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Computer Science Teachers' Perceptions, Beliefs and Attitudes on Computational Thinking in Greece

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Abstract. The role of teachers is very important for the educational utilization of Computational Thinking (CT) and its integration in education. As with any innovation, CTs' successful integration considerably depends on the perceptions, beliefs and attitudes of the teachers who will be asked to implement it. The study of these characteristics, concerning Computer Science (CS) teachers in Greece, was the objective of a survey research, theoretically supported by the Theory of Reasoned Action (TRA) and the Technology Acceptance Model (TAM). Findings reveal intense interest of participants on CT and their willingness to participate in professional development programs. Participants also reveal misconceptions of CT and negative attitudes toward its integration in education, that require further study and discussion. The researchers propose directions for the design and implementation of appropriate teachers training programs, while the findings can be exploited to support any effort of integrating CT in education.

Keywords: Computational Thinking, perceptions, attitudes, beliefs, computer science teacher, TRA, TAM.

1. Introduction

STEM education was placed in the center of interest in many countries, lately, resulting on an increased interest on Computer Science/Informatics integration in education (the terms Computer Science and Informatics are considered synonymous in the present context), as a basic component of the STEM educational approach (Henderson *et al.*, 2007). The international educational and research communities have proposed the term "Computational Thinking" as a conceptual vehicle to facilitate the dialogue on the role of Computer Science in general education. CT is therefore emerging as a key competence for future scientific and technological progress and the need to familiarize students with computational ideas in the context of basic education is now urgent (CSTA and ISTE, 2011). Adopting this view, numerous initiatives have been developed internationally to promote CT in education and produce appropriate educational material (Grover and Pea, 2013). However, it was soon clear that effective teachers' training is one of the most important success factors of any attempt to exploit the pedagogical dynamics of CT (Yadav *et al.*, 2011; Yadav *et al.*, 2014). As Cuny (2011) argues, proper training and support of teachers is a bigger challenge than the development of an appropriate Curriculum, emphasizing thus, the need to prepare teachers accordingly with the aim to integrate CT in their daily pedagogical activities (Lye and Koh, 2014).

According to the Theory of Reasoned Action (TRA) (Ajzen and Fishbein, 1980; Fishbein and Azjen, 1975) and the more recent Technology Acceptance Model (TAM) (Davis, 1989), success of an attempt to integrate any innovation, and thus CT, in education, depends on teachers' attitudes and perceptions about it. Moreover, teachers' perceptions and attitudes about teaching and learning greatly influence the teaching practices they adopt, as well as the learning outcomes that arise (Brown, 2004).

Based on the above, the purpose of this research was to investigate the perceptions, beliefs and attitudes of Computer Science teachers who teach in Greek public, secondary or primary, schools about CT and its integration in Education. Our aim was to contribute evidence which could inform any effort of designing efficient training of in-service teachers and proper preparation of candidate/future teachers for the integration of CT in education. We also aimed to contribute to the methodology of the investigation and analysis of teachers' perceptions, beliefs and attitudes towards CT, by using, and thus proposing, certain data collection instruments and data analysis methods (k-means clustering on Likert-type answers to identify groups of similar perceptions, beliefs and attitudes). The methods adopted in our research aimed to identify groupings of teachers' attitudes and beliefs towards CT, to subsequently guide the treatment of their possible misconceptions and mistaken beliefs and plan their effective preparation, through proper training programs, for the integration of CT in their teaching. The following sections present the conceptual approach of CT, as adopted by the authors, the theoretical framework of the research, followed by findings on the CS teachers' answers on a questionnaire-based survey, and finally, summary and discussion of the results.

2. Theoretical Background

2.1. *Computational Thinking*

Overviewing the evolution of the term, "Computational Thinking" was introduced by Seymour Papert (1991), while researching on the influence of programming on the development of children thinking, using the LOGO programming language in MIT. Later, Andrea diSessa introduced the definition of *computational literacy*, to describe how computers can catalytically change education, by using methods of Computer Science to produce creators of dynamic cognitive content rather than consumers of it (diSessa, 2000). Wings' article entitled "Computational Thinking" (Wing, 2006) followed, in which CT was defined as *"the ability to solve problems, design systems and* *understand human behavior, based on concepts fundamental to Computer Science"*. Wing essentially introduced the issue of CTs' integration in education, claiming that CT is a basic competence that all literate citizens need to develop in the context of compulsory education, additionally to reading, writing and arithmetic. Two workshops, organized by the National Academy of Sciences (NRC, 2010) and several others organized by CSTA and ISTE, aimed at the creation of an "operational definition" of CT, which would refer to the key concepts and skills related to CT, along with examples of its integration in different subjects (CSTA and ISTE, 2011). Wing came up with a revised definition, according to which *"Computational Thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent"* (Wing, 2011). Since then, an extensive scientific dialogue on the meaning of the concept has been developed (e.g. NRC, 2010; Barr and Stephenson, 2011; Grover and Pea, 2013; Kalelioglu *et al.*, 2016) but, despite the efforts, the community has not yet resulted to a commonly accepted definition (Rose *et al.*, 2017; Weintrop *et al.*, 2016; Fessakis *et al.*, 2018).

Following Wing's action towards the promotion of CT's integration in general education, many questions arose for the scientific community, concerning the concept of CT itself, as well as the human resources to be involved. A key issue to resolve was the definition of CTs' dimensions and concepts that should be taught. Wing suggested that computational thinking consists of dimensions including: *abstraction, problem decomposition, pattern recognition, algorithmic thinking and logical thinking* (Wing, 2006). Later, Isbell and Stein argued that the curricula of computing courses should be revised to include core competences in *modeling, scales and limits, simulation, abstraction, automation and interpretation of data*, also known as the computationalist mindset (Isbell, Stein *et al.*, 2009). According to CSTA and ISTE's framework for K-12 education, CT consists of nine core concepts and capabilities, including *manipulation of data (collection, analysis, representation), problem decomposition, abstraction, algorithms and procedures, automation, parallelization, and simulation* (CSTA and ISTE, 2011). Several other sets of dimensions were proposed from time to time (NRC, 2010; Barr and Stephenson, 2011; Grover and Pea, 2013; Selby, 2015), enhancing the ambiguity that prevails the term. A union of the proposed sets of CT dimensions (CSTA and ISTE, 2011; The College Board, 2010; Royal Society, 2012) was published by Fessakis *et al.* (2018) and was adopted for the construction of the questionnaire in the present research, aiming to explore CTs' conception by CS teachers. According to the authors, the CTs' set of dimensions highlighted in the various definitions consists of *creative problem solving, algorithmic approach to problem-solving, problem solution transfer, logical reasoning, abstraction, generalization, representation and organization of data, systemic thinking, evaluation, and social impact of computation*.

Modern conceptual approaches of the scientific community acknowledge CT as a multidimensional concept that includes, as individual components, important concepts, methods and practices that computers scientists use to solve computational problems that arise in various fields of science or everyday life (Fessakis, *et al.*, 2018; Riley and Hunt, 2014; Denning and Martell, 2015). These multiple dimensions of the concept of CT increase its complexity and raise further questions concerning it. However, the exact set of dimensions that CT consists of is still under discussion, as the exact definition of the concept itself. Besides the definition of the term itself, questions about the appropriate school subjects of integration, educational approaches, school grades, software tools and material infrastructure, as well as assessment methods, still concern the research and educational communities (Fessakis, *et al.*, 2018) and CS teachers' beliefs on them constituted some other issues of investigation in our research.

Computer Scientists may be considered familiar with CT, since it is connecting CS concepts to other curriculum disciplines. This familiarity does not attribute a special talent these scientists possess, but it is rather their educational background and experience in solving problems using computers that provide them with these skills and conceptual schemata. However, between K-12 teachers, educational policy makers and future teachers' educators there is still confusion on the exact meaning of the term (Yadav, *et al.*, 2014). The big question on which people have the appropriate training to effectively support such a venture (Barr and Stephenson, 2011) is still open and CS teachers' perspective was also an issue of our investigation.

