grades 1-3, computer activities are supposed to be fully integrated with other activities like reading, writing, calculating, drawing, playing etc. At the next stages of education, students are expected to use computers as tools supporting learning of various subjects and disciplines, in a formal, non-formal, and incidental manner in school and at home [31].

4.4. Teacher Training

A key question in the quality of informatics teaching in primary education is teacher training. Out of the 52 respondent countries, 77% have included elements of informatics into primary teacher education programs (data for one non-European country is not available) (Fig. 3). 27% of countries include all main aspects of computing in primary teacher training programs (answer “Yes”). However, almost half of the surveyed countries (46%) has teacher training mostly limited to digital literacy. In two countries (4%, Finland and Czechia), on the contrary, primary teacher training in informatics mostly includes 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 and dominates among all countries, even in those who have introduced informatics-related curriculum in primary education or where 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 elements in primary education are taught by school teachers of informatics (Latvia).

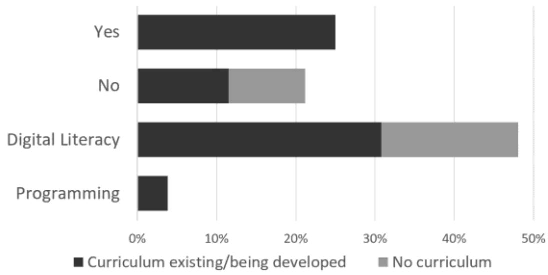

Fig. 3. Informatics inclusion in primary teacher education programs, N = 52

Further probing of the experts provided more generalized information on the topic. In all 15 countries of the Phase II study, pre-service and in-service teacher training activities are taking place. It is included in pre-service teachers' education programs in colleges and universities, but the time allocated for the subject differs from university to university even within the same country. The majority of experts' state that there should be more training. It is also stated, for instance, that "newly graduated students can serve as an example for more experienced teachers to learn from" (the Netherlands). In Greece and Bosnia and Herzegovina, informatics is usually taught by a computer science graduate, and therefore, more pedagogical training rather than subject training is needed. An expert from Malta stated the need to train university tutors in the basics of informatics and usage of information technologies in their work, so that student teachers can see good examples of information technology integration in educational processes.

Professional development courses are organized as in-service teacher training in informatics. Countries are developing online courses for teachers, organize face-to-face training and provide funding opportunities for competence development. Several cases are presented below.

In Australia, in-service teacher training has been "... a challenge to up-skill teachers. There have been many funding opportunities offered by both federal and state governments. Some schools and teachers are still resistant to change". The United Kingdom offers a new programme for in-service teachers funded by the government in England called the National Centre for Computing Education (NCCE), with £84m, which runs from November 2018 to July 2022. In Sweden, the National Agency for Education has developed online courses (about programming and how to program) and is also paying for university courses for teachers. There is more training for in-service teachers taking place than for pre-service. The Ministry of Education of Romania provides support and takes care of in-service teacher training. In Ukraine, in-service teachers are provided every year with online courses and a few weeks of learning at regional centers during summer. Poland states that many local and national activities are taking place. In Russia, it is defined by the Federal standard that each teacher must take a refresher course of at least 72 hours every 3 years. Courses for primary school teachers include all subjects, including computer science. Each publishing house, whose textbooks are included in the official Federal list of textbooks recommended by the Ministry of Education, provides methodological support to teachers on the basis of its methodological services. At the same time, primary school teachers are accustomed to the outdated model of teaching only the theoretical foundations of computer science.

Switzerland and Belarus state to have mandatory preparation of pre-service and in-service teachers. In Indonesia, teacher training is organized by the government and community services by the Bebras Indonesia community. Bebras Indonesia NBO collaborates with about 50 universities all over the country, to introduce the Indonesian K-12 informatics curriculum to neighboring schools.

4.5. Educational Resources and Methodological Aspects

The experts were asked questions about tools (hardware and software), educational resources and methods used in their countries for informatics education in primary school. The experts noted that there is an endless list of tools and they vary from school to school (they can choose themselves). A typical scenario for tools is described by an expert from Australia: “Some schools are creating smart gardens using micro:bits or Arduinos. Some schools run Coding Clubs using Code Club Australia resources. Others use Lego robotics and compete in the First Lego League. In primary schools, students use visual programming to implement solutions using a variety of tools and platforms at the discretion of the teacher, including but not limited to: Scratch, Blockly, Lego robotics, ScratchJr, Sphero, Ozobot, Dash robot, Swift playgrounds, Kodable, code.org, etc. Many schools use the Bebras challenge to teach and test CT skills.”

