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On the Future of Computational Thinking Education: Moving beyond the Digital Agenda, a Discourse Analysis Perspective

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Abstract: This article explores the development directions of the phenomenon of Computational Thinking (CT) from the perspectives of discourse analysis. The motivation is based on the understanding of CT as an advanced educational approach, methodology, and community, aimed at a set of learners' digital and further competences having a huge impact on modern education and society. The novelty of this study lies in the attempt to look holistically at CT and its perspectives, considering it as an evolving phenomenon per se, leaving aside discussion on its internal characteristics or applications. The study utilizes a comprehensive analysis, applying discourse analysis and social semiotics methods. The results present the most trended storylines associated with CT and its context, providing a thorough introduction to the CT discursive landscape. The findings and discussion present a reflective insight into the discursive landscape directions, focusing on meaning-makers and their identities, the transformative and transductive potential of CT, observing the phenomenon's development paths from a metaphorical perspective and positioning it towards the development of the socio-technical networks it mediates. In the conclusion, the options for development and possible trends in the reconstitution of the CT phenomenon are outlined.

Keywords: Computational Thinking; STEM education; maker culture; sustainability issues; discourse analysis; STS; science and technology studies; futures studies

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1. Introduction

The aim of this study is to analyze the developmental tendencies of the phenomenon of Computational Thinking (CT). CT is an advanced educational approach, methodology, and community, aiming at a set of learners' digital and further competences. Historically inspired by advances in computer science (CS) and related developments in the CS education, CT has been positioning itself as a solution to a number of emerging post-industrial challenges that have a major impact on CS education and, in particular, Science, Technology, Engineering and Mathematics (STEM) education, as STEM is widely influenced by digital technology and computational methods. At the same time, CT lays the foundations for the Maker culture in terms of its empowerment and further development. In all these positions, the phenomenon of CT is an important player in the educational landscape, extending its influence widely to almost all levels of education, e.g., early development, primary, secondary and undergraduate education. In this context, the question of the perspectives of CT in a broader sense of its understanding seems interesting and important both to the CT community itself, as well as for the wider educational community, educational stakeholders, and the general public involved. However, the topic is quite complex, as it joins technical, social, and human aspects into a single whole. Thus, to understand the perspectives, the task of the researcher is to thoroughly explore all facets and aspects of the phenomenon and its discourse.

In the study of CT, scholars have focused on refining definitions of CT, e.g., Román-González et al. [1] have distinguished three types of definitions of CT: (1) generic definitions that focus on CT as a thought process, as it was originally introduced by Wing [2];

(2) operational or model definitions that describe what CT entails, based on five fundamental elements introduced by Selby and Woollard [3]; and (3) educational and curricular definitions derived from different frameworks. From the perspective of definition-based approaches, CT can be understood as a way of thinking, used for developing solutions in a form that ultimately enables the execution of those solutions. The executor—a computational agent (i.e., computer or robot)—must ensure that results are achieved by executing them automatically. According to Román-González and Robles [4], CT is defined as a kind of thinking skill that could be transferred and applied in the process of solving real-world and significant problems. Thinking computationally refers to the ability to effectively approach and solve problems based on computer science principles and methods [5]. Whichever viewpoint one holds regarding the definition of CT, it is important to be pragmatic in developing the best ways to teach it.

The Maker Movement [6] is an example of an evolving societal institution that incorporates various forms of activity based on a collaborative involvement in the production of artifacts that have a certain amount of value. It is these kind of values (implicit and explicit), considered from a variety of personal (even non-human) and societal perspectives, that "make" makers the important players in the educational landscape. As an example, the contemporary FabLab educational environment is an integral part of the Maker Movement [7–9], based and focused on developing a range of advanced competences, including a set of digital competences [10], coinciding with the directions and aims of the Education 4.0 agenda [11]. Considering this background, a natural link between CT education and the Maker Movement can be noted [12,13], thus arguing that the future of the former and the practice of its development can influence the practices and trends of the latter. At the same time, focusing only on the "computational" aspects of contemporary makers could result in a distorted picture of the future, as numerous social issues [14–17] are just as or even more important to consider and explore. All this makes it interesting to explore the "anti-digital" perspective of makers, going beyond the already established CT–computational making trend [18], by exploring other, namely "non-digital" perspectives on CT education, and computational making.

In terms of environmental issues, CT and the Maker Movement contribute noticeably to economic, social, and environmental sustainability [19–21]. The Maker Movement, beginning as a socially oriented and community-based bottom-up initiative, is today also influencing leading industries "through increased efficiencies, distributed local production and the circular economy" [20]. All of this, supported by digital advances and new approaches such as long-tail marketing [22] and redistributed manufacturing, makes the environment more resilient "to future megatrends such as climate change and globalization of supply networks" [23]. At the same time, CT can be positioned as a prerequisite for a professional discourse on sustainability [21], linking CT and the Maker Movement to educational and practical work on ecology and the impact of technology on the environment.

In general, the main problem while studying CT and its educational realm is the apparent controversy between two (at the least) practical attitudes, where the first one is focused on the operational aspects and the second on the developmental aspects [24–26]. This is a fundamental watershed, and we argue that it is based on fundamental differences in worldviews and approaches to the aims and objectives of education. However, in today's complex and contradictory world, any state of stability is in itself fragile and unstable. Therefore, we would like to understand tendencies and draw perspectives, and CT is no exception. We ask the question: what are the prospects of the CT phenomenon?

The means of expressing the meanings of CT are certainly multimodal in nature. In our study we employ discourse analysis, focusing on its multimodal aspects and issues of social semiotics [27,28]. "Recognizing the agency of the sign maker and their (implicit and explicit) intentionality" [27] is the primary focus of our study. In general, we consider CT as a kind of an emerging semiotic phenomenon, a "motivated sign" [27] that expresses, usually consciously or unconsciously, the implicit interest of the resource maker. Namely, such interests provide politically motivated conditions for the future transformations we

intend to explore. At the same time, when considering futures, we focus on the epistemic, semiotic, and sociocultural aspects of the development of the phenomenon.