2.2. *Theory of Reasoned Action (TRA) and the Technology Acceptance Model (TAM)*

To theoretically frame our research, we used the Technology Acceptance Model, one of the most well-known research models to predict acceptance of technology by individuals, verified by different studies so far (Surendran, 2012). Preceding the TAM, Ajzen and Fishbein (Ajzen and Fishbein, 1980) proposed the Theory of Reasoned Action (TRA), according to which the likelihood of a person to present a certain behavior is affected by the persons' attitudes and beliefs towards this certain behavior. Behavioral "attitude" refers to the overall positive or negative assessment of the individual for that behavior, while "beliefs" define the degree a person accepts that something exists or is true, especially one without proof. Attitudes and beliefs are thus internal structures that help individuals interpret their experiences and identify their behavior (Nespor, 1987; Pajares, 1992). Consequently, in the case of teachers, their attitudes and beliefs can greatly influence their teaching practices and the educational process in general, therefore they consist an issue of investigation.

TRA was enriched with the assumption that the adoption of a certain behavior or technology depends on the estimated ease of use and the estimated usefulness, creating the Technology Acceptance Model (TAM) (Davis, 1989). The TAM consists of four structures: the *estimated ease of use* – that is, "the degree to which a person believes that the use of a particular system does not require effort", the *estimated usefulness* – that is, "the degree to which a person believes that using a particular system would improve his/her professional performance", the *attitude towards use* – that is, the general feeling of like or dislike towards the use of a certain system and the *behavioral intention* – that is, the subjective possibility of a person to use a particular system (Fishbein and Azjen, 1975).

The above theoretical framework has already been applied internationally to explore teachers' intention to integrate CT in their teaching practice. Thus, a recent study by

Ling and his colleagues, using a sample of 159 primary school teachers in Malaysia, reported a positive attitude towards CT, increased estimated ease of use and an intention of integration by most of the participants, alongside with several misunderstandings concerning the concept (Ling *et al.*, 2017). A similar research in Italy reported the existence of confusion in the notion of the CT concept between teachers, who thus managed to dissociate it from the use of technology (Corradini *et al.*, 2017). In other research by Yadav, Gretter, Good and McLean (2017), future teachers seemed to have over-simplified perceptions about CT and often confuse it with the use of technology and mathematical thinking. In general, there seems to be a positive predisposition towards CT, perhaps due to its promotion in the international educational community as an innovation, thus the teachers' perceptions and level of understanding about CT are found to be rather problematic, creating risks for the quality of the classroom curriculum implementation (Fessakis *et al.*, 2018). The attitudes and beliefs that teachers possess are affected by multiple factors which significantly differ from one country to another, so their investigation needs to be implemented specifically for each country. In the field of investigating the perceptions, beliefs and attitudes on CT that CS teachers in Greece present, there was no previous work detected.

3. Research

3.1. *Research Rationale*

The purpose of this research is the contribution to the integration of CT in education, by examining and better understanding the human resources factor. More specifically, the research estimates, based on the TAM, the intention of Greek CS teachers to properly train and integrate CT in their teaching practice. In parallel, by exploring teachers' attitudes and beliefs, as well as their perceptions on the content of the CT concept, the research aimed to collect valuable data for the design of effective teachers' professional development programs concerning CTs' integration in education. The research methodology used in our investigation of teachers' perceptions, beliefs and attitudes, could be proposed for the conduction of similar context research, aiming to investigate the above factors in other countries, or using a sample of non-CS teachers.

3.2. *Research Questions*

The research questions that guided our investigation of CS teachers' perceptions, beliefs and attitudes were the following:

RQ1. What are the CS teachers' perceptions on CT?
RQ2. What are the CS teachers' beliefs concerning CT?
RQ3. What are the CS teachers' general attitudes towards CT?
RQ4. What are the teachers' beliefs on the integration of CT in education?

3.3. *Research Methodology and Conditions*

Methodologically, our research was a survey. A specially designed questionnaire was used for the collection of the data, by which we recorded teachers' responses to questions examining their perceptions on CTs' meaning, their attitudes and beliefs on CT and its dimensions and practices, as well as their attitudes towards the potential of in-service training and the integration of CT in education. The questionnaire, which took 15–20' minutes to answer, was developed in the Google Forms service and was organized in four sections: one concerning the demographics data, followed by three sections, each containing items to examine teachers' perceptions, beliefs and attitudes on CT respectively, following the research design schema. The items (questions) that were selected consisted a combination of questions previously used in similar surveys (Yadav *et al.*, 2011; 2014), enriched with questions derived from the study of the literature, to examine each of the three investigated factors. The questionnaire was delivered through e-mail to approximately 6000 CS teachers in Greece, via the School CS Teachers' Pedagogical Advisors. CS Teachers' Pedagogical Advisors in Greece are highly qualified and experienced CS teachers, delegated with the responsibility of providing professional development guidance and mentoring the in-service CS teachers of a specific geographic region. The 22 Pedagogical Advisors serving in Greece were asked to forward the call for participation in the survey to the email boxes of the CS teachers of their region of responsibility, on November 12, 2018. Three weeks later, 136 valid answers were gathered, a number considered sufficient for survey research using sampling (Yount, 2006, p. 7–4).

The key findings of the survey research, organized in sections corresponding to the questionnaire sections and the research questions respectively, are presented in what follows. Concerning the limitations of the research, since the participation on the survey was voluntary, the sample can be considered occasional and there was no prior mechanism to ensure its representativeness. Based on the demographics data of the sample (Table 1), the authors claim that the sample is sufficiently representative of the general Greek CS Teachers' population in terms of the basic dimensions (sex, age, degree level). Answers of the participants overall show that they have an increased interest on CT and this has been their strongest motivation to take the survey. This will be taken into consideration while interpreting the findings, in the sense that participants were rather more optimistic about CTs' integration than the typical Greek CS teacher. Finally, based on research methodology manuals, the number of 136 sample individuals is considered satisfactory for survey research (Gall, Borg and Gall cited in Cohen *et al.*, 2000, p.93; Yount, 2006).

3.4. *Demographics of the Sample*

The sample of the research consisted of 136 K12 CS teachers, who were teaching in various types of schools (primary, secondary, higher education) in Greece at the time of the survey and were asked to fill the digital questionnaire. Concerning the demographics of the sample, 54.41% (74 teachers) of the participants were male and 45.59% (62 teach-

Table 1
Demographics of the sample

Variable	Value	Count	%
Sex	Male	74	54.41
	Female	62	45.59
Age	31–40	55	40.44
	41–50	62	45.59
	>50	19	13.97
Basic degree	University degree	95	69.85
	Technological Institution degree	41	30.15
School of service	Primary	33	24.26
	Secondary	95	69.85
	Primary, secondary and higher	8	05.89

ers) female, distributed in various age groups (40.44% aged 31–40, 45.59% aged 41–50 and 13.97% aged > 50) and various types of basic degrees. Most of them (69.85%) hold a University degree and others (30.15%) hold a Technological Institution degree (in Greece there is a variety of degrees that CS teachers can hold). Teachers served in different types of schools at the time of the survey conduction, as follows: 24.26% in primary education, 69.85% in secondary education, and 5.89% in primary, secondary and higher education at the same time. CS teachers holding a PhD Degree can deliver courses at University Departments, as adjunct lecturers, and this option was represented in the questionnaire. However, the questionnaire was only delivered in CS teachers working in primary and secondary schools, so we assume that those who selected the higher level, were participants who also work at that level of education at the same time. The demographics data are presented in Table 1.

4. Results and Discussion

4.1. *CS Teachers' Perceptions on CT*

The meaning (abstract representation – conceptual model) that teachers ascribe to the CT concept was a subject of investigation in our research. We will refer to this meaning using the term *perceptions*, as the teachers of the sample, at the time of the survey, had not had attended any formal training on CT to elaborate the understanding of the concept. Information concerning possible misunderstandings, incomplete conceptions and other findings will assist specialists to better organize relevant training and create proper educational material. Furthermore, the raised interest that the sample teachers showed on CT, combined with their level of studies, increases the importance of the study of their perceptions, since they are expected to have the potentially optimal perceptions on the certain field. What follows is findings concerning the ways in which teachers conceptualize CT (based on their answers), as well as the relation they perceive between CT and CS.

