Computational Thinking in Greek Educational System for K-12: towards the future teaching approach

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***Abstract*—Computational thinking is considered an important skill set for 21st-century learners and became a subject of focus in K-12 education in recent years. It cultivates problem-solving and algorithmic thinking and can be helpful in wider aspects of everyday life, besides programming and computer science. In this paper, we investigated what is the Greek Primary and Secondary School Teachers' understanding and awareness as far as Computational Thinking is concerned. Since teachers are the agents of change, it is critical to find out how familiar and/or skilled they are with the Computational Thinking notion. Thus, we applied a qualitative questionnaire all over the whole Greek State where 406 teachers answered. The study led to a number of interesting conclusions regarding the teacher's readiness, as well as more generic aspects according to their profile and faculty.**

***Index Terms*—computational thinking, teachers, curriculum, skills, education**

I. Introduction

Computational Thinking, according to Jeanette Wing's paper [1] is defined as "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer, human or machine can effectively carry out". At the beginning of her research carrier, Wing supported that computational thinking is defined as a way of approaching and conceptualizing problems, which draws upon concepts fundamental to computer science such as abstraction, recursion, or algorithms [2]. Wing also supported that CT must be taught to everyone and not only to those who plan a career in CS or STEM field. This option is based on Papert [3] work.

Chrysoula Velaora is a recipient of financial support in the context of a doctoral thesis. The implementation of the doctoral thesis was co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme - Human Resources Development, Education and Lifelong Learning - in the context of the Act - Enhancing Human Resources Research Potential by undertaking a Doctoral Research" Sub-action 2: IKY Scholarship Programme for PhD candidates in the Greek Universities.

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Despite there is no doubt that CT is being considered an important competence of the 21st century as reading, writing and arithmetic [1], [4], there is still a lack of consensus on CT definition. Literature searching shows that the different definitions fall into three alter categories/areas. ([5], p. 25). Definitions that fall into the first category, are in line with the opinion that CT is a perception way of devising a problem solution that can be depicted, processed and executed by any agent, such as a computer or a robot. Complementary, CT recognises real-life problem aspects that can be formulated by a computer. [6], [7]. The second area approaches Computational Thinking as a purely problem-solving method [8], [9] while the third area as an intellectual skill that can be used in analysing and solving serious real-life problems following and applying algorithmic principles and methods [10], [11], [12]. In this scope, teaching and learning about how to solve problems and how computer systems work means competence in computational thinking can be applied in different contexts [13].

In spite of the above approaches, a subset of core concepts and skills is recursively emerging from the literature. More specifically, listing the core CT skills: 1) Abstraction (the process of making an artefact more understandable through reducing the unnecessary detail [14]) is mentioned on [15]-[19] 2) Algorithms (a way of getting to a solution through a clear definition of the steps [14]) is mentioned on [15], [17]-[19] 3) Decomposition (a way of thinking about artefacts in terms of their component parts [14]) [2], [15], [17], [18] 4) Generalization (related with patterns identification, similarities and connections, and exploiting those features [14]) is mentioned on [15], [16], [19] and 5) Evaluation (a way that validates not the correctness but the efficiency of a problem solution) [20].

The above skills are very important for young people in order to participate in the digital society, for their professional development and for their everyday life ([19], p.54). Based on that, the question that emerges is where should and could these competencies be taught.

Answering this question requires developing an understanding of teaching and learning computational thinking and establishing common ideas of computational concepts, practices, and perspectives within a school system [21]. Currently, computational thinking challenges the work of education systems all over the world, especially with regard to the development of competence models, teacher education, and curriculum integration of computational thinking [22], [23]. Additionally, Grover and Pea [17] claim that there is a need for empirical work in classroom environments.

The potential and challenge of teaching and learning CT skills pushed many educational reformation initiatives to integrate CT skills into curricula across Europe and beyond. In line with this policy, many European countries have already integrated CT teaching skills into their curriculum, while other countries are still working in that direction. European Commission conducted two pieces of research among members countries to investigate the extent of CT principles integration into curriculum, the first in 2016 [24] and the second in 2021 [5]. Both of these works depicted the status and the progress countries' members noticed in the CT skills into curriculum integration. This paper investigates the Greek teacher's understanding, awareness and readiness to support their lessons with CT principles. Findings are getting more interesting if count that by nowadays there was no coordinated teachers training initiated by the Greek State. A key consideration is the extent to which CT is allocated across the full spectrum of subject area studies and, also, in multi-disciplinary and interdisciplinary contexts.