The research question we are going to explore is as follows: What, if any, are the possible trends of "reconstitution" of the CT? Will it remain in its present format, or will it evolve, and what are the possible directions of such evolution? Certainly, any phenomenon is situated in context. Obviously, the evolution or changes in the context affect its embedding as well. The problem is how to relate such contextual changes and their trends to the changes and trends of the embedded entity under study. In exploring this issue, if one aims to develop and simulate a comprehensive theoretically-based model, many interdisciplinary details would need to be covered, which is unlikely to be conceivable in practice. At the same time, such a model would be in any case a biased one, as it would be based on a set of methods and attitudes of the developer. In contrast, the study of the discourse of the phenomena would provide a field that encompasses both the phenomenon being studied and its context. The phenomena and the context will be intertwined in the discourse; therefore, the aim of such a study is not analytical, but merely descriptive, based on the methods and approaches of discourse analysis and futures studies.

We will discuss the research methods in detail later in the text, but what is observable by studying the available discourse is the ongoing and persistent dynamics in the development of the CT phenomenon. This includes a spectrum of alternatives and variations and provides an opportunity to identify possible trends in the constitution of the phenomenon. It is this "discursive" contingency that provides an opportunity to explore future possibilities and implement a combination of discursive analysis and futures studies as a research methodology.

The paper is structured as follows. The "Background on the methodology" section follows the "Introduction" section with a theoretical discussion on the methodology we implemented for the study. It includes a subsection titled "Utilizing critical analysis perspective" that discusses critical points related to discourse analysis, Science and Technology Studies (STS) and futures studies. We consider critical-political issues to be important for the exploration of agentive relations in such a complex socio-technical domain as CT. In the subsection "More on discourse analysis perspectives", we discuss the role of contingency in the discourse landscape, designing a set of sources for discourse analysis associated with a kind of "non-systemic" narrative. The final subsection of this section, entitled "Utilizing futures studies perspective", discusses the incorporation of the futures studies principles into our research framework.

The next section, "Materials and Methods", provides information on the implementation of the methodology, including examples of data sources and indicators for sampling principles, as well as the stages of research implementation and data analysis. The subsequent section, "Results: narratives and storylines" presents a brief content summary of the selected narratives related to the CT theme. This provides an insight into the sampled non-systemic landscape of CT, presented in the order they are ranked by search engines, without any intention of providing a systematic order or classification of any kind.

The "Findings and discussion" section examines CT development trends based on controversies and clashes identified in the analysis of the collected data. Its subsection "CT in terms of semiotics" examines semiotic perspectives, following a multimodal social semiotic agenda, viewing CT as a kind of agentive semiotic transformer that transforms and transducers the CT related statements into the same or other forms of semiotic expression. The next subsection "CT as cognitive transducer" examines further semiotic transformations, positioning CT as a kind of semiotic transducer with respect to its "cognitive" aspirations. The subsection "CT identity from the perspectives of semiotics" discusses the mediating role of CT in the development of a new type of virtual identity, namely, the identity of the "computational" thinker. The subsection "CT from a metaphorical perspective" considers an important point related to futures studies; metaphorical aspects can be considered as important driving forces of the constitutive development of the phenomenon under study. The final subsection of this section, entitled "CT from the STS perspectives and

uncovering the driving controversies", attempts to position CT as a mediating agent for a new overarching socio-technical network motivated by power relations and educational policy agendas. The "Conclusions" section presents concluding statements.

2. Background on the Methodology

2.1. Utilizing Critical Analysis Perspective

The study is primarily based on discourse analysis. By discourse we understand narratives and other non-academic content, e.g., publicly available web resources. Based on a number of methodologies, discourse analysis provides a comprehensive approach to identify all the "hidden" intensities of the phenomenon under study. The following points should be clarified.

The meaning of discourse in relation to education, especially its definition and understanding by scholars, is somewhat blurred [29]. On the one hand, this enables researches to immerse themselves in the practice of considering epistemological or ontological focuses [29]; on the other hand, it empowers futures studies with "assets" such as "indeterminacies, contingencies and difference[s]" [30].

Given the former, two main issues come to the fore: (1) is discourse analysis (always) a political endeavor, and (2) how are critical perspectives (if any) embedded in the discursive analytical realm? Considering the latter, because we are engaged in unravelling the mosaic of the future, to what extent is "discursive" truth, per se, and does it have prospects of being studied from the foresight perspective? These questions are important to clarify in the search for a coherent research agenda.

First, should we consider CT education as (mostly) situated in methodological or didactic realm and focus on theoretical or analytical aspects, or should we focus (mostly) on political aspects, because it is politics and political decisions that most influence the future (at least in the educational realm to which CT education belongs)? Generally speaking, discursive approaches are those that are responsible for the construction of social reality [31]. It is the political effort that is responsible for these steps and we can further argue that "language is always 'political' in deep sense" [32]. As a consequence, following J. Dee, we can argue that "all discourse analysis needs to be critical" [32] to one degree or another. Namely, critical moments are those "drivers" that motivate such "discursive acts" (Harré and Gillet, 1994 as cited in [31]) to be undertaken in the domain of discursive practices. These "hidden" political motives may provide an explanation for the controversy. Then, despite solid theoretical foundations, the practice of discourse analysis is blurred amidst a "vast number of discourse analytical approaches which have quite different theoretical foundations as well as methodological implications" (R. Keller, 2011 as cited in [33]), which implies numerous attempts to "customize" methodology and adapt it to specific contexts (see for example [31,34,35]). We will follow this tradition.