4.1.1. T*eachers' Perceptions on CT*

Teachers were asked the open-ended question *Q06. In my opinion, Computational Thinking is…* and their answers varied in content and meaning. Among others, they gave answers such as: "problem solving with the use of computer science concepts", "a set of skills necessary to formulate and solve problems", "combining techniques, knowledge and tools to analyze and solve problems in various science fields", "algorithmic thinking of solving every day (and not only) problems", "a set of skills that everyone needs to learn and use", "organization, analysis, and process of the data of a problem in order to solve it", "the use of algorithmic thinking to solve problems with the help of a computer", "CT is a skill that can be developed by all students", "it includes several actions to solve a specific problem, such as: problem-formulation, organization-analysis-data representation, modeling and simulations, algorithmic thinking and automation, problem-solving tools and generalization of solution", "the way computer scientists think, in particular data analysis, problem solving, algorithmic thinking etc.", "the ability to solve problems", "analytic thinking", "computer-related skills" etc. The answers

Table 2
Teachers' perceptions of CT

In my opinion, Computational Thinking is…	Count	%
Category 1. CT = Problem Solving Method		
Algorithmic solution of a problem	38	27.94
Way of thinking for problem solving	25	18.38
Way of thinking for problem solving using a computer	16	11.76
Solving problems as a computer scientist does	13	9.56
Logical problem solving	8	5.88
Sum	**100**	**73.52**
Category 2. Confuse the CT concept with a certain CT dimension		
Analytic ability	5	3.68
Computer programming	2	1.47
Logical organization and analysis of data	1	0.74
Mathematical thinking	1	0.74
Systemic thinking	1	0.74
Sum	**10**	**7.37**
Category 3. CT = Epistemological method		
Epistemological method	2	1.47
Category 4. Irrelevant		
Digital age skills (CT = Digital Literacy – ICT)	8	5.88
Understanding of the computer operation	2	1.47
Numerical computing capability	1	0.74
Sum	**11**	**8.09**
Category 5. Unclear or No answer		
Unclear	10	7.35
No Answer	3	2.21
Sum	**13**	**9.56**

were coded, categorized, summarized and they are presented in Table 2. The categories of the answers are of decreasing correctness, the first is CT = Problem Solving Method which includes quite correct answers, the second includes the answers that identify CT with one of its dimensions (e.g. CT = Data Analysis), the third mentions CT as an epistemological method which is a quite sophisticated view but it requires more interrogation to clarify what the teacher mean, the fourth category concerns irrelevant and obvious misunderstandings of CT, and the last category concerns the absence of answer or answers without a clear meaning.

On the basis of the answers of category 1, (100/136; 73.52%) teachers connect CT with some method of problem solving – most of them coincide CT to Algorithmic Thinking (38/136; 27.94%), a percentage of them describes it as a particular way of thinking about solving a problem (25/136; 18.38%), while some consider that this solution should include the use of a computer (16/136; 11.76%) and few identify CT as Logical Problem Solving (8/136; 5.88%). Of special interest is the group of teachers who state that CT concerns the solution of a problem (CT = problem solving method) in a way that a computer scientist does it. Responses of this group are very close to the scientific meaning of CT (can that be defined, given the international dispute over the issue). CT is indeed the ability to solve problems using the principles and techniques of CS, but respondents do not clearly state that the problem may come from different scientific fields and that its solution has an epistemological use (only 2 respondents gave the answer – CT = Epistemological Method).

Responses of the other categories reveal various misconceptions and incomplete notions of CT. More specifically, answers of category 2 (10/136; 7.37%) identify CT with some of its dimensions, while category 4 answers mistakenly match CT with digital literacy or comprehension of computer function. One person mentions that CT is the arithmetic capacity in general. The rest of the participants answered with ambiguity or did not answer at all (category 5). Despite their specialized studies (CS degree), great percentage (25.02%) of the sample gave inappropriate answers and presented a problematic understanding of the CT term. From the rest, a big percentage matches CT with the Algorithmic approach of problems, reducing and in parallel limiting it to a kind of knowledge they possess well, without properly ascribing its modern interdisciplinary and epistemological meaning. It seems that teachers have not yet developed satisfactory knowledge schemata on CT and this fact is hampered by the international ambiguity on the term, combined with its multidimensional nature. The problem is likely to be intensified in teachers of other school subjects.

Searching for correlations between demographic factors and the answers in Q06, the X^2 test showed independence between them, which is interpreted as existence of homogeneity in the distribution of the teachers' perceptions along the demographic factors. CT is a quite new concept and is rather familiar to CS professionals involved with learning procedures, so this homogeneity was rather expected. This fact also supports the adoption of the term "*perceptions*" instead of conceptions to describe the mental models that teachers construct about CT.

Table 3
Relation between CT and CS

Relation between CT and CS	Count	%
CT is a concept wider than CS, because it further includes the ability of solving problems in various disciplines, even without the use of computers	72	52.94
CT and CS have common attributes, but each one also has special, discrete attributes	34	25.00
CS is a concept wider than CT, because it further includes e.g. the study of computation, programming languages and computer hardware	24	17.65
CS and CT are the same	6	4.41
Sum	**136**	**100.0**

4.1.2. *Relation Between CT and CS*

Findings of Q06 seem to be strengthened by the answers in *Q08. In your opinion, what is the relation between CT and CS?* Only 25% (34/136) of the participants gave the correct answer, that CT and CS intersect and are not totally different cognitive fields. Most of the teachers (72/136; 52.94%) stated that CS is a subset of CT (Table 3). The answers overall also have a homogeneity regarding the demographic factors, with the misunderstandings being equally distributed along the demographic groups.

4.2. *CS Teachers' Beliefs on CT*

What follows is the investigation of teachers' beliefs on the specific dimensions and practices of CT, as well as their general beliefs on the concept and the recognition of CS application in other science fields.

4.2.1. *Beliefs on CT Dimensions*

Trying to evaluate teachers' beliefs on CT and order the dimensions it consists of, we used Q11, where teachers were asked to select the most important dimensions of CT in their opinion. The available dimensions were based on the classification proposed by Fessakis *et al.* (2018). The specific question was important for the investigation of teachers' beliefs on CT, because it revealed the structure (recognition of dimensions and sub-concepts) they attribute to it, as well as the classification they acquire on CTs' dimensions by significance. As expected, Algorithmic Thinking was the most popular dimension, followed by Data Analysis, Problem Decomposition and the rest. Important is the fact that some dimensions are under-represented, e.g. Automation, Understanding People (Artificial Intelligence), Pattern Matching and Cybernetics. A small number of participants (27/136; 19.85%) answered that all dimensions are equally important (Table 4).

Investigating the correlations between CT dimensions and demographic factors, general preferences on dimensions such as Abstraction, Data Representation, Generalization and Automation were observed, some being statistically important and others

Table 4

Beliefs on CT dimensions

Q11. Which of the following CT dimensions do you consider important?	Count	%
Algorithmic Thinking – AL	108	79.41
Data Analysis – DA	82	60.29
Problem Decomposition – PD	77	56.62
Modeling – MO	62	45.59
Logical Reasoning – LR	59	43.38
Abstraction – AB	57	41.91
Data Representation – DR	56	41.18
Testing – TE	53	38.97
Generalization – GE	48	35.29
Evaluation – EV	47	34.56
Data Collection – DC	44	32.35
Data Science – DS	41	30.15
Simulation – SIM	33	24.26
Problem Translation – PT	30	22.06
Automation – AU	23	16.91
Understanding People – UP	22	16.18
Pattern Matching – PM	13	9.56
Sequencing – SE	12	8.82
Cybernetics – CYB	5	3.68
All the above mentioned	27	19.85

not. It seems that the classification that teachers acquire on the dimensions' importance is related to the level of the school they serve in. To visualize this finding and present it in a more comprehensive way, a diagram was drawn to compare the order of significance of the dimensions per level of school, for the two basic education levels (primary and secondary).

The frequency of preference of each dimension, as well as its final ranking in the preferences list appear in Table 5, which is sorted in order of the primary teachers' preferences.