II. Computational thinking in compulsory education

A. Computational thinking in K-12 curriculum: policy and practice in action.

The first study between European countries investigating the extent to they ['countries'] have fostered CT skills into their compulsory curriculum, was conducted by European Commission in 2016 [24]. The study aimed to provide a comprehensive overview of CT skills for schoolchildren, encompassing research findings and initiatives at grassroots and policy levels. Specifically: 1. analyzed definitions and frameworks of CT skills in the context of compulsory education 2. analyzed findings for the development of CT ingenuity in the K-12 curriculum and 3. documented the development of CT skills in compulsory education in Europe and provided a comprehensive synthesis of evidence, including implications for policy and practice. The collected data constitutes a wide range of evidence from extensive desk research, a survey of Ministries of Education and interviews with experts. It is worth mentioning that in this study, the Greek MOE did not reply to the survey questionnaire. However, the Greek Institute of Education Policy and the MOE Directorates for primary, secondary and VET education provided the study with general information on the status of CT in the Greek education system ([24], p.14). The study results were published on the European Commission's official website and reported many deviations as far as the rationale for CT introduction in many countries. The main rationale for introducing CT in most countries is to foster the 21st-century skills necessary to fully participate in the digital world. Seven countries (CZ, EL, IE, NL, NO, SE, UK-WLS) were planning to introduce CT into compulsory education. By 2016, the Greek state had not yet applied a concrete education policy towards CT skills integration to the curriculum nor about teacher training. The report [25] prepared by the Committee of Continuous Educational Affairs of the Greek Parliament and published in May 2016, just suggested the inclusion of CT in the curriculum as a short-term priority. It also suggested the implementation from the first year of primary to the final year of secondary school, although the actual scope of the implementation has not yet been decided.

B. Reviewing computational thinking in compulsory education: state of play and practices from computing education.

The second study [5] designed, conducted by the European Commission's Joint Research Centre (JRC), aimed to survey how European and non-European countries apply the CT principles to the K-12 curriculum. The survey was conducted between April to December 2021 and supervised by the Institute for Educational Technology of the Italian National Research Council, the European Schoolnet and Vilnius University. The survey's goal was to bring up to date the [24] report as far as the actions and policy initiatives for the development of CT skills in K-12 curriculum in Europe. The Survey outcomes revealed that CT principles were integrated into K-12 curriculum by all participating countries, giving special emphasis to skills like creativity (EL, FR, LT, LU, PT), communication (LT, PT, SK), critical thinking (EL, HR, LT, LU, RO, SK), collaboration (EL, FR, PT, SK), personal development (HR, SK, RO), and analytical skills (EL, IT, RO). Also, about the pedagogy of CT skill concerns, the study shown two trends: 1. CT skills are considered as the outcome of Computer Science methods implication (algorithms & programming); 2. fundamental CS notions (algorithms & programming) are paired with digital sufficiency and digital literacy data. The main sanity that makes European countries adopt CT is to develop 21st-century skills, which are considered fundamental for an active life in the digital world. The same outcome came up from the first survey [24].

C. Computational Thinking in Greek Schools

While the first study [24] showed that the Greek State was planning to apply a new policy for merging CT skills in compulsory education, the second study showed that CT skills developed: 1. as a distinct learning topic 2. as a cross-curriculum teaching approach ([5], p. 35). As part of a considerable ongoing K-12 curricula reform, a compulsory lesson called "ICT in education and informatics" has been unified into the new K-6 curriculum. This lesson contains CT – problem-solving, programming and digital skills. This reform also includes the increase of teaching hours from one to two per week for the Informatics lesson. This lesson is compulsory and is now taught at the lower secondary education level. The basic teaching topics covered are algorithms, programming, computer systems and networks, problem-solving, data analysis, digital literacy and digital citizenship. The testing phase implementation of the new curriculum was launched in the 2021-2022 school year, involving 112 schools, while a larger scale carrying out will follow this in 2022, and outspread to all schools will start from 2023-2024.