Considering discourse analysis as the underlying methodology, we will utilize some critical "mechanisms" related to our research context, in particular employing methods related to STS. The role of STS here is "to deconstruct 'objective' endeavors in technological and scientific domains, and reconstruct them as complex entanglements of humanity, discourse and materiality [. . .] through practices and human/non-human alliances" [36]. In other words, STS can be seen as an "interpreter" of non-human agency that is inherited in the domain of computational artefacts. Considering critical perspectives, there is a clear overlap of methods: both critical discourse analysis (CDA) and STS "struggle" for values [37,38]; however, STS shifts focus to aspects of technical politics [23] related to socio-technical agency that are in the focus of our research context.

The next aspect that needs to be clarified is the place of futures studies—how to combine or, in other words, extend the reinforcement of the discourse analysis supported by STS to be considered within futures research. Following J. Dator, the task of the futures studies is to uncover alternatives and evaluate consequences while examining "events, emerging trends, images and actions" [39]. We will partially follow this agenda by focusing on emerging issues and trends as well as imaging, leaving other issues to future research.

To summarize, we count on a critical-political view of discourse analysis as an approach or methodology for social action within social practice, to be undertaken utilizing STS methods to explore agentive (both technical and social) relations in the existing socio-technical realm of CT education. This provides us with a set of emerging trends and images that we are going to uncover and display.

2.2. More on Discourse Analysis Perspectives

Academic discourse seeks to analyze and synthesize scientific truth in a purposeful way, but how does this relate to the developmental potential of the phenomenon under study? It is the unconscious and the implicit that gives access to individual self-potential and self-realization [40] and shapes the social and the related institutional (Farrell, 2008 as cited in [40]). The reflective uncovering that is hidden or obscured is the way to understand the transformative potential, perspectives, and tendencies of institutional reconstitutionalization more broadly. However, there is a seeming contradiction that needs to be discussed. How does one arrange such a process of self-reflection for the matter of the unconscious? Is it even possible? Here the role of the external investigator comes to the fore, rummaging through the trivia of narrative media and acting as a therapist, "uncovering unconscious self" and accessing "its self-reflective process by which meaning is created" (Giddens, 1991 as cited in [40]).

The method of such discovery lies in an area that is clearly outside the formalities of academic writings. This is due to the fact that the structure of the formal academic discourse, and we will discuss this later in detail, is based on a number of pre-designed expletives, and so is arguably not contingent in nature. What is the possibility of such rigidity evolving? Similar to nature, it is contingency and its empowered evolution with its possibilities and idiosyncratic variations that make the contribution of futures studies conceivable and meaningful, because "contingency is why even though some trends may be predictable over the long-term and the past may be explicable, the future is unknowable" [41]. However, despite this pessimistic assertion about the incognizability of the future, we nevertheless count on predicting trends, even while acknowledging the uncertain nature of the future. We acknowledge that "societal life was and is obviously always characterized by contingencies that never have been calculable" [42], but, from our perspective, we do not seek to adopt the stance of "strict rationalism" that usually characterizes academic discourse, or to focus on "causality", which "always tends to negate or to ignore the occurrence of the new and surprising" [42]. Moreover, "the tendency to think in (causal) regularities ignores the freedom of action and the freedom of individuals to choose their own values [. . .]" [42]. To solve this problem, our idea is to realize a kind of "systemic contingency" revealed in the "non-systemic" discourse represented in non-peer-reviewed and of out-of-sight constitutional narratives. In short, moving forward, we count on a combination of critical discourse analysis and trend analysis [43] as a futures studies approach. We can now formulate our research agenda in a broader sense: to identify and study the accessible contingent discourse in terms of scenarios of constitutive evolution of the CT phenomenon.

Continuing the metaphysical ontological perspective of CT, and this is an important point, it is clear that it requires the consideration of an ontological duality, as it involves cognitive aspects or aspects of (possibly reflective) experiences and meanings with the practical aspects of actions that implement these experiences in physical space. We can understand and explore this by adhering to the position of social interactionism [44], which argues that "in order to understand human behavior in any depth, we must examine discourse, because it is through discourse that the meanings and norms that guide human thought and action are constituted" [31]. It is important to analyze what constitutes such a discourse and how to explore it. If we consider academic content as discourse, it tends to be structured and based on a foundation of prior knowledge and thus is expected to be formulaic rather than "discursive" in nature. At the same time, from the perspective of futures studies, we are only interested in an entity with possible contingent behavior,

therefore structured or prevailing descriptions determine the development of patterns with a pre-determined evolutionary path and subject to deterministic means of analysis, which is clearly beyond our interest as futurologists.

To summarize, in order to overcome the problems described, we must focus (1) on non-academic content related to the research topic and focus our efforts on a set of sources for discourse analysis associated with non-peer-reviewed narratives such as web resources, viewpoints, editorials and other similar sources; and (2) on contextual-related academic and non-academic writings and narratives (which are related to CT but are not directly dedicated to it). Such insights allow us to examine the contingent behavior and trends of the entity in its context, thus increasing the confidence of our predictions.

2.3. Utilising Futures Studies Perspective

The next point to discuss is an approach to futures studies. If we have a structured discourse analysis, how does it allow us to identify ways forward, especially given a phenomenon as heterogeneous as CT? Observing the existing approaches, we can try to classify them as (A) predictive (modelling and predictive trends), (B) meta-transformative (causal layered analysis), (C) interpretive-reflective (STS), and (D) existential (see, for example, [45]) approaches. For example, one could apply a predictive modelling approach (see, for example [46]), however, such an approach aims at a predictive study of the descriptive aspects of the phenomenon, which is difficult to accept within the considerations of our study. Such description of a phenomenon such as CT can be constructed from different perspectives and angles, thereby actually creating a kind of kaleidoscope of pictures, leading to a false faith in it as a future predicting tool. Interpretive approaches are quite appealing, although too radical for our current research agenda. Transformative approaches aim to move into a kind of meta-transformative-space. Will the application of such transformative approaches finally allow us to highlight developmental tendencies? Based on a solid methodological framework (such as the well-known causal layered analysis methodology presented in [47]), we can view such a meta-space as located at the "top level". However, this it is not as straightforward as it may seem at first sight and may require some additional considerations to be developed (see, for example, the discussion in [48]).