Based on the table of the teachers' preferences on CT dimensions, the arachnoid comparison chart of Fig. 1 was created. The red (inner) helical layout curve represents the preferences of Primary education teachers from Algorithmic Thinking (AT) in the center to Sequencing (SE) in line 20. The blue (outer) line represents the preferences of Secondary education teachers on the same CT dimensions. One can graphically see the overturning in the order of significance for the dimensions Abstraction (AB) and Data Representation (DR), which are also detected as statistically important, while similar but less intense turns occur for Generalization (GE), Simulation (SI), Automation (AU) and Sequencing (SE). Teachers' beliefs on the importance of a CT dimension are related to what they consider as developmentally appropriate for children of the certain level of education they teach at, albeit it is not certainly identified to what

Table 5
Preference on CT dimension per school level

CT Dimension	Primary/F	Primary/RANK	Secondary/F	Secondary/RANK
AT	24	1	77	1
DA	20	2	56	2
PD	18	3	53	3
LR	15	4	41	6
MO	15	5	40	7
TE	14	6	34	9
EV	12	7	30	10
DC	12	8	28	11
DS	10	9	27	12
GE	9	10	37	8
DR	8	11	43	5
PT	8	12	19	14
ALL	8	13	17	16
UP	8	14	11	18
SI	7	15	22	13
AB	5	16	47	4
AU	3	17	17	15
PM	3	18	10	19
ST	1	19	4	20
SE	0	20	12	17

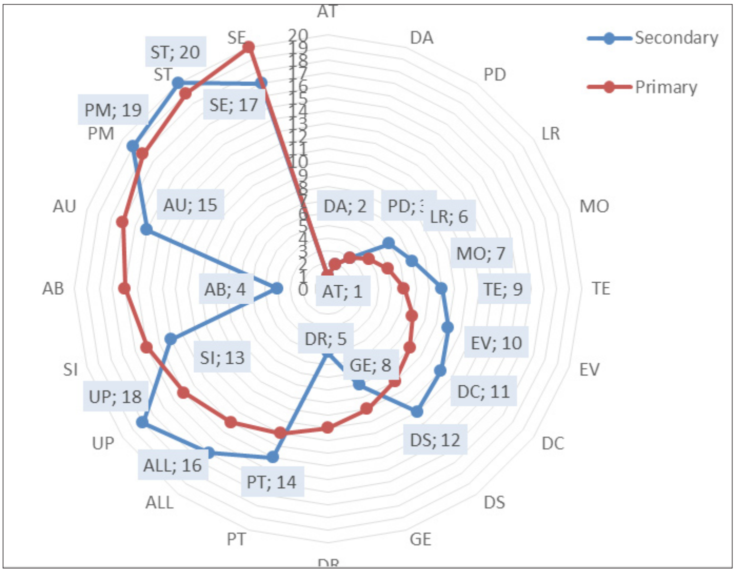

Fig. 1. Arachnoid comparison chart on CT dimensions.

is epistemologically and didactically suitable for that level. As an example, Simulation (SI) seems to have higher priority for secondary education teachers, although someone would expect that to happen for primary education teachers. In general, importance of CTs' dimensions according to the level (grade) of education is a field that needs to be studied in light of Didactics.

What was interesting to investigate was the existence of groups of teachers' who mainly give similar answers to certain questions. For this purpose, the method of analysis of K-means clusters with the Determinant criterion (W) was applied. We investigated the detection of three to five clusters, with random initial partitioning, and the clustering in three groups was selected since it was the easier to interpret. The central objects (Respondents 33, 72 and 3) of each class, along with the answers they gave in each question, are shown in Table 6.

The first class consists of 58 respondents whose answers include only the Algorithmic Thinking (AT), Data Analysis (DA) and Problem Decomposition (PD) dimensions, the most popular and common for all grades. The second class includes the above dimensions and some additional, such as Modeling (MO), Abstraction (AB), etc., and it consists of 55 respondents. The third class includes those who state that all dimensions are equally important (23 respondents). Most of the teachers are members of the first two classes, showing partial recognition of the dimensions and therefore incomplete understanding of the CT concept and its epistemological significance. The percentage of teachers who recognize the basic dimensions (first class) is rather high (~ 42.65%) and this class is the most numerous. Basic summary data about each class of the K-means analysis are presented in Table 7. The profile plot of the answers of each class is graphically represented in Fig. 2.

Table 6

Central objects – answers of the 3 classes

Class	AT	DA	PD	MO	LR	AB	DR	TE	GE	EV	DC	DS	SI	PT	AU	UP	PM	SE	ST	ALL
1 (Obs33)	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 (Obs72)	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
3 (Obs3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 7

Summary of data of the K-means analysis

Class	1	2	3
Objects	58	55	23
Sum of weights	58	55	23
Within-class variance	2.9595	3.5764	0.0000
Minimum distance to centroid	1.1545	1.5068	0.0000
Average distance to centroid	1.6808	1.8614	0.0000
Maximum distance to centroid	2.3463	2.4416	0.0000

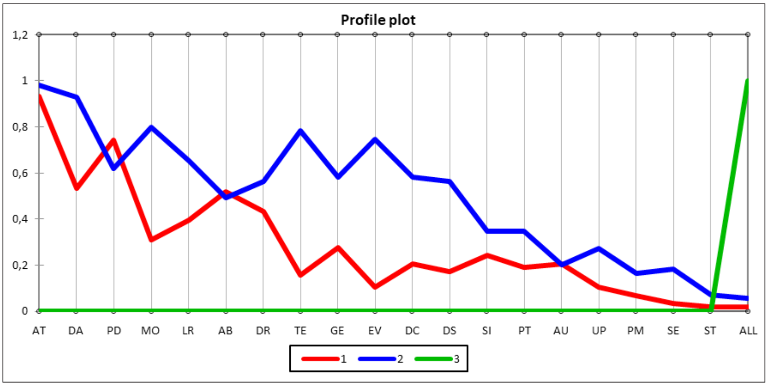

Fig. 2. Profile plot of the answers of the 3 groups.

4.2.2. *Beliefs on CT Practices*

Question Q12. Which of the following do you consider as CT practices? investigates teachers' beliefs on CT practices. Responses presented in Table 8 are important, as they provide information about the characteristics which teachers believe that give a CT orientation in an activity.

Important practices (e.g. Persevering and Tinkering) are left behind by teachers, who tend to select more common ones. Additionally, basic practices, according to "The Great Principles Framework" (Denning, 2009; Denning and Martell, 2015), such as a) Programming, b) Engineering of Systems, c) Modelling and d) Applying, are missing, or not selected in high frequency. However, it is likely that there is no clear understanding of the CT practices, given the misconceptions earlier associated with the concept.

Table 8
Beliefs on CT practices

Q12. Which of the following do you consider as CT practices?	Count	%
Logical Thinking	119	87.50
Algorithms	117	86.03
Analysis	111	81.62
Logic Problem Solving	109	80.15
Critical Thinking	88	64.71
Planning	88	64.71
Coding	85	62.50
Debugging	81	59.56
Creating	76	55.88
Reflecting	65	47.79
Application	62	45.59
Use of Computers	61	44.85
Tinkering	52	38.24
Collaborating	46	33.82
Persevering	33	24.26

Table 9
Application of CT in practice

Q13. Which of the following are examples of application of CT in practice?	Count	%
Find the shortest path from one place to another.	114	83.82
Program a robot to perform an action.	110	80.88
Segmentation of a process in separate and distinct steps to understand computer performance.	108	79.41
Process of resolution of the quadric equation.	93	68.38
Teaching of programming language to create algorithms for the solution of certain problems.	91	66.91
Problem of planning of a trip.	85	62.50
Creation of an automatic control application using a microprocessor.	78	57.35
Search of names in a phone-book.	73	53.68
Execution of a science experiment about electricity.	52	38.24
Study of historical facts and statistical data to research the causes of immigration.	46	33.82
Study of poetry and contrast of poems and lyrics to find similarities.	37	27.21
Teaching of traditional dances.	35	25.74
Creation of a painting.	11	8.09

4.2.3. *Application of CT in Practice*

Teachers' beliefs on the application of CT in practice were investigated through examples proposed in Q13. The participants did not seem to recognize opportunities for interdisciplinarity involving CT, such as e.g. performing physics experiments or literature (Table 9). There is probably a need for preparation and dissemination of indicative examples and the creation of interdisciplinary working groups to improve the situation in the field, a proposal that is also supported by previous relevant research (Fessakis *et al.*, 2018). The search for correlations to demographic factors did not lead to any meaningful correlations.