Only experts from Australia, Greece, The Netherlands, Russia, and the United Kingdom mentioned that they have repositories for educational resources. Other countries lack modern and up-to-date literature and nation-wide resources for teachers. Also, the methods used for primary education in all 15 countries mostly depend on teachers. Teachers need a lot of support, starting from teacher training and resources.

Methodology used to teach informatics elements in primary education highly depends on a school or a teacher. But, among most usually used methodologies, experts mention: collaborative learning, group and pair work projects, problem solving, inquiry-based learning, role-playing, game-based learning, learning by doing, tinkering, interdisciplinary approach, PRIMM (Predict, Run, Investigate, Modify, Make), Use-Modify-Create, design approach, worked examples. Some schools (e. g. in Australia) are using the TPACK model and others are using the SAMR (Substitution, Augmentation, Modification, and Redefinition) model.

5. Results II. Survey on Teachers’ Understanding of CT

5.1. Teachers’ Attitudes on Computational Thinking

Teachers were asked the open-ended question *Q1: Describe what you understand by CT.* All respondents answered this question. The answers were grouped in 6 categories, based on the frequency, that show the same or similar understanding, and summarized in Fig. 4. The main categories are described below.

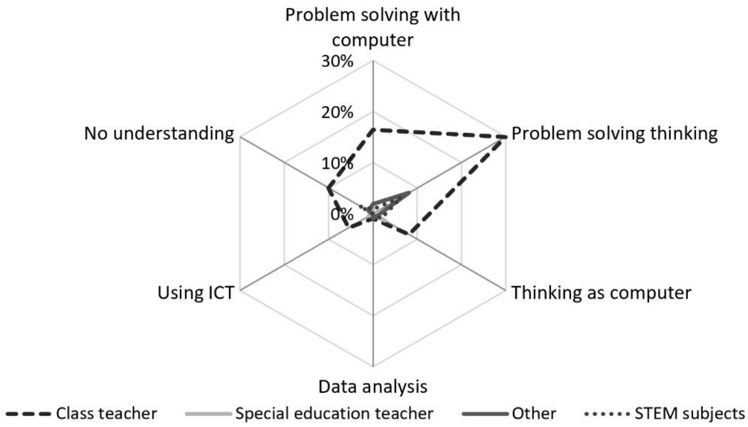

Fig. 4. Understanding of computational thinking by different types of teachers (N = 110)

The category “Problem solving thinking” includes logical and critical thinking and decision making, and according to the teachers’ answers it can be defined as “an ability of a person to solve problems having interiorized the concepts in a computational language and having a critical sense”. One more description that characterizes this category: “to think in logical, discrete steps and reduce, reformulate complex problems into well characterized models to which we can apply standard solution methods”. The answers of 44.5% of all teachers fall into this category (83% from Portugal, 72% from Sweden, 60% from Spain, 46% from Finland, 35% from Lithuania and 33% from Belgium).

The category “Problem solving with computer” consists of answers related to problem solving and practical use. According to the answers, it can be defined as “ability to objectively analyze and evaluate a problem, develop possible solutions to the problem and then format these solutions in ways that a computer could execute”. The answers of 20% of all teachers were assigned to this category (the category was based on the answers of teachers from Spain and Belgium).

The category “Thinking as computer” involves programming as well as using algorithms, and according to teachers’ answers, it can be described as “it is learning to think like a computer and how you can use computers to do logical measurements”. The answers of 13.6% of all teachers fall into this category (23% from Belgium, 17% from Portugal, 14% from Sweden).

6.4% of teachers showed misconceptions in understanding CT by providing answers related to the use of only CT, for example described as “computational thinking is using ICT in daily purposes”. Answers that were categorized as “No understanding” were provided by 13.6% of teachers (36% from Finland and 35% from Lithuania).

We have analyzed teachers’ understanding of CT according to different types of teachers. The results, presented in Fig. 5, show that 54% of STEM subject teachers and 42% of class teachers (i.e. primary school teachers) as well as 64% of other teachers understand CT as problem solving thinking. Unfortunately, 23% of STEM and 14% of class teachers provided answers showing no understanding.