Reflective approaches are based on elaborating a kind of "ubiquitous insight" methodology, such as that proposed in STS (in relation to future studies). The motivation for this is that we cannot claim to be objective, i.e., "[. . .] knowledge-makers are part of what they study and that their methods should reflect this" (Harding, Sandra (1993), as cited in [49]). Another aspect is that "truths" are in fact location-dependent. "This means that 'the same' object may be one thing in one place, and another somewhere else" [49]. Thus, if we manage to develop a set of prescriptions (as in case of predictive or transformative approaches), this can only be achieved by (a) reflecting ourselves in the form of our hopes and expectations and (b) relying on a prescribed set of locations for the phenomenon under study. Another aspect is that counting on trend detection, we clearly assume that the phenomenon under study is dynamic and evolving, and thus perhaps agentive and, in a heterogeneous case such as CT, mediates the process of assembling its own, residing in a related socio-technical realm, r network. Moreover, we should view this in a non-normative way, counting on a kind of "creative mess" and "warry of stories about consistency and coherence" [49].

To summarize, as a solution, we could focus on different forms of controversies (epistemic and metaphorical) as "hidden" means for developing tendencies and possibilities to be explored. In our case, the focus could be on the study of, for example, "epistemic controversies" [36]. This allows us to study a "complex phenomena [such as CT] [. . .] focusing on their digital and epistemic manifestations" [36], "digging up" metaphorical clashes, looking for hidden meanings in terms of semiotic or sociocultural accounts. All these implicitly drive the constitutive development of the phenomenon under study.

3. Materials & Methods

We employ a multimodal discourse analysis [27,50] as an approach to our study. CT is inherently a multimodal phenomenon and can be viewed as a multidimensional semiotic entity [50], where each mode of expression can be considered as a means to realize the usually hidden interests of the resource maker. Therefore, when analyzing multimodality, one can study questions on modal affordances or other issues, looking at it from the agentive perspectives of the meaning maker. In the case of CT, it is multimodality that is the key to "uncovering" the semiotic manifestations [50] of community in their power-related meanings.

To clarify, the focus of our research is not on modeling, classification, or other forms of generalization of the current state of the phenomenon, which would expect to cover as many cases as possible, leading to a kind of holistic picture of the "current". On the contrary, we focus on a limited number of selected items, covering possible directions of reconstitution of the phenomenon, mapping the landscape of the "controversial" futures on the basis of storylines and emerging discourse coalitions (for example, see [33] as an example of this approach). At the same time, the multimodal approach to discourse analysis suggests that one should focus on the micro-level through micro-observations of the phenomenon and associated discourse, thus "revealing" usually hidden controversies and as yet unrealized political intentions and viewing this as the driving forces behind the development of the phenomenon. At the same time, as already noted, we focus on the epistemic, semiotic, and sociocultural aspects of the development of the phenomenon, looking for controversies and clashes considered as drivers of its constitutional development (for example, see [36] as an example of this approach).

We focus on a "non-systematic" selective set of resources, including web-based resources of an educational and promotional nature, non-academic publications, editorials, reports, guides, and opinion papers whose titles or keywords included the wording "CT" or "computational thinking". Selective searches included the Google Search tool, Google Scholar and Eric search engines. We do not circumscribe our selection by a particular type of educational level, focusing on the overall CT agenda, highlighting the social aspects and implicit meanings of the narrator. As a selection criterion we use the highest ranked sources by the search engine, looking for patterns and similarities, and selecting the most representative story based on our own preferences and expertise.

In general, we focus on including items that tend to go beyond the "current" academic viewpoint of what CT is all about. Examples of the selected data sources include but are not limited to: (a) institutional web resources (e.g., [51]); (b) non-per-reviewed academic publications such as editorials or viewpoints (e.g., [52,53]); (c) publications in non per-reviewed and university journals (e.g., [54]); (d) reports (e.g., [55]); and (e) blogs and personal web-sites (e.g., [56]). All of the selected resources were written in English. We did not use a reliability coefficient in our study as all data analysis was conducted by the same researcher.

The analysis is based on the following. First, we begin with the identification of storylines. The goal for this is not categorization, but simply a "title" for the type of social interaction that a particular storyline implements in organization of social participants [50]. The aim is to analyze the hidden meaning and rhetoric of the resource maker, focusing on textual and non-textual elements and analyzing affordances of rhetoric means, considered as semiotic resources. We will then attempt to recognize the agency of the resource maker. Based on the above, we aimed to implement the following steps for analysis: (1) designing a set of sources for discourse analysis based on narratives opened to emerging trends to be identified; (2) conducting a discursive analysis focusing on political (in a general sense) and agentive aspects: (i) storylines and discourse coalitions; (ii) agentive forces, (iii) identities; and (iv) rights and duties; (3) applying a critical stance: (A) discursive perspective (i) values, and (ii) attitudes, (B) STS perspective (i) agency, actors and politics; and (4) performing futures analysis: clarifying emerging issues, trends, and possible consequences.

4. Results: Narratives and Storylines

Below we provide a brief description and insight into selected narratives and storylines. As we mentioned, we focus on a "non-systemic" set of resources, trying to provide the most contingent and flexible picture of the CT landscape to further "uncover" it toward possible future development trends.