4.2.4. *General Beliefs on CT*

Table 10 below summarizes the answers in *Q14. Which of the following statements concerning CT are valid?* which detect the general beliefs of teachers about CT. The table shows the frequency in which each Proposal (P1–P17) was mentioned as correct, along with the corresponding percentage on the sample count, in descending order of frequency. Teachers have mixed beliefs, some correct (e.g. P8, P14) and others wrong (e.g. P4, P13, P15).

At this point, it was interesting to search for groupings of beliefs that frequently appear at the same time in the answers of the teachers (or groupings of teachers with the same or similar beliefs). The Determinant (W) criterion was used to analyze clusters of teachers' beliefs. Two classes resulted, as shown in Table 11.

The central observations (Respondents 35 and 94) of each class, along with their answers in the questions, are presented in Table 12.

The first class consists of 81 respondents, who believe that CT lies within the borders of CS and consists a distinct part of it, or identify CT with a certain dimension of it, such

Table 10

General beliefs/perceptions on CT

Q14. Which of the following statements concerning CT are valid?		Count	%
P1	CT is the understanding of how computers work	122	89.71
P2	CT is the use of logical thinking to solve problems	120	88.24
P14	CT is connected to various scientific fields & can be introduced in various disciplines	98	72.06
P3	CT is connected to critical thinking	92	67.65
P5	CT promotes creativity and innovation	88	64.71
P6	CT provides new ways of solving problems	83	61.03
P9	CT concerns the application of CS principles to solve problems in other scientific fields	72	52.94
P7	Emphasizes on knowledge creation rather than simple use of information	69	50.74
P12	Provides ways of dealing with physical, social, etc. phenomena	57	41.91
P4	CT is identical to mathematical thinking	55	40.44
P11	CT includes the use of mathematical calculations to solve problems.	51	37.50
P10	Includes abstraction of general principles and application to other situations	49	36.03
P8	Consists a method of producing knowledge, like the experiment in Science	34	25.00
P13	Is an independent subject, not related to other subjects of the curriculum	11	8.09
P15	Is related only to CS and can be taught only within it	11	8.09
P17	CT can be developed only by students with prior knowledge of CS	3	2.21
P16	CT can be taught only to students with a high level of mathematical knowledge	2	1.47

Table 11

Distribution of answers in 2 classes

Class	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
1	0.85	0.83	0.63	0.04	0.58	0.53	0.46	0.12	0.41	0.36	0.23	0.40	0.07	0.69	0.10	0.01	0.00
2	0.96	0.96	0.75	0.95	0.75	0.73	0.58	0.44	0.71	0.36	0.58	0.45	0.09	0.76	0.05	0.02	0.05

Table 12

Central objects – answers of the 2 classes

Class	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
1 (Obs35)	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
2 (Obs94)	1	1	1	1	1	1	1	0	1	0	1	0	0	1	0	0	0

as programming. The second class contains 55 respondents, those who, in contrast to the first, select more often the P4, P5, P6, P8, P9 and P11 proposals (55/136 persons). Teachers of this class perceive the creative nature of CT and consider it as a tool of knowledge construction in various scientific fields, combined with mathematical techniques. One would say that they link Computer Science to Applied Mathematics. Basic data concerning the K-means analysis are shown in Table 13 and the profile plot of the classes' answers is graphically represented in Fig. 3.

Table 13
Summary of data of the K-means analysis

Class	1	2
Objects	81	55
Sum of weights	81	55
Within-class variance	2.6932	2.5481
Minimum distance to centroid	1.1943	1.1152
Average distance to centroid	1.6137	1.5621
Maximum distance to centroid	2.3268	2.1080

Fig. 3. Profile plot of the answers of the 2 groups.

4.3. *CS Teachers' Attitudes Towards CT*

To investigate CS teachers' general attitudes towards CT, we used a series of Likert type questions which are presented in Table 14, along with the corresponding distribution and

Table 14
Teachers' attitudes on CT

CS teachers' attitudes towards CT	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
CT is a competence that all students should develop	0 (0.00%)	0 (0.00%)	4 (2.94%)	30 (22.06%)	102 (75.00%)
I am interested in integrating CT in my teaching	1 (0.74%)	0 (0.00%)	6 (4.41%)	33 (24.26%)	96 (70.59%)
I can integrate CT in my teaching	1 (0.74%)	1 (0.74%)	33 (24.26%)	37 (27.21%)	64 (47.06%)
I would like to attend training about teaching practices of integrating CT in my teaching subject	5 (3.68%)	5 (3.68%)	16 (11.76%)	39 (28.68%)	71 (52.21%)

percentages of the answers. Positive attitudes are expected to increase the possibility of the teachers' engagement in efforts of integrating CT in education, as well as the possibility of their future teaching CT in their classes. A 5-point Likert scale was used to rank the answers, with values from *1-Strongly Disagree* to *5-Strongly Agree*. The Cronbach's alpha coefficient for the questions of Table 4 is 0,64 which is considered acceptable value for internal consistency – reliability of the answers.

4.3.1. *Feasibility of Integration*

Concerning the *usefulness-purposefulness of CTs' integration in education*, great majority of participants believes that CT is a competence that all students should develop, answering "agree", or "strongly agree", to the relevant question (132/136; ~97.6%). The X^2 goodness-of-fit test ($\mu = 4.72$, $\sigma = 0.51$) resulted that the distribution of the answers significantly differs from the normal [$X^2(2, N = 136) = 17.97$, $p < 0.05$], with the number of teachers who answered 4 or 5 being bigger than expected.

4.3.2. *Interest in Integration*

CS teachers' *interest in integrating CT in their teaching* was also examined, with majority of the participants declaring their interest (129/136; ~94.85%), although the X^2 goodness-of-fit test ($\mu = 4.72$, $\sigma = 0.51$) resulted that the distribution of answers also differs from the normal [$X^2(2, N = 136) = 1398.14$, $p < 0.05$], since many more than expected teachers answered 5 to the relevant question.

These two findings support the assumption that the participants are persons with a rather increased interest in CT and have a pre-existing positive attitude towards it.

4.3.3. *Ease of Integration*

Investigating the *perceived ease of integration*, answers to the relevant question show that high percentage of participants believe that they can integrate CT in their teaching (101/136; ~74.27%), while some (33/136; ~24.26%) seem uncertain and only 2/136 (~1.48%) disagree. There is also a significant difference from the normal distribution, confirmed by the X^2 test ($\mu = 4.19$, $\sigma = 0.88$), [$X^2(2, N = 136) = 22.0265$, $p < 0.05$].

4.3.4. *Intention to Attend Training*

The participants' *intention to attend proper training* was also examined. Most of the participants clearly stated their intention to attend training on teaching methods of integrating CT in their school subject (110/136; ~80.89%), while 16/136 (~11.76%) were uncertain and 10/136; (~7.36%) did not wish to attend training. The X^2 test ($\mu = 4.22$, $\sigma = 1.03$) resulted a significant difference from the normal distribution [$X^2(2, N = 136) = 42.4765$, $p < 0.05$], with more than expected teachers answering 4 or 5.

To investigate the profile of participants who wish to attend relevant training on CT or not, the K-means clustering method with the Determinant (W) criterion was applied and three clusters resulted, dividing teachers into three groups, according to their answers. The central objects of each class (Respondents 15, 29 and 21), along with the answers they gave in each question, are shown in Table 15.

Table 15
Central objects – answers of the 3 classes

Class	Q21. I am interested in CT	Q24. I wish to attend training	Q26. My existing knowledge is sufficient
1 (Obs15)	5.0000	5.0000	4.0000
2 (Obs29)	5.0000	5.0000	3.0000
3 (Obs21)	5.0000	2.0000	4.0000

Table 16
Summary of data of the K-means analysis

Class	1	2	3
Objects	72	40	24
Sum of weights	72	40	24
Within-class variance	1.8120	2.0936	2.9221
Minimum distance to centroid	0.9885	1.0530	0.9957
Average distance to centroid	1.3175	1.3924	1.5717
Maximum distance to centroid	2.0356	2.1815	3.9147

The first class consists of 72 respondents who gave positive answers to Questions Q21, Q24 and Q26 and therefore are interested in CTs' integration in their teaching and wish to attend training, while they believe that their prior existing knowledge is almost sufficient. The second class consists of 40 participants who are interested in CTs' integration in education, they wish to attend training, though they are not sure about their prior knowledge adequacy. In the third class there are 24 participants who are interested in CTs' integration in their teaching, they do not wish to attend training, and believe that their prior existing knowledge may be enough. Table 16 presents general data about the K-means analysis.