5.2. How Teachers Teach Computational Thinking in Class

Teachers were asked an open-ended question *Q5: If you already work on computational thinking in class, describe how*. Only half of teachers answered this question. The answers were categorized according to the usage of tools: programming (coding), robotics, tangible devices, and unplugged activities. 43% of the teachers who answered this question named the tools they have used to develop CT skills of pupils. The tools, mentioned by the teachers, are the following: Scratch, ScratchJr, code.org, Minecraft Education, LEGO, WeDo, Bee-bots, Ozobot, mBot, micro:bit, Makey Makey, Scottie Go, Cubetto, Bebras cards.

Half of the teachers who responded to this question have described their work on CT in class through the methodology aspects. Some examples: "I try to induce pupils to "think on paper" including drawing the problem, finding patterns such as geometric shapes and to identify pieces of the problems to solve one by one. I also encourage pupils to reformulate problems into easier ones, i.e. if the numbers are large and hard to grasp, make a new problem with easy numbers where the pupil can anticipate the answer"; "Face situations through critical thinking with sequences and instructions to solve a problem in a simpler way".

In 7% of the answers, the teachers described the usage of ICT as enhancing their pupils' CT skills. It shows limited understanding of computational thinking in education.

5.3. Factor Analysis

Closed-type questions regarding CT education and understanding by the teachers (see Table 2) have been analyzed by conducting factor analysis. The factor analysis has been chosen for a twofold reason: to reduce the number of variables and to validate our questionnaire. This method aims at identifying clusters (components) of items for which responses for the questionnaire on understanding of CT had common patterns of variation. Each factor corresponds to a group of variables whose members correlate more highly among themselves than they do with variables not included in the factor. Table 2 shows the identified four factors using Varimax with Kaiser Normalization rotation method.

Four factors have been identified:

1. Active integration of computational thinking (questions Q2, Q3 and Q4).
2. Computational thinking as algorithmic thinking and/or as problem-solving (Q7, Q13, Q14).
3. Computational thinking has been associated with a tool (Q8, Q9 and Q10).

Computational thinking as digital literacy and thought processes (Q11 and Q12).

Table 2. Results of factor analysis

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Q4. I work already on CT in my class.	.888			
Q3. I understand how I can integrate CT in my lessons.	.846			
Q2. CT is integrated in the curriculum of my school.	.846			
Q13. Identifying elements and their relationships within a system is a dimension of CT.		.816		
Q14. CT aims at working with algorithms.		.641		
Q7. CT is the human capability to solve complex problems.		.602		
Q8. CT can only be learned by applying digital tools.			.825	
Q10. CT can only be learned through programming.			.768	
Q9. CT incorporates thinking skills to use computers effectively.			.483	
Q11. CT is a basic skill comparable to reading, writing, calculating, …				.841
Q12. CT is an abstract and logical thought process.				.660

Factor 1 corresponds to practical CT skills development in an educational process. Those teachers who understand well what CT is, have integrated the CT development in their lessons. Factors 2 and 4 show two important aspects of CT: understanding of CT as algorithmic thinking and/or as problem solving, also understanding of CT as basic skills and thought processes. Factor 3 shows limited understanding of CT as depending on the usage of a particular tool (e.g.: CT can be learned only by using digital tools, only through programming, and using computers effectively).

Distribution of teacher opinions within each factor is shown in Figure 5. For the reasons of representation simplicity, we converted the 5-point Likert scale to the 3 groups of positive, neutral and negative answers (“agree”, “neutral”, “disagree”).

The data analysis revealed that 44% of respondents actively integrate CT in their lessons, 33% of teachers are of neutral position, and 24% do not integrate CT at all (Fig. 5, F1). The vast majority of respondents (78%) do agree that CT is understood as an algorithmic thinking and problem-solving ability (Fig. 5, F2). However, 24% of surveyed teachers think that CT is associated with a tool (digital tool, programming only or using a computer only) (Fig. 5, F3). In addition, more than half of the respondents (55%) have no strong opinion on this question, i.e., 79% of the teachers have some level of misunderstanding of CT education. At the same time, 73% of teachers associate CT with literacy and basic skill as reading, writing, and abstract and logical thinking (Fig. 5, F4).