4.1. CT as an Advanced Educational Skill

We start our observation of the narrative landscape of CT with a storyline that focuses on CT as an advanced educational skill. The storyline: (1) begins by describing CT and its constitution (not explicitly related to computing or programming); (2) usually focuses on positioning of CT as a skill; (3) describes its application in relation to problem solving; (4) provides links to other types of skills, usually related to problem or project solving; (5) refers to subjects and disciplines to enhance learning; and (6) refers to STEM. This storyline could be labelled as "science teaching-driven" as it comes from the science teaching community and is partially motivated by the lack of success in science teaching, leading to a search for new approaches.

As computer science (CS) is seen as an advanced discipline, the methods and techniques used in CS can also be used in science disciplines (and as part of STEM), e.g., *four of the skills used to solve CS problems can be applied in other classes as well*. At the same time, it is emphasized that this is not only "an enhanced" problem solving skill but also an approach to integrate disciplines into a single educational "continuum" such as an integrated STEM, a kind of "language" that enables new educational discourse to be constructed.

Here the social level focuses on advanced teaching methods such as project-based learning, which respond to the demand of effective education and are not actually related to professional competences, but rather to a universal set of "soft skills" such as critical thinking, confidence, ambitions, and curiosity; skills *needed to tackle ambiguous problems*. The narrator positions itself as an "advanced" educator-practitioner offering an "engaging" curriculum (as opposite to the unattractive "disciplinary" approach) where CT acts as the central competence on which the curriculum is built. The ideological commitment is to: (1) engage students in solving critical real-world problems, and (2) equip them with "advanced" competences that go beyond classroom teaching.

Agency and relations—the narrative positions CT as an agentive phenomenon in the following sense: it declares the promotion of the student agency in the form of empowering students with self-confidence to address ambitious interdisciplinary problems, and societal and science related issues such as genome engineering, the criminal justice system and technology impact analysis, yet its role as mediator is not clearly emphasized. CT is mostly considered here from the semiotic perspectives as a kind of a universal or multimodal "language" or a "label" that refers to advanced and innovative teaching environments. We believe that this semiotics perspectives can be called as "mildly technocratic" because it does promote technocratic educational values, but does so implicitly by positioning the CT "label" as a kind of exponent of the "critical" perspective.

4.2. CT as an Advanced Competence for a New-Age Citizen

CT is positioned here as a set of competences in the digitalization of society, acquired through CT education, which enable full *participation in a computational world.* The question is how to design a K-12 curriculum in the right way to ensure that such competences are developed. The described advantages of CT are three-fold, enabling a set of (1) advanced professional competences, (2) universal civic competences of the digital age, such as lifelong learning, and (3) critical perspectives and citizen engagement in democracy. The motivation for professional competences includes the widespread proliferation of smart technologies and the need for *people to know about and know how to interact with such technologies.* Interestingly, in addition to the "classic" set of professional competences, such as the internet and other areas of programming, this includes newly "emerging" competences such as big data, computational modelling and simulations, and system analysis. The motivation for

critical engagement is not straightforward. The slogan is *from the CS literacy to the democracy*. The obvious question arises: how is this connected? Referring to S. Papert, one might suggest that "learning programming provides a meaningful context for children to learn how to think about themselves, their learning, ideas, and experiences" [57]. Looking more closely at the narratives, however, in practice the various social contexts of learning CS and programming focus on engaging and motivating students to become professional coders. Such opportunities for all (including minorities and underrepresented groups) are a means of strengthening equal learning opportunities and civic democracy.

The social level here focuses on: (1) engaging and motivating *future CS professionals* to learn CS, including engaging minorities and underrepresented groups. The other focus (2) is engaging future teachers by introducing CT as an innovative educational method. Education stakeholders (3) is the next social group to be addressed. This is an interesting shift: How can CT help to engage stakeholders? The motivation for this is not explicitly stated, and CT is promoted as an integrated competence for K-12 STEM curricula. At the same time, it is not clear if CT is the "magic wand" that will attract teachers. Usually, if we talk about CS in high school, it is based on coding and other advanced issues and requires a long experience and relevant practical knowledge to impart. Another issue is that CS is a very dynamic field, requiring a continuous effort to update the level of competence, which should occur in conjunction with involvement in professional activities; therefore, a good CS teacher should be an experienced CS professional, which is impossible to organize in practice. How can this problem be solved? There are several options for CS teacher to focus on: (1) introductory level only, leaving the "professional" level to universities and companies; (2) universal competences such as CT, thus leaving CS outside the school curricula, with the premise that CT enables easy progression to advanced CS; and (3) advanced teaching methods such as visual programming and similar.

The narrator positions itself more as an educational policy maker focusing on advanced educational methods for K-12 and STEM education. Aspects of educational policy related to curriculum development and educational commitments are therefore discussed. The ideological commitment is declared to be critical: to promote educational policies aimed at modern and democratic education. Agency and relationships—unlike in the previous storyline, here CT is positioned as having agentive features—work to form "a bridge" to the "computational world" of advanced computer technology users and computer science experts. CT is considered here mainly from a metaphorical perspective, denoting CT as a kind of a "ticket" to the advanced "computational" world. We believe that these metaphorical perspectives can be called "partially technocratic" as they promote technocratic values, in part explicitly referring to the commitments to computer science education as a valued competence for technical progress.

4.3. CT as a Mental Enhancer

Here the storyline (1) typically focuses on describing CT as related to enhancing mental activity "in formulating problem to admit a computational solution" [54]. This assumes that computer scientists have an advanced ability to solve some usually "difficult" problem as they are able to apply computational resources in an advanced way, and usually emphasize an advanced algorithmic and systematic approach to problem solving. It provides (2) links to other "thinking" usually related to programming or CS. The plot can be labelled as "CS driven" because it comes from the CS teaching community and is motivated by the challenges of teaching programming and CS. The link with other disciplines (3) is based on the assumption that such disciplines (not only educational but also scientific) can be strengthen by advanced research methods based on CS breakthroughs such as computational modelling and experimental simulations.