4.3.5. *Attitudes Towards CS Competitions*

Using Q27–Q30 we investigated teachers' attitudes towards CS competitions. Most of the teachers participate with groups of their students in the "Hour of Code" (102; 75.00%), but also most of them have never participated in a robotics competition (107; 78.68%) (World Robot Olympiad Hellas organizes regional and national robotics competitions for schools yearly). This fact can probably be explained by the great organizational effort and the certain equipment needed for the participation in robotics competitions. Most of the teachers believe that participating in such events can assist the development of CT (95; 69.85%), while 110/136 (80.88%) stated willing to motivate students to participate in a competition related to CT. Answers are presented in Table 17.

Table 17
Attitudes towards CS competitions

Teachers' attitudes towards CS competitions	Answer	Count	%
Have you ever participated with groups of students in a robotics competition?	Yes	29	21.32
	No	107	78.68
Do you participate with your students in the "Hour of Code"?	Yes	102	75.00
	No	34	25.00
In your opinion, does participation in relevant competitions help the development of CT?	Yes	95	69.85
	Maybe	34	25.00
	No	7	05.15
Would you motivate your students to participate in a CT relevant competition?	Yes	110	80.88
	Maybe	23	16.91
	No	3	02.21

4.4. *Integration of CT in Education*

The successful integration of CT in education requires appropriate planning, after the relevant factors have been investigated. In this section we study teachers' beliefs on CTs' integration in education and the role it can play on students' development. Participants were asked to express their beliefs on the teachers considered most appropriate to teach CT and the levels of education at which this should happen. They were also asked to propose teaching approaches, tools, environments and materials that could be used to integrate CT in education, as well as teaching subjects in which it could be integrated. Finally, potential methods of assessment were investigated.

4.4.1. *Who Can Teach CT*

Question *Q09. Who can teach CT?* was used to investigate participants beliefs on the persons who should teach CT. According to the answers, most participants believe that every teacher could teach CT after proper training (78/136; ~57.35%), while few (16/136; ~11.76%) believe that everyone can teach CT regardless of prior training. The matter was approached in a rather "self-seeking" way by 42 participants, who answered that only CS teachers can teach CT (42/136; ~30.88%). The X^2 test of independence showed not statistically important correlations between answers in the question and demographic factors. The frequencies and percentages of the answers are presented in Table 18.

Table 18
Who can teach CT

Q09. Who can teach CT?	Count	%
CS teachers, as well as other subjects' teachers after attending proper training	78	57.35
Only CS teachers can teach CT	42	30.88
All subjects' teachers, regardless of the CS knowledge they possess	16	11.76
Sum	**136**	**100**

4.4.2. *Self-efficacy on Teaching CT*

The X^2 test ($\mu = 3.98$, $\sigma = 0.91$) resulted a marginally important difference from the normal distribution on *teachers' self-efficacy on CT* [$X^2(2, N = 136) = 6.0599$, $p = 0.0483 < 0.05$]. Most of the teachers felt confident enough to teach CT (94/136; ~69.11%), some were uncertain (36/136; ~26.47%), and few didn't feel confident (6/136; ~4.42%). The teachers' answers revealed a generally increased self-efficacy, although they previously stated their intention to attend relevant training.

4.4.3. *Necessity of Certain Infrastructure*

Teachers' beliefs concerning the necessity of existence of certain infrastructure for the teaching of CT were examined, and their answers to the relevant questions are presented in Table 19. According to them, only 22/136 (16,17%) seem to disconnect CT from certain equipment, while 79/136 (58,09%) clearly state that certain equipment is needed. A number of 35/136 (25,74%) cannot decide if they need equipment or not. Those who disagree probably believe that CT can be taught using the existing infrastructure (e.g. school PC labs) and/or through experiential and/or unplugged activities. The X^2 test ($\mu = 3.64$, $\sigma = 1.24$) resulted that answers in Q25 significantly differ from the normal distribution [$X^2(2, N = 136) = 19.2379$, $p < 0.05$], with more than expected teachers answering 1 or 5.

4.4.4. *Role of CT in Education*

Concerning the role of CT in education, answers vary in content and frequency. Participants seem to have mainly positive and correct beliefs concerning CTs' role, however stereotypes are not absent, such as the claim that CT can improve the performance only of students who prefer the Science branch of studies. Most teachers acknowledge CTs' role on the enhancement of students' problem-solving ability and concern it a basic skill that all students should acquire. Frequency and percentage of answers are presented in Table 20.

Searching for groups of teachers with similar views on CTs' role in education, we applied the K-means clustering method with the Determinant (W) criterion for two to five groups and random initial partitioning. The most interpretable results concerned the case of three groups. Table 21 presents the centers of the three classes, while Table 22 presents the central observations (Respondents 13, 2 and 3) of each class, along with their answers to each question.

Table 19

Beliefs on the necessity of infrastructure

Necessity of infrastructure	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
My prior knowledge in CS is sufficient for my teaching CT	1 (0.74%)	5 (3.68%)	36 (26.47%)	48 (35.29%)	46 (33.82%)
To integrate CT in my teaching, there is a need for certain infrastructure / equipment	12 (8.82%)	10 (7.35%)	35 (25.74%)	37 (27.21%)	42 (30.88%)

Table 20

Role of CT in education

Q10. What is the role of CT in education?		Count	%
P3	Enhances the students' ability of problem solving	120	88.24
P1	Is a basic skill that all students should acquire	116	85.29
P6	Enhances the preparation of CS professionals	48	35.29
P5	Helps student think like a computer scientist	44	31.62
P4	Can improve the performance only of students in the Science area of studies	27	19.85
P2	Is an additional skill that is not necessary for all students to develop	14	10.29
P7	Concerns only those students who intend to pursue studies and career in the Science fields	4	2.94
P8	CTs' integration in education is not necessary	3	2.21

Table 21

Distribution of answers in the 3 classes

Class	P1	P2	P3	P4	P5	P6	P7	P8
1	0.86	0.12	0.98	0.26	1.00	0.70	0.09	0.05
2	0.57	0.35	0.83	0.70	0.00	0.17	0.00	0.04
3	0.94	0.01	0.84	0.00	0.00	0.20	0.00	0.00

Table 22

Centroids of the 3 classes

Class	P1	P2	P3	P4	P5	P6	P7	P8
1 (Obs13)	1	0	1	0	1	1	0	0
2 (Obs2)	1	0	1	1	0	0	0	0
3 (Obs3)	1	0	1	0	0	0	0	0

Table 23

Summary of data of the K-means analysis

Class	**1**	**2**	**3**
Objects	43	23	70
Sum of weights	43	23	70
Within-class variance	0.7940	1.0593	0.3656
Minimum distance to centroid	0.4485	0.6819	0.2611
Average distance to centroid	0.8029	0.9606	0.5195
Maximum distance to centroid	1.7827	1.4846	1.0196

Basic data on the K-means analysis are shown in Table 23 and the profile plot of the classes' answers is graphically represented in Fig. 4.

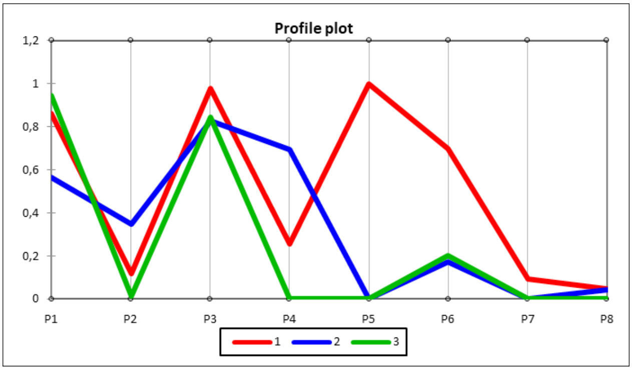

Fig. 4. Profile plot of the 3 classes of answers.