III. Related Work and Research Questions

Surveys conducted in Malaysia [26], [27] and in a Midwestern state [28] revealed a lack of understanding of CT skills among teachers. Most of teachers in Chile [29], Australia [30], and Hong Kong [31] were not aware of the term CT. Teachers, after relevant training, positively changed their perceptions and skills about CT [27], [29], [30]. The study, concerning Computer Science teachers in Greece, revealed that teachers did not have a deep understanding of CT's meaning and their attitude was not positive regarding its inclusion in education [32]. In Turkey, there was a significant difference between in-service and pre-service teachers in their CT skills [33]. Based on the mentioned related work literature review, a set of research questions is proposed:

RQ1. How does teachers' subject area (STEM or non-STEM) affect their beliefs and perceptions of CT?

RQ2. How does teachers' grade level taught (primary or secondary) affect their beliefs and perceptions of CT?

RQ3. How do teachers' years of experience affect their beliefs and perceptions of CT?

RQ4. How does teachers' education level affect their beliefs and perceptions of CT?

IV. Data analysis

A. Participants

This study included 406 teachers from primary (N=136) and secondary education (N=270) during the year 2021 in Greece. Of these teachers a) 203 teach STEM courses, such as maths, science, computers, or technology and 203 teach non-STEM courses, b) 45 teachers have 1-5 years of work experience, 73 teachers have 6-15 years, 208 teachers have 16-25 years and 80 teachers have 26-35 years, c) 158 teachers are bachelor's degree holders, 228 teachers are master's degree holders and 20 teachers are doctorate holders.

B. Questionnaire

The questionnaire was anonymous and the participating teachers got informed by either a dedicated email message or social media. The questionnaire consists of two parts. In the first part, four questions were included in order to collect demographic information regarding teachers' subject area, grade level taught, years of experience, and education level. In the second part, the survey included questions to a) acquire teachers' beliefs about how familiar they are with CT (one question); and their beliefs about CT's teaching to compulsory education (one question) where 5 Likert-type scale answers were adapted, b) assess teachers' perceptions of the concept of CT; its relationship with artificial intelligence and problem solving (four questions) where 5 Likert-type scale answers were adapted, and c) assess their perceptions on what computational thinking involves (five questions) where respondents were given five choices of answers (yes or no). The survey items are shown in Table I.

TABLE I
ITEMS INCLUDED IN THE TEACHER SURVEY

	Questions	Responses
Q1	How familiar are you with the term "Computational Thinking"?	1 = not at all 2 = only a little 3 = to some extent 4 = rather much 5 = very much
Q2	CT could be taught in compulsory education?	1 = strongly disagree 2 = disagree 3 = neutral 4 = agree 5 = strongly agree
	It is said that...	
Q3	CT means "I'm thinking like a computer".	
Q4	CT helps us to solve CS problems and NOT everyday problems.	
Q5	CT is related with Artificial Intelligence.	
Q6	CT deals with problems that can be solved by a calculator.	
	CT involves...	Yes or No
Q7	algorithmic thinking.	
Q8	decomposition.	
Q9	generalisation/patterns.	
Q10	abstraction.	
Q11	evaluation.	

C. Tools

The IBM SPSS 26 statistical package was used to analyze the data. Spearman's rank correlation coefficient was used to analyze the validity and examine the strength of the relationship between questions. Cronbach alpha coefficient was used as a measure of internal consistency. Mann-Whitney U test was used to test the equality of means in two independent samples of the same population and Kruskal-Wallis H test in three or four independent samples. A Chi-square test was used to test if the expected frequencies significantly differentiate from observed frequencies in two or more samples. The basis for the above tests is that if the significance value is greater than 0.05, then there are no differences between samples and at a significance level of 0.05 we accept the null hypothesis.

V. Results

We calculated the mean of the items Q3-Q6, concerning teachers' perceptions of the concept of computational thinking, creating the variable CT1. Also, we counted how many of the items Q7-Q11, concerning their perceptions on what computational thinking involves, they answered yes creating the variable CT2. All the correlations between the items of the variable CT1 are significant at the 0.01 level (2-tailed) and all the correlations between the questions of the variable CT2 are significant at the 0.01 level (2-tailed) except for the correlation between algorithmic thinking (Q7) and evaluation (Q11) which is significant at the 0.05 level (2-tailed).

In below Tables are presented the corresponding results of the statistical tests, percentages of the teachers who answered yes at the items Q7-Q11 and sums of percentages of the teachers a) who answered 4 = rather much or 5 = very much at the item Q1; 4 = agree or 5 = strongly agree at the item Q2; 1 = strongly disagree or 2 = disagree at the items Q3-Q6; yes in 4 or 5 questions at the items Q7-Q11; and b) whose the mean of the answers at the items Q3-Q6 is less or equal to 2.