4.4. CT as a Disciplinary Enhancer

CT is positioned as a universal approach suitable for breaking new ground in almost all existing disciplines, including natural sciences, engineering, social sciences, humanities

and arts. To promote itself to the general public, this storyline emphasizes the possibility of applying CT to "everyday life", promoting CT as a "mental enhancer" applicable to everyday life problems and being affordable to the general public to learn as "CT for all". Unlike the previously described "disciplinary" plot originating in CS, this one emphasizes the need to return from the "clouds" of technological advancements and to instead try to appeal to the general public, although this looks unconvincing. First, it talks about benefits of computer experiments and simulations, and then it "shifts down" to issues such as "Why do they always put the dressing before the salad? The sauce before the main dish? The silverware at the start?", summarizing that to solve this problem "they need some pipeline theory" [54]. In terms of educational applications (4), it promotes CS and programming education as being acceptable to all (with CT), not just CS students. With the advent of visual programming techniques this seems acceptable, but at the same time may be questionable, as it simplifies CS into a kind of "citizen science", although the tendency towards such "simplification" may be seen in another forthcoming storyline.

4.5. Beyond CT

This storyline is motivated by the need to "improve" CT, considering it insufficiently effective to solve certain problems or simply outdated in the face of ongoing technological advances and emerging socio-technical problems. The reported "problems" of CT vary, e.g., (1) the problem that CT, as related to CS, is not practical enough, and therefore not attractive to students. This declining interest is due to the fact that technical education focuses on details rather than practical applications that should have an *authentic impact on students' lives*. This theoretical focus demotivates students who ask: *when are we are going to use this in our lives*? The solution is to situate *computing education into a real-world context and, that the problems should connect to the specific personal interest and lives of the learners.* The next problem (2) is that focusing on real world applications can be practically problematic for *non-dominant groups* who are *traditionally underrepresented in the computing field*. The solution is to connect with students' real-life problems. All these underline the need to move towards a more practical education focused on real and personally relevant problems. Formulating and solving such problems will increase student engagement in CS. Another solution presented (3) is to move from purely indoor, in front of the screen activities to outdoor computing, a kind of "recontextualizing" to address *possibility spaces* to ***move beyond*** *computational thinking to a perspective of computational action*.

We will discuss this in more details later, but in brief, it is an important shift as it contributes to a socially biased view of technology. This is a fundamental difference in paradigms. As will be shown later, the narratives describing various "improvements" still remain within technical paradigms; this narrative, in contrast (consciously or unconsciously), contributes to this shift. Moreover, there is an understanding that such a shift will face organizational difficulties, which modern educational solutions must help to overcome. There is an interesting emphasis on empowering students to develop personally meaningful technological solutions that at the same time have an impact on community life. The idea is that students should *have the opportunity to use their computing skills in ways that have a direct impact on their lives and their communities*. This point is worth discussing because if one is to equate the personal and the social, clarification, at the least, is required. Another contradiction is that the meaning of community is quite broad, as the narrative refers to community in two different ways. The first is a community of "users" of technology and the second is a community of "implementers", "makers" or "creators". The interrelationship of these communities lies in the area where the "users" and "makers" overlap, i.e., "users" recognize the "makers" as such and the "makers" recognize themselves as such. This refers to concepts such as *computational identity* and digital *empowerment*. Here we see that the narrative has shifted technical aspects of CT to psychological and sociological aspects that go beyond the "classical" meaning of CT, but maintain a connection to the "computational", practically forming the background for a new discourse to emerge.

4.6. Enhanced CT

On the contrary to the previous plot, these are focused on a kind of a "technical improvements" of CT with respect to its definitions, content and applications, being motivated by current technical progress in CS, big data, machine learning, and artificial intelligence (AI). As new technologies emerge, CS education and related CT education should refocus on these new technological developments. For example, "AI thinking" is positioned as a more advanced "enhanced" CT. Whereas CT focuses on computational logic and algorithms, AI thinking is about "capturing" specific AI features and translating them into potential cognitive abilities for learning. It speaks of the "AI community" as an alternative to the "CT community" to stimulate research and promote AI knowledge and applications among the public. However, it is not clear from the narrative what the prospects are for the CT community; whether it will be transformed or simply abolished. The social level here focuses on advanced K-12 students and undergraduates who are engaged in modern digital technologies based on AI and machine learning. It also appeals to the community of professionals to promote such "enhanced CT" in educational practice. The narrator positions itself as an expert in advanced CT methods. The ideological commitment is to highlight efforts that enable a sustainable future combined with smart technology for the benefit of society.

4.7. CT for Smart Kids

The motivation behind this story is to involve children, starting even from kindergarten, in advanced educational activities, such as *solving algorithms*, thus resulting in early cognitive development. The solution is to incorporate CS into children's play activity, thereby providing the right direction and content for the evolution of brain structures. The social level here focuses on parents and their children from a very early age. The narrator is an expert in early childhood development and focuses on the development of advanced educational programs. The ideological commitment is to engage in smart technology, to educate "active" technology users, to motivates CS learning for underrepresented groups and minorities, to expect parents to develop their child, and to engage in critical citizenship. The motivation is: the sooner we start, the better the results, which will be understood as ensuring the future advanced competences we will achieve.

4.8. CT for Holistic Child Development

This storyline positions CT as a new methodology to create a holistic vision of child development pedagogy. The motivation is as follows: CT education needs to be supported and scaffolded. This goes in two directions: education for skills and dispositions. The narrative argues that there is no consensus on the scope of CT. At the same time, each skill in the skillset can be developed independently of each other. CT *dispositions* aim to improve "classic" CT skills and include universal *competences* from *dealing with complexity* to the ability *to communicate*. The aim is to engage learners with "new" media as well as *social interactions with no media at all*. The concept of a *connected world* is introduced. At the same time, the notion of CT as a mediator of connections to *different academic domains* is implicitly introduced. Another link is that CT, by enabling problem solving, supports children to acquire the full range of dispositions and competences *for living and learning in a media-diverse, highly connected world*.