The first class (in red) consists of 43 members with the most positive and correct beliefs on the role of CT in education. Teachers in this class usually select P1 and P3 (the most popular beliefs on CT – *it concerns all students because it enhances their ability of problem solving*), as well as P5 and P6 which are also correct. The second class (in blue) consists of 23 members who more often select P2 and P4. Most teachers in this class believe that CT does not concern all students but mainly those who wish to pursue studies and career in the Science field. The third class (in green) consists of 70 people who select P1, P3 and P6. These statements consist positive opinions on the role of CT in education and are the three most popular ones. The difference between the third and the first class is that members of the first class have more complex and sophisticated views, as they select more statements to express themselves.

4.4.5. *Education Level of CT Integration*

Regarding the level of education in which CT should be integrated, participants seem to acknowledge secondary education as the most appropriate, while Kindergarten gathers the smallest number of answers (26/136; ~19.12%). This may be partially explained by the fact that CS teachers do not teach in Kindergarten and so they miss contact with that grade of education. Meanwhile, in global literature, the purposefulness of CTs' integration in pre-school education is increasingly emphasized. Table 24 presents the frequency and percentage of the answers.

Table 24

Grade of integration

Q15. Integration and teaching of CT in education:	Count	%
In Kindergarten (Pre-K)	26	19.12
In Primary School (K1-K6)	97	71.32
In Lower High School (K7-K9)	124	91.18
In Upper High School (K10-K12)	119	87.50
In Tertiary Education	86	63.24

4.4.6. *Teaching Approaches of CT*

Various teaching methods and approaches were proposed for the integration of CT in education and Table 25 summarizes the participants' answers. Teachers who answered the relevant question mention general and progressive approaches, such as Problem-Based Learning (PBL), Game-Based Learning (GBL) and Inquiry Learning (INQL). However, not sufficient information can be deduced from the answers. It is possible that answers are the teachers' preferences on teaching approaches in general, rather than on CT specifically. Given the misunderstandings detected, we believe that answers in this question mostly represent the teachers' general views on the CS subject, rather than on CT specifically.

Investigating the statistically significant correlations to demographic factors, some interesting results came up. Women more often select Role Playing Games (RPG) [$X^2(1, N = 136) = 5.2134$, $p = 0.0224 < 0.5$], and much less often select Lecture (LEC) [$X^2(1, N = 136) = 4.0069$, $p = 0.0453 < 0.5$]. Role Playing Games (RPG) are also more often selected by those who hold a University CS degree [$X^2(1, N = 136) = 6.0587$, $p = 0.0138 < 0.5$] and those who serve in primary education [$X^2(3, N = 136) = 11.2609$, $p = 0.0104 < 0.5$]. Project-Based Learning (PrjBL) is much more often selected by younger teachers (aged 31–40) and much less often by older ones (aged 41–50) [$X^2(2, N = 136) = 13.5337$, $p = 0.0012 < 0.5$].

4.4.7. *Tools, Environments and Materials to Integrate CT*

Similar results came up regarding the tools and activities that could be used for CTs' integration in education. Teachers were asked *Q17. What types of activities – digital tools can be used to teach CT in class?* and the distribution of their answers is presented in Table 26.

The method of Experiment, for example, is rather under-represented, perhaps because teachers have not connected CT to its epistemological use in other disciplines. Teachers' proposals (selection *Other*) were very few, but quite interesting. The search for statistically significant correlations between answers in this question and demo-

Table 25

Teaching approaches

Q16. Which teaching approaches can be used to teach CT?		Count	%
PBL	Problem-Based Learning	127	93.38
GBL	Game-Based Learning	117	86.03
INQL	Inquiry Learning	101	74.26
PrjBL	Project-Based Learning	88	64.71
RPG	Role Playing Games	58	42.65
LEC	Lecture	20	14.71
FT	Front Teaching	19	13.97
ROB	Other – Robotics	1	0.74
LIT	Other – Creation of Literature texts summaries	1	0.74
CaS	Other – Case study	1	0.74

Table 26

Activities – tools to teach CT

Q17. What types of activities – digital tools can be used to teach CT in class?		Count	%
CODE	Coding	115	84.56
ROB	Robotics kits	114	83.82
SCR	Scratch / ScratchJr	109	80.15
APPIn	App Inventor	88	64.71
SG	Serious Games – Educational digital games	87	63.97
PYT	Python	86	63.24
ARD	Arduino / Raspberry pi	85	62.50
UNPL	Unplugged activities	79	58.09
SIM	Simulation tools	68	50.00
MW	Educational microworlds	64	47.06
JAV	Java	61	44.85
EXPO	Experiment – Observation	55	40.44
SPRS	Spreadsheets	24	17.65
MULT	Multimedia applications	17	12.50
WWWB	WWW Browser	15	11.03
OFFA	Office Applications	10	7.35
ARAN	Other – Arithmetic Analysis	1	0.74
Fortran	Other – Fortran	1	0.74
ML	Other – Machine Learning	1	0.74
Prolog	Other – Prolog	1	0.74
micro: bit	Other – micro: bit	1	0.74

graphic factors resulted in some interesting findings. Women more often select Microworlds (MW) [$X^2(1, N = 136) = 5.5399, p = 0.0186 < 0.5$]. Teachers with a Technological Institution degree more often select the use of WWW Browser (WWWB) [$X^2(1, N = 136) = 4.3040, p = 0.0380 < 0.5$] and Arduino/Raspberry pi (ARD) [$X^2(1, N = 136) = 4.3040, p = 0.0380 < 0.5$], a finding considered important since physical computing environments can ease the development of CT. Finally, teachers who serve in secondary education less often select the use of a WWW Browser (WWWB) [$X^2(3, N = 136) = 14.46, p = 0.0023 < 0.5$].

4.4.8. *School Subjects to Integrate CT*

Teachers were asked about the school subjects in which they believe that CT could be integrated, and their answers (Table 27) show a preference in the STEM disciplines, rather than social sciences and theoretical subjects. However, of great importance is the fact that they acknowledge the importance of an interdisciplinary and thematic approach for the integration of CT in education curricula. Similarly, important is the number of 29/136 respondents (~21.32%) who answered that CT can be integrated in every school subject.

Investigating possible correlations to demographic factors, we found that women less often select History (HIST) [$X^2(1, N = 136) = 4.2439, p = 0.0394 < 0.5$], while they

Table 27

Integration in Scientific fields

Q18. In which of the above scientific fields can CT be integrated?		Count	%
MAT	Mathematics	100	73.53
SCI	Science	95	69.85
TEC	Technology	87	63.97
ALG	Algebra	78	57.35
INTERD	Interdisciplinary	70	51.47
THEMA	Thematic	64	47.06
GEOM	Geometry	56	41.18
LIFE-SCI	Life Sciences – Biology	40	29.41
LANG	Language	26	19.12
SOC	Social Sciences	24	17.65
HIST	History	23	16.91
ART	Art	20	14.71
GEOG	Geography	16	11.76
PHI	Philosophy	15	11.03
NUTR	Nutrition	13	9.56
DANCE	Dance	11	8.09
PHED	Physical Education	7	5.15
LIT	Literature	6	4.41
ALL	All the above	29	21.32

more often select Thematic (THEMA) [$X^2(1, N = 136) = 4.0351, p = 0.0446 < 0.5$] and All the above (ALL) [$X^2(1, N = 136) = 4.0361, p = 0.0445 < 0.5$]. Teachers who work in primary education do not select Art (ART) at all, a quite impressing fact since art is considered a STEAM discipline, where CT is an important dimension.

4.4.9. *Assessment of CT*

Concerning the teachers' beliefs on the assessment of CT, Table 28 summarizes their answers to the relevant question. Answers vary from correct (e.g. P3, P7, P8, P9) to more conventional and restrictive (e.g. P1, P4, P5). The matter of CTs' assessment remains open, along with the matter of its clarification and any progress on the conceptual understanding of CT is expected to improve the views on the methods of its educational assessment. Discussion on CTs' assessment is important, as it will be a key measure of success of any attempt to integrate CT in education.

Investigating statistically significant correlations to demographic factors, holders of Technological Institutions degrees more often select P2 and seem to adopt a constructionism approach more often than others, probably because of the assessment methods followed during their studies. Furthermore, women less often select P7 and thus seem to not seriously link evaluation to the Curriculum. There is a chance that many of them teach in primary schools, where there is no clear Curriculum and strong adherence to it.