A. Research question 1

The fields that are related to the concept of "STEM education" are technology, engineering, maths and science [34]. We removed the primary school teachers from the analysis of the first research question because they usually teach all fields. The internal reliability of the variable CT1 (0.606) and the variable CT2 (0.665) were assessed using Cronbach's alpha, which are considered acceptable values.

TABLE II
COMPARISON IN TERMS OF TEACHERS' SUBJECT AREA

Variables	P-value	Sums of Percentages	
		Non-STEM	STEM
Q1	0.000	3.7	27.0
Q2	0.000	22.2	48.5
Q3	0.094	18.5	34.1
Q4	0.113	29.6	49.3
Q5	0.398	12.6	17.4
Q6	0.021	31.5	54.4
CT1	0.273	17.4	30.4
CT2	0.000	14.8	36.7

Mann-Whitney U test results, as are presented in Table II, showed that STEM teachers significantly differentiate from non-STEM teachers on teachers' beliefs about how familiar they are with the term "Computational Thinking"; if it would be useful to teach CT as a subject; and their perceptions on what CT involves. There was no significant difference in their perceptions of CT except from on if CT is dealing with problems that can be solved by a calculator (p-value = 0.021).

TABLE III
COMPARING STEM VS NON-STEM TEACHERS

Variables	P-value	Percentages	
		Non-Stem	Stem
Q7	0.000	18.1	51.9
Q8	0.013	25.9	49.6
Q9	0.003	20.4	43.3
Q10	0.127	21.5	40.0
Q11	0.994	26.7	42.6

Chi-Square Tests results, as are presented in Table III, showed that STEM teachers significantly differentiate from non STEM teachers who chose algorithmic thinking, decomposition, and generalisation/patterns. STEM teachers do not significantly differentiate from non STEM teachers who chose abstraction and evaluation. Looking at the percentages, as are presented in Table II and III, we conclude that majority of the teachers who have a better insight about CT are STEM teachers.

B. Research question 2

The internal reliability of the variable CT1 (0.579) and the variable CT2 (0.687) were assessed using Cronbach's alpha.

TABLE IV
COMPARISON IN TERMS OF TEACHERS' GRADE LEVEL TAUGHT

Variables	P-value	Sums of Percentages	
		Secondary	Primary
Q1	0.025	20.4	6.4
Q2	0.418	47.0	22.9
Q3	0.569	35.0	19.0
Q4	0.731	52.5	24.9
Q5	0.221	20.0	10.6
Q6	0.302	57.1	28.6
CT1	0.955	31.8	16.7
CT2	0.085	34.2	15.3

Mann-Whitney U results, as are presented in Table IV, showed that primary teachers significantly differentiate from secondary teachers on how familiar they are with the term "Computational Thinking". There was no significant difference on if it would be useful to teach CT as a subject; their perceptions on CT; and what CT involves.

TABLE V
COMPARING PRIMARY VS SECONDARY TEACHERS

Variables	P-value	Percentages	
		Secondary	Primary
Q7	0.005	46.6	18.7
Q8	0.091	50.2	22.7
Q9	0.026	42.4	17.5
Q10	0.423	40.9	19.2
Q11	0.128	46.1	25.6

Chi-Square Tests results, as are presented in Table V, showed that primary teachers significantly differentiate from secondary teachers who chose algorithmic thinking and generalisation/patterns. Primary teachers do not significantly differentiate from secondary teachers who chose decomposition, abstraction, and evaluation. Looking at the percentages, as are presented in Table IV and V, we conclude that majority of the teachers who have a better insight about CT are secondary teachers.

C. Research question 3

Kruskal-Wallis H test results, as are presented in Table VI, exhibited there was significant difference between teachers with different years of experience on how familiar they are with the term "Computational Thinking"; if it would be useful to teach CT as a subject. There was no significant difference on their perceptions on CT and what CT involves except from on if CT is dealing with problems that can be solved by a calculator (p-value = 0.026).