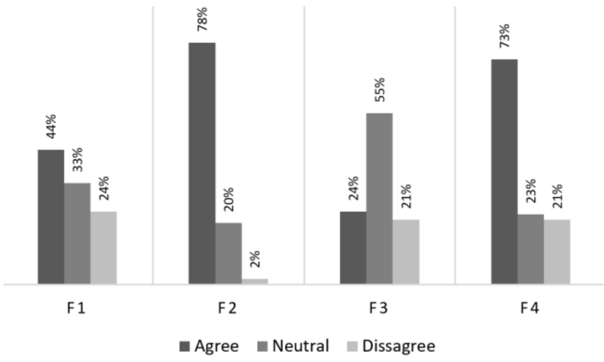

Fig. 5. Teachers' understanding of computational thinking, distributed among factors (N = 110)

Teachers indicated their needs in order to better integrate CT in their class work. This was an answer to the open-ended question of the questionnaire (Q6. Describe your needs to work on computational thinking in class). 72 respondents (65.4%) submitted their answers to this question. Out of qualitative answers, we defined 6 categories of the needs: educational resources, best practice examples, more time allocation, technological support, providing fundamental knowledge, and focus on teacher training. Some teachers indicated needs corresponding to several categories in the same answer (e.g. "More educational resources and technological support"). Major categories are related to methodological support and teacher training: they might be overlapping, but we leave them as separate categories, as they have been derived from the wordings used by the teachers. Analysis of teachers' needs by categories for each factor is presented in Fig. 6.

Respondents positively contributing to Factor 1 *Active integration of computational thinking in their classes* ("agree", 47%, N = 72) mostly need educational resources and technological support (14% out of all respondents who answered this question, or 29% out of those who actively develop CT skills in their lessons) (see Fig. 6, Factor 1). They also need more best practice examples on how to teach CT as well as more teacher training (10% out of all respondents who answered these questions, or 21% out of those who actively develop CT skills in their lessons). Respondents who negatively contribute to Factor 1, i.e., do not apply CT to education in practice ("disagree", 32%, N = 72), indicated their need for fundamental knowledge (10% of all respondents who submitted answer to this question, or 41% out of those who do not develop CT skills in their lessons). They also expressed a need for more educational resources (35%), more best practice examples (29%) and more teacher training (20%). We notice that those teachers, who do not actively develop CT skills of their students, did not indicate that they needed more time allocation or technological support in order to change their practice.

The vast majority of teachers who submitted an answer about their needs are positively contributing to Factor 2 *Computational thinking as algorithmic thinking and problem-solving* (86%). Most of them indicate that more educational resources (28% out of all respondents who answered this question, or 32% out of those who agree on this factor question group), best practice examples (correspondingly, 22% and 26%) and focus on teacher training (22% and 26%) are needed. Respondents who do not see CT as algorithmic thinking and problem-solving skills, mention time allocation and best practice examples as their need (50% in “disagree” group).

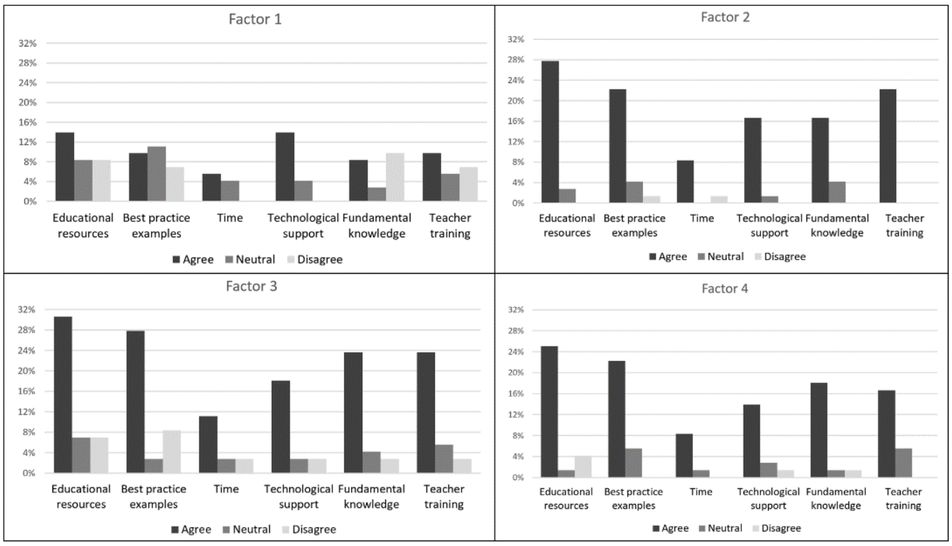

Fig. 6. Teachers’ needs, represented by Factors 1–4 (N = 72)

Factor 3 shows limited understanding of CT, i.e., CT is here assumed associated with particular tools. 31% out of those teachers who expressed their needs, do associate CT with particular tools. The pattern of needs is similar to that of Factor 2 (Figure 6, Factor 3). Despite understanding of computational thinking, teachers mostly indicate the need of educational resources, best practice examples, providing fundamental knowledge and focus on teacher training. Time allocation and technological support are not among top level needs. Teachers who do not associate CT with a tool (7%, N = 72), mostly indicate the need of best practice examples and educational resources. Factor 4 shows a similar pattern as the one of Factor 3.