Table 28

Assessment of CT

Q19.	How can assessment of CT be implemented?	Count	%
P6	Students developed behaviors (practices) to solve a problem	108	79.41
P4	Through problem solving exercises with predefined steps	86	63.24
P1	Students acquired specific skills (e.g. learned coding)	81	59.56
P2	Students created an artifact	61	44.85
P3	Through the assessment of the personal students' portfolio	51	37.50
P8	Comparing the knowledge and skill of students with predefined scaled performance descriptions	40	29.41
P7	Students can interpret the CT curriculum concepts	23	16.91
P5	Through written assessment (tests, exams)	21	15.44
P9	Other – Application of knowledge	2	1.47
P9	Other – Originality of the solution	1	0.74

5. Answers to the Research Questions

The purpose of the research was the investigation of Greek CS teachers' perceptions, beliefs and attitudes on CT and its integration in education. After the collection and processing of the data provided, useful conclusions resulted, which can be summarized as answers to the research questions, as follows.

RQ1. What are the CS teachers' perceptions on CT?

Teachers seem to perceive CT as a problem-solving method, mainly coinciding it to Algorithmic Thinking, or connecting it to ways of thinking for the solution of a problem, either with the use of a computer, or not. Misconceptions on CT mainly concern the concepts' confusion with a certain dimension of it (mainly computer programming or analytic ability), or with other skills such as numerical capability and digital age skills. CTs' value as an epistemological method is not detected in satisfactory extent. Concerning the relation between CT and CS, misconceptions also occur, as most teachers mistakenly consider CS as a subset of CT and only ¼ of them perceive that CT and CS 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.

RQ2. What are the CS teachers' general beliefs concerning CT?

Concerning their general beliefs on CT, teachers are divided in two major groups: those who consider CT as a creative, epistemological competence which is exploiting Mathematics and Computer Science in various fields of Science and often identify CT with the Mathematics Science, and those who detect CT within the boundaries of Computer Science, as a distinct entity, or identify it with some of its individual dimensions.

Regarding CTs' dimensions and practices, teachers are generally divided in 3 groups: those who acknowledge that all CT dimensions are equally important, those who acknowledge three dimensions as the most important (Modeling-MO, Generalization-GE and Abstraction-AB), and those who acknowledge the three most important dimensions plus some extra ones. Out of CT practices, the most frequently selected are Logical Thinking, Algorithms and Analysis.

RQ3. What are the CS teachers' general attitudes towards CT?

Teachers seem to have a positive attitude towards CT and its integration in education, albeit they are somehow divided concerning the adequacy of their prior knowledge and express a desire to attend relevant training. They state willing to encourage their students to participate in a CT relevant contest, especially if it did not require the existence of sophisticated and/or expensive technological infrastructure. However, a small percentage appears to be negatively oriented to the integration of CT in education and the reasons need to be further investigated.

RQ4. What are the teachers' beliefs on the integration of CT in education?

Teachers' beliefs on CTs' integration in education were positive and progressive. In their opinion, CT seems to concern all students as enhancing their problem-solving ability and its integration is proposed to take place in secondary education. To teach CT, modern progressive approaches of learning and a variety of tools and methods were proposed, however without recognizing its epistemological use in other disciplines. The STEM subjects were preferred, but the interdisciplinary and thematic approach of the concept was also acknowledged. The variety of the proposed assessment methods strengthens the prevailing ambiguity on the concept.

6. Summary and Conclusions

The research conducted was an attempt to contribute to the designation of the current state regarding the placement of CT in education. The investigation of the perceptions, attitudes and beliefs of CS teachers who teach in Greek schools, is a prerequisite for any initiative to integrate the concept in basic education. For the successful integration of CT in the classroom curriculum, teachers need to have clarified the practices and dimensions of the term and have acquired the appropriate knowledge on the Didactics of its content. The importance of this stage of preparation has been acknowledged in relevant literature and is perhaps of even greater importance than the creation of corresponding educational material (Cuny, 2011). The investigation of teachers' perceptions, attitudes and beliefs concerning CT revealed groupings of similar CS teachers' beliefs and misconceptions on the term. These groupings can be used to guide effective teachers' preparation procedures or professional development programs, since the misconceptions and beliefs pointed out in these groups can consist points of interest in the teachers' training programs, aiming to help them clarify the term.

The samples' teachers did not acknowledge the epistemological nature of CT and rather limited it, or identified it, with some dimension of it. However, they recognized the interdisciplinary and thematic nature of CT and this fact is positively evaluated. The question that remains open is whether CT will be integrated in education as a discrete teaching subject or through its integration in other teaching subjects. Since quite few teachers mistakenly identified CT to some of its dimensions (mostly reduced CT to Algorithmic problem solving), what is evident is the need for them to clarify the "Interdisciplinary Computing Science" nature of CT. To support this need, serious training and support needs to be planned for teachers, so that they can properly and effectively serve the integration of CT in education. Teachers should clarify that CT concerns the use of computation to produce knowledge in any field and the misconceptions detected through our research could contribute basic axes around which proper training programs could be designed.

The attitudes recorded were generally positive and optimistic, with few reservations and resistance from a small percentage of participants. Teachers have positive intention on attending CT-relevant training, despite the high self-efficacy they present due to their degree studies. This finding can be quite useful for the effective organization and conduction of relevant training programs. Such programs should focus on the disambiguation of the term and the distinction between CT and Mathematics, between CT and CS, or between CT and a certain dimension of it. Further attention should be given to the dimensions and practices of CT, since many of the participants failed to identify the importance of basic CT dimensions, while the practices proposed were insufficient. A successful training program should focus on the fact that the various CT dimensions and practices are equally important and should be addressed spherically and thematically for the successful integration of CT in education.

After the several misunderstandings and misconceptions of the teachers have been recorded, a more focused and appropriate training can be planned. Additionally, findings can be considered compatible with the TAM, since CS teachers appear to be familiar with the CT concept and acknowledge its great importance in education, and in parallel state their intention to integrate it in their teaching and attend relevant training, supporting the view that the perceived ease of use and perceived usefulness of technology can affect the adoption of a certain behavior. Participants themselves proposed a wide variety of learning approaches, tools and methods to teach CT, mainly in STEM subjects. What needs to be further emphasized, while designing training programs, is the interdisciplinary nature of CT and its valuable use as an epistemological tool in other disciplines. Since CS teachers currently serving in primary and secondary education stated willing to support the integration of CT in education, what they need is appropriate support so that they can bring CT in class. Special workshops can be organized for groups of teachers, so that they can be shown how to teach CT in a practical and experiential way. Proper educational material (learning designs and activities corresponding to certain age groups) could also be developed and provided to the teachers, for class use. Student festivals and workshops can also be organized, where students, along with their teachers, can be invited to participate with their works and artifacts that integrate CT. Mostly, participation in international initiatives concerning CT, such as the Bebras – International Challenge on Informatics and Computational Thinking should be encouraged and promoted.

The constraints of the survey include the occasional character of the sample and the identified increased interest of the participants on CT. The sample teachers presented increased interest on CT, while the CS knowledge resulting from their degree studies, as well as the high correlation between CT and CS, may have affected some of the given responses. Furthermore, the certain conditions (voluntary participation) of the research conduction limit the potential of generalizing the results.

What we propose is the extension of the survey on teachers of all subjects and levels of education, with certain focus in pre-school education, which was not represented in our research. Moreover, the potential of CT development from a pre-school age and its pedagogical value have already been documented in prior research (Fessakis *et al.*, 2013). The findings concern active CS teachers in Greece and generally align to those of relevant previous research (Ling *et al.*, 2017; Corradini *et al.*, 2017; Yadav *et al.*, 2017). Using the framework of a complex conceptual model of CT, with multiple dimensions and practices, combined with the TAM model, our research revealed several misconceptions that CS teachers present. The findings lead the researchers to significant remarks on the current state concerning CS teachers and CT, and the conclusions resulted, along with the proposed directions for the treatment of the misconceptions, could be creatively used for the design and planning of proper training and initiatives for the cultivation of CT and its integration in the Greek education system, with the potential of expansion in other countries' education systems too. Our research could also constitute the basis for comparative research among different countries, or among teachers of different subjects, in the wider context of research on CT and its educational potential.

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