Chi-Square Tests results, are presented in Table VII, exhibited there was significant difference between teachers with

TABLE VI

COMPARISON IN TERMS OF TEACHERS' YEARS OF EXPERIENCE

Variables	P-value	Sums of Percentages			
		1-5	6-15	16-25	26-35
Q1	0.041	2.5	3.4	16.7	4.2
Q2	0.001	8.6	11.8	38.2	11.3
Q3	0.108	5.7	7.9	28.6	11.8
Q4	0.298	9.4	12.8	39.7	15.5
Q5	0.763	2.7	5.7	16.3	5.9
Q6	0.026	9.1	15.0	44.8	16.7
CT1	0.422	4.9	7.4	26.4	9.9
CT2	0.098	5.9	9.4	26.6	7.6

TABLE VII

COMPARING TEACHERS WITH DIFFERENT YEARS OF EXPERIENCE

Variables	P-value	Percentages			
		1-5	6-15	16-25	26-35
Q7	0.106	7.1	11.3	36.0	10.8
Q8	0.031	9.4	13.5	37.9	12.1
Q9	0.130	7.1	8.9	32.8	11.1
Q10	0.188	6.4	11.6	32.3	9.9
Q11	0.536	7.1	13.5	37.4	13.5

different years of experience who chose decomposition (p-value=0.031). There was no significant difference between teachers with different years of experience who chose algorithmic thinking, generalisation/patterns, abstraction, and evaluation. Looking at the percentages, as are presented in Table VI and VII, we conclude that majority of the teachers who have a better insight about CT have 16-25 years of experience.

D. Research question 4

TABLE VIII

COMPARISON IN TERMS OF TEACHERS' EDUCATION LEVEL

Variables	P-value	Sums of Percentages		
		Degree	Master	Doctorate
Q1	0.000	6.4	19.0	1.5
Q2	0.002	24.6	42.1	3.2
Q3	0.254	22.7	29.1	2.2
Q4	0.964	29.6	43.8	3.9
Q5	0.273	13.3	16.0	1.2
Q6	0.794	32.0	49.3	4.4
CT1	0.497	20.2	26.4	2.0
CT2	0.000	14.0	32.8	2.7

Kruskal-Wallis H test results, as are presented in Table VIII, exhibited there was significant difference between teachers with different education level on how familiar they are with the term "Computational Thinking"; if it would be useful to teach CT; and what CT involves. There was no significant difference between teachers with different education level on teachers' perceptions on CT.

Chi-Square Tests results, as are presented in Table IX, exhibited there was a significant difference between teachers with different education levels who chose algorithmic thinking, decomposition, generalisation/patterns, and abstraction. There was no significant difference between teachers with different education levels who chose evaluation (p-value 0.499). Looking at the percentages, as are presented in Table VIII and IX, we conclude that majority of the teachers who have a better insight about CT are master's degree holders.

TABLE IX

COMPARING TEACHERS WITH DIFFERENT EDUCATION LEVEL

Variables	P-value	Percentages		
		Degree	Master	Doctorate
Q7	0.010	21.9	39.9	3.4
Q8	0.000	22.9	46.3	3.7
Q9	0.001	19.2	36.5	4.2
Q10	0.000	18.0	39.7	2.5
Q11	0.499	26.8	40.9	3.9

VI. DISCUSSION

The current study is focusing on Greek teachers' attitude toward CT notions and perceptions. Working on the four (4) distinct research questions (RQ1-RQ4) there was turned out that the majority of the research participants were significantly differentiated a) on how familiar they are with the CT concepts; b) on their opinion about whether the CT should be taught in compulsory education and the most important c) on what the CT involves in its core concepts. Delving into the last outcome details, it is seen that there was a deviation as far as the CT core concepts, on the concepts of Algorithmic Thinking and Decomposition. In terms of this finding, it's more than obvious that teachers need more dedicated training.

Furthermore, no matter the teachers' a) years of experience b) subject area c) educational level and d) grade level, teachers seem to be agreed that a) CT doesn't mean "thinking like a computer"; b) CT isn't related with AI; c) CT help people to solve any kind of problem and d) CT isn't related with problems that can be solved by a calculator.

Even though this paper examines teachers' attitude utilizing a small number of research questions, we strongly believe that findings can be further utilized by authorities and design new educational material more dedicated to teachers' development.

VII. CONCLUSION

After the study of teachers' research data, it turns out that STEM teachers working at Secondary Schools who have 16-25 years of experience and are master's degree holders, are more familiar with CT notions and perceived CT principles better than the rest of the participants. Moreover, since teachers' attitude a) towards their familiarity with CT concepts (Q1) b) over their belief about whether CT could be taught in compulsory education (Q2) and c) over their opinion about what CT involves (CT2) are significantly differentiated, it is concluded that teachers need dedicated training on CT concepts and teaching methods. Especially on Algorithmic Thinking and Decomposition concepts (Q7, Q8). The limitations of this study are: a) the participants were volunteers, which limits the generalization of the results and b) the evaluated parameters, which might be limited by the teachers' ability to rate correctly.