Libraries are positioned as a "unique" extra-curricular environment responsible for bridging the gap between insufficient school and home practices in CT education. At the same time, libraries are positioned as a "community engager", aimed at involving families in CT educational practice and forming a CT mindset. The focus is on underserved and under-resourced communities, increasing equity *for diverse communities*. At the same time, libraries are positioned to *become leaders in encouraging CT for families.* Example of CT educational programs for children aged from 0–3 years old, 4–6 years old, and 7–9 years old, as well as for families with multi-aged kids are given.

Here, the social level focuses on an extended circle of participants including (a) children and families; (b) professional educators; and (c) policy makers. The extended circle of actors addresses both educational as well as marketing and policy objectives (libraries as highly competent and innovative service providers). The narrator positions itself as an expert in semi-formal early development, focusing on a whole child and offering a different (compared to traditional schooling) approach to the subject. The ideological commitments are (1) to engage underrepresented groups and communities with high-level competences such as CT, and (2) to provide an "equal" start from the beginning of the school period. The agency and relations–agentive and relational features of CT are as follows. CT aims at consolidating a special type of community consisting of individuals, professional, semi-formal educational institutions (libraries), and formal educational institutions (schools) supported by multimodal resources in the form of play, hands-on, formal educational, and development activities. It contributes to the development of professional agency, aiming to expand the community by attracting new members. At the same time, it serves to promote the institutions itself in order to gain further recognition and more funding (as a hidden motivation).

5. Findings and Discussion

5.1. CT in Terms of Semiotics

We will examine semiotic perspectives following a multimodal social semiotic agenda [27,50]. First, we can clearly trace the agentive property of CT that enables meaning-makers to position themselves as: *educational experts; advanced educators; innovative educators; professional development organizations; educational researchers; international initiatives; media channel; independent, non-profit organization; online courses; ongoing partnership; and consultancy services.* We can observe a wide spectrum of meaning-makers identities associated with CT in one form or another.

CT can be further labelled as an agentive semiotic transformer that enables a number of semiotic transformations: historically starting first with its computer science driven technical program [2], CT has allowed a set of cognitively and socially linked declarations to emerge, such as:

- (Cognitively linked.) *Challenging questions and ambiguous puzzles; a phenomenal way to foster this mindset; your students may surprise you; a skillset for solving complex problems; a deeper way of understanding; highly correlated with intelligence; predict what may happen in the future; generic problem solving; a thought process; encouraging playful thinking; to think differently; expressive or creative process*.
- (Socially linked.) *The knowledge and skills for a computational world; a cultural shift; powerful connections; independent learners; future employment opportunities; direct impact on lives and communities; inclusive education; for underrepresented groups; a pillar of modern society; future success*.

At the same time, CT can be positioned as an agentive multimodal semiotic transducer: It conditions a series of transformations of first purely textual declarations into a set of "performative" activities integrated into its constitution: (1) play activities of various forms and directions; (2) semiformal educational activities such as contest-based education [58]; or (3) the Maker Movement [59,60]. For example, CT addresses the systemic transformation of children's play activities, considering scenarios and tools such as:

- (Hands-on focus.) *Remixing traditional activities in innovative way; can be organized based on discrete parameters such as color, shape, size, and function; empty cereal boxes, paper rolls, and cans are transformed; infused into story-time; image-based; visual; letter cards; hands are extended up; adjusted bodies; mimicked; placed into particular order; personalized digital stories*.
- (Community focus.) *Strengthen bonds; shared family experiences; build new relationships; to support learning for the families in the community; require efforts of all sectors of the education community.*

Another example is the Maker Movement. It is largely influenced by CT [13,61,62], and the transformation of laboratory activities into high-tech performative activities, from crafts to high-tech consumables. For example:

- (Hands-on focus.) *Breathe into your craft; ability to tinker; students create real-world things; student-made artefact; innovative science experiment; real-time data; to terraform a neighborhood; build habitats; using felt, paper, and colored markers.*
- (Community focus.) *Partnerships with community makerspaces; bring this truly all-inclusive learning experience into their schools, districts, and communities; reach the students with whom we often struggle to connect; build learning communities; newly formed community; the world of making and computational thinking.*
- (Cognitive focus.) *Developing the grit and metacognitive skills; growth in critical thinking; need to overcome rigorous intellectual challenges; instill the necessary confidence; capable, and feel proud; investigate the potential impact.*
- *(Policy focus) Funding for a dedicated space; to democratize education; to grow into thoughtful, confident leaders.*

5.2. CT as Cognitive Transducer

We can continue to explore the CT phenomenon in terms of semiotic transformations aimed at cognitive aspects. Such narratives are usually titled as "From CT to 'new forms' of thinking". It is interesting to highlight that these "new forms of thinking" are developed in the tradition of their "predecessors" and use some "advanced" professions or approaches as additions to the word "thinking", such as *logical, economic, systems, physical, mathematical, engineering, design, artificial intelligence thinking,* and many more [24,63]. These emerging phenomena tend to use CT as a point of reference for their occurrence and as a template for the construction of their constitutions, as, for example, *ingredients of computational thinking directly applied to AI thinking*. However, AI thinking must go beyond what computational thinking offers. This provides a direction for considering AI thinking from the semiotics perspectives as *fashioned after computational thinking.* At the same time, CT provides a set of valuable social connections that allow the transduction of the initial CT affordances into a new *messaging framework* for the AI community, encompassing *messages on technical, political, and ethical issues.*