5.4. Limitations of the Research

The limitations of this research are driven by a challenging task to compare implementation of informatics in different countries due to the difference in the education systems. For instance, only 17 out of 52 surveyed countries (33%) introduce informatics in grades 1 or 2. 19% of countries start teaching informatics in grade 5 or 6 while in some countries, grade 5 is already the starting grade for secondary school. There are also differences in school implementation and regional implementation within a single country, as generalized by the experts. It should also be mentioned that the data analyzed here reflects the situation for the time of the survey, i.e. 2019. One of the future research directions is studying further developments of informatics and CT implementation in primary school comparing to the study results presented in this article.

The next limitation is due to the dynamics of the informatics (CT) integration into primary education and the number of teacher respondents, the size of subgroups (e.g. teacher profession) do not allow to study differences between subgroups. The topic of misunderstanding of CT by the primary school teachers needs further investigation and is also one of the directions for future work.

6. Conclusion and Discussion

Introduction of informatics education in primary schools is a difficult and challenging task. According to the ACM Europe and Informatics Europe strategy [7] the most important challenges are: 1) curriculum development; 2) teacher preparation (education) and training; 3) research of the implementation process and what should be taught. We addressed them in this paper.

Active participation of experts representing 52 countries for quantitative study and 15 countries for qualitative study indicates the importance of the problem. 21% of surveyed countries of quantitative study undergo active development of informatics curriculum for primary education (91% of these countries belong to the European region).

The current tendencies and trends we learnt by answering our first research question are the following.

The results of the quantitative study have shown that CT and concepts related to informatics subject are introduced in the majority of surveyed countries (83%) in primary education. However, there are a lot of differences in the level of its implementation.

Informatics is introduced in grades 1 or 2 in 33% of surveyed countries. In these countries, the most implemented are Digital content skills, and more than 70% of these countries introduce other areas, related to algorithms and programming, problem solving, data and information, virtual communication and safety. The titles of the content areas differ among the countries, but include similar concepts.

At the time of the research, many countries pay priority to have informatics as a separate subject in primary education rather than integrating into other subjects. However, this result cannot be strictly interpreted (see Limitations section). Due to the interdisciplinary nature of primary education, it seems natural to have integrated informatics education. Additional insights from the qualitative research and experts' opinions and recommendations tell us that integration relies to a large degree on teachers' competence and curriculum flexibility. Experts expressed the wish for natural integration into other subjects' topics together with a separated subject.

Still more attention should be paid to primary teacher education and training. The results from the quantitative study show that training in primary teacher education programs is mostly limited to digital literacy in the majority of surveyed countries, even in those who have introduced an informatics-related curriculum in primary education or where such a curriculum is being developed. Additional experts' comments revealed that at the time of this research, more attention is paid to in-service teacher professional development and teacher training than to pre-service teacher education. Furthermore, informatics, CT and digital literacy courses are included in professional development programs. There are national activities and financial support from the state to take informatics-related courses. Some countries introduce the requirements for primary teachers to accomplish some minimal number of CT and/or informatics courses during a defined period of time. Countries that have an official curriculum of informatics, or where it is being developed, include informatics/CT related modules in the future teachers' study programs. However, the level of training of pre-service teachers differs from university to university even within the same country.

The results of the teachers' study on their understanding or misconceptions related to CT (as posed by the second research question) show that:

– Almost half (44%) of the respondents actively integrate CT in their lessons, but one third (33%) is of a neutral position, and 24% do not integrate CT at all.
– Four factors have been identified, related to integration of CT into the primary school lessons and CT understanding by the teachers: 1) active integration of CT; 2) CT as algorithmic thinking and/or as problem-solving; 3) association of CT with a tool; 4) CT as literacy and thought processes.
– The vast majority of teachers (79%) have some level of misunderstanding of CT education as related to the tool usage. This requires further investigation and confirms again the need of teacher training on CT and its integration in their lessons.
– Time allocation and technological support are not essential for teachers in order to start introducing CT in their lessons. Instead, additional fundamental knowledge and methodological support in the form of educational resources, more practical examples and focus on teacher training is needed. This result confirms the essential need for teacher training and methodological support.

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