REFERENCES

[1] J. Wing, "Computational Thinking's Influence on Research and Education for All," Italian Journal of Educational Technology, vol. 1, no. 1, Jul. 2017, doi: 10.17471/2499-4324/922.

[2] J. M. Wing, "Computational Thinking." ACM Press, 2006.

[3] S. Papert, Mindstorms: children, computers, and powerful ideas. New York: Basic Books, 1980.

[4] J. Voogt, P. Fisser, J. Good, P. Mishra, and A. Yadav, "Computational thinking in compulsory education: Towards an agenda for research and practice," Educ Inf Technol, vol. 20, no. 4, pp. 715–728, Dec. 2015, doi: 10.1007/s10639-015-9412-6.

[5] European Commission. Joint Research Centre., Reviewing computational thinking in compulsory education: state of play and practices from computing education. LU: Publications Office, 2022. Accessed: Mar. 27, 2022. [Online]. Available: https://data.europa.eu/doi/10.2760/126955

[6] B. Eickelmann, A. Labusch, and M. Vennemann, "Computational Thinking and Problem-Solving in the Context of IEA-ICILS 2018," in Empowering Learners for Life in the Digital Age, vol. 524, D. Passey, R. Bottino, C. Lewin, and E. Sanchez, Eds. Cham: Springer International Publishing, 2019, pp. 14–23. doi: 10.1007/978-3-030-23513-0_2.

[7] I. Corradini, M. Lodi, and E. Nardelli, "Conceptions and Misconceptions about Computational Thinking among Italian Primary School Teachers," in Proceedings of the 2017 ACM Conference on International Computing Education Research, Tacoma Washington USA, Aug. 2017, pp. 136–144. doi: 10.1145/3105726.3106194.

[8] O. Hazzan, N. Ragonis, and T. Lapidot, "Computational Thinking," in Guide to Teaching Computer Science, Cham: Springer International Publishing, 2020, pp. 57–74. doi: 10.1007/978-3-030-39360-1_4.

[9] L. Zhang, J. Nouri, and L. Rolandsson, "Progression Of Computational Thinking Skills In Swedish Compulsory Schools With Block-based Programming," in Proceedings of the Twenty-Second Australasian Computing Education Conference, Melbourne VIC Australia, Feb. 2020, pp. 66–75. doi: 10.1145/3373165.3373173.

[10] R. Israel-Fishelson, A. Hershkovitz, A. Eguíluz, P. Garaizar, and M. Guenaga, "The Associations Between Computational Thinking and Creativity: The Role of Personal Characteristics," Journal of Educational Computing Research, vol. 58, no. 8, pp. 1415–1447, Jan. 2021, doi: 10.1177/0735633120940954.

[11] M. Román-González, J.-C. Pérez-González, and C. Jiménez-Fernández, "Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test," Computers in Human Behavior, vol. 72, pp. 678–691, Jul. 2017, doi: 10.1016/j.chb.2016.08.047.

[12] V. J. Shute, C. Sun, and J. Asbell-Clarke, "Demystifying computational thinking," Educational Research Review, vol. 22, pp. 142–158, Nov. 2017, doi: 10.1016/j.edurev.2017.09.003.

[13] J. Ainley, W. Schulz, and J. Fraillon, "A global measure of digital and ICT literacy skills," UNESCO, 2016, [Online]. Available: https://research.acer.edu.au/ict_literacy/12

[14] A. Csizmadia and C. Selby, "Computational thinking A guide for teachers," Jan. 2015. [Online]. Available: https://www.researchgate.net/publication/327302966

[15] V. Barr and C. Stephenson, "Bringing computational thinking to K-12: what is Involved and what is the role of the computer science education community?," ACM Inroads, vol. 2, no. 1, Art. no. 1, Feb. 2011, doi: 10.1145/1929887.1929905.

[16] I. Lee et al., "Computational thinking for youth in practice," ACM Inroads, vol. 2, no. 1, Art. no. 1, Feb. 2011, doi: 10.1145/1929887.1929902.

[17] S. Grover and R. Pea, "Computational Thinking in K–12: A Review of the State of the Field," Educational Researcher, vol. 42, no. 1, pp. 38–43, Jan. 2013, doi: 10.3102/0013189X12463051.

[18] C. C. Selby and J. Woollard, "Refining an Understanding of Computational Thinking," p. 23.

[19] J. M. Wing, "Research Notebook: Computational Thinking–What and Why?," p. 8, 2011.

[20] H. Abelson and S.-C. Kong, Eds., Computational Thinking Education, 1st ed. 2019. Singapore: Springer Singapore: Imprint: Springer, 2019. doi: 10.1007/978-981-13-6528-7.

[21] S.-C. Kong, "A framework of curriculum design for computational thinking development in K-12 education," J. Comput. Educ., vol. 3, no. 4, pp. 377–394, Dec. 2016, doi: 10.1007/s40692-016-0076-z.

[22] Y. B. Kafai, "From computational thinking to computational participation in K–12 education," Commun. ACM, vol. 59, no. 8, pp. 26–27, Jul. 2016, doi: 10.1145/2955114.

[23] C. Bescherer and A. Fest, "Computational Thinking in Primary Schools: Theory and Causal Models," in Tomorrow's Learning: Involving Everyone. Learning with and about Technologies and Computing, vol. 515, A. Tatnall and M. Webb, Eds. Cham: Springer International Publishing, 2017, pp. 663–667. doi: 10.1007/978-3-319-74310-3_68.

[24] European Commission. Joint Research Centre., Developing computational thinking in compulsory education: implications for policy and practice. LU: Publications Office, 2016. Accessed: Mar. 27, 2022. [Online]. Available: https://data.europa.eu/doi/10.2791/792158

[25] Committee of continuous Educational affairs of the Greek parliament, "National and social dialogue for education. Observations, suggestions, and implementation timeframe." IEP and MOE of Greece, 2016. [Online]. Available: https://www.minedu.gov.gr/publications/docs2016/morfotikwn_porisma.pdf

[26] Ung, Ling & Saibin, Tammie & Labadin, J. & Aziz, Norazila. (2018). Preliminary Investigation: Teachers' Perception on Computational Thinking Concepts.

[27] Ling-Ling Ung, Jane Labadin, Fitri Suraya Mohamad, Computational thinking for teachers: Development of a localised E-learning system, Computers & Education, Volume 177, 2022, 104379, ISSN 0360-1315, https://doi.org/10.1016/j.compedu.2021.104379.

[28] Jocelyn Simmonds, Francisco J. Gutierrez, Federico Meza, Catalina Torrent, and Jaime Villalobos. 2021. Changing Teacher Perceptions about Computational Thinking in Grades 1-6, through a National Training Program. In Proceedings of the 52nd ACM Technical Symposium on Computer Science Education (SIGCSE '21). Association for Computing Machinery, New York, NY, USA, 260–266. DOI:https://doi.org/10.1145/3408877.3432542

[29] Fesakis, Georgios & Prantsoudi, Stavroula. (2019). Computer Science Teachers' Perceptions, Beliefs and Attitudes on Computational Thinking in Greece. Informatics in Education. 18. 227-258. 10.15388/infedu.2019.11.

[30] R. Kong and G. K. W. Wong, "Teachers' perception of professional development in coding education," 2017 IEEE 6th International Conference on Teaching, Assessment, and Learning for Engineering (TALE), 2017, pp. 377-380, doi: 10.1109/TALE.2017.8252365.

[31] Bower, M., Wood, L. N., Lai, J. W. M., Highfield, K., Veal, J., Howe, C., Lister, R., & Mason, R. (2017). Improving the computational thinking pedagogical capabilities of school teachers. Australian Journal of Teacher Education, 42(3), 53–72. https://search.informit.org/doi/10.3316/aeipt.215475

[32] Sands, P., Yadav, A., Good, J. (2018). Computational Thinking in K-12: In-service Teacher Perceptions of Computational Thinking. In: Khine, M. (eds) Computational Thinking in the STEM Disciplines. Springer, Cham. https://doi.org/10.1007/978-3-319-93566-9_8

[33] Günbatar, Mustafa Serkan. (2019). Computational thinking within the context of professional life: Change in CT skill from the viewpoint of teachers. Education and Information Technologies. 24. 10.1007/s10639-019-09919-x.

[34] Gonzalez, H. B., & Kuenzi, J. J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. Congressional research service.