5.3. CT Identity from the Perspectives of Semiotics

Another aspect for discussion: Does CT mediate a new type of identity, and if so, what is identity of the "computational thinker"? Does CT add a new dimension to it and how does it differ from the identity of a "classical" person, whose identity is not affected by CT? In general, the development of a digital identity in terms of semiotics is explored in the literature (see, for example, [64]), however, the focus is on ICTs and technical aspects. Our semiotic focus is on how CT contributes to a "new" type of identity. For example, what are the attitudes and other characteristics of identity and what are the impacts and connections in relation to social aspects? What is the impact on the social agency of the subjects? In general, following L. Resnyansky, we aim to "dissect" CT "as a semiotic space in which social identities are constructed" [64]. In doing so, we speak of a reflective type of identity, thereby developing a profile of the computational thinker. First, CT identity is based on a specific type of language and related CT definitions. It focuses mainly on (1) *pedagogical identity* and can be described as the identity of an advanced practitioner educator who possesses some specific competences in educational methodology, e.g., competences in advanced approaches to project and problem-based learning, distance educational technologies, or personal development methodology. Next, (2) it focuses on institutional marketing efforts, labelling institutions as innovative service providers and forming the *identity of the institutional community* associated with such innovative methods. Further, (3) it focuses on educational policy makers and administrators who promote advanced organizational structures associated with CT. For example, CT Alliance [65] claims to create an institutional network mediated by CT, considering CT

as an "educational asset". Another example is the world-wide CT learning with Scratch software movement [66]. This is an example of a transduced semiotic entity, as it is CT that allowed the Scratch community to thrive.

5.4. CT from a Metaphorical Perspective

We do not aim at a detailed study of the metaphorical content of the CT phenomenon, referring it to future research, however, such metaphorical aspects can be considered as important drivers of the constitutive development of the phenomenon. Therefore, we will not systemize or classify the metaphors described, instead our aim is to provide some kind of metaphorical discourse for further analysis. The aim of our study, in contrast to applied research focusing on aspects of practical pedagogy (see, for example, [67]), is to uncover the constitutive aspects of the CT phenomenon. In general, metaphors allow "a kind of framework that allows a two way process: technologies are characterized based on metaphors taken from the reality of the daily life and these metaphors shape the evolution and the perception of this reality" [68]. We consider metaphors related to education, community and values, cognition, and educational policies. The two types of metaphors are: (1) related to CT definitions (definitive) and (2) related to accompanied issues and "induced" by CT agency (inductive) (see Table 1).

Table 1. Metaphorical landscape of CT elaborated by the authors.

Classification	Definitive	Inductive
Methodology (educational approach)	*CT is a tackler (of challenging questions and ambiguous puzzles); stripper (stripping away unnecessary details to develop a generic solution); fosterer (of CT mindset); rich toolkit; provider of an intricate linkage; an entity that could be brought into a class; sits at the heart of the new statutory program; body of knowledge that can equip; a skillset (for solving complex problems); the step that comes before programming; a set of soft skills; valuable entity; a non-verbal measure of intelligence; breaking down problems; breaking down tasks; unique 'secret weapon'.*	*Allows to dissect the system; refashioning themselves as cartoon babies; meticulously crossing their genotypes to create endless generations; to decompose a dunk; their own ancient civilization; 3D amusement parks based on a human body; representing blood cells with bumper cars; representing neural networks with ziplines; leverage pattern recognition; trends in data; activity is clustered; bringing CT into your classroom; a computational world; gathering and organizing data; expressing (life) procedures as (computational) algorithms; stands to impact learning; looking for patterns in the puzzles; painstaking process that teaches us; crucial information; ingredients of CT.*
Community and Values	*Have impacts on managing relationships.*	*Represent a fair system; educators, policymakers, and families are realizing the value of coding.*
Cognition	*CT is related to algorithmic thinking, critical thinking, logical thinking, system thinking; CT is a unique way of thinking; CT skills are versatile approaches (to problem solving).*	*Algorithmic music composition; breaking down a complicated problem; developing cognitive muscles; diving into new challenges; independent learners; a way of a deeper understanding of a digital world; to view the subject of computing as a whole; empower educators and students to understand better; skills will be richly valuable over a lifetime; able to articulate a problem.*
Policy	*Is applicable through workforce; benefitting cutting-edge research.*	*Schools will benefit from weaving CT across disciplines; a cultural shift that all educators value; efforts of all sectors of the education community; skills that are attractive for future employment opportunities; benefits for future employment.*

5.5. CT from the STS Perspectives and Uncovering the Driving Controversies

We can consider CT as a mediating agent for a new overarching network based on (1) CT facilitating engagement in technological innovation, (2) CT facilitating the formation of accompanied social networking processes, and (3) CT facilitating the formation of a set of virtual identities. The Maker Movement supported by CT is a prime example. The Maker Movement has evolved into a hybrid socio-technical network entity [16], where the network is not just a means of communications, but an inherited property that allows for the constitution of Makers phenomenon per se. The reason for this is that CT enables (through its epistemic focus) a landscape-complex network of makers to evolve further, beyond a direct production-technology formation [69] into an inextricably linked social entity where material (technology) and intangible (CT) artefacts play mediating roles in its formation and development. This epistemic focus enables one to study the agentive impact of socio-technical factors based on various forms of "controversies" of different types. Going further, the relational nature of ontologies should be emphasized: "[. . .] ontologies are relational effects that arise in practices (Barad, 2007), and that since practices vary, then so too do objects. This argument is important in STS because it softens realities–it means that they are not given (Abrahamsson and others, 2015). It also means that we might imagine realities that are better" [49].

What are the implications of such ontological relational effects for CT phenomenon? Because it depends on practices, we could study these practices to highlight the "shadows" of these "softened" realities. Another aspect is that these relational effects are universal in nature and apply to material and immaterial entities and their networks. Generally, we could study such relational effects for different forms of ontologies, actually selecting the most "suitable" for the purpose of its study in each specific sets of realms. In practice, as one of the solutions, this could lead to the development of analyses based on the study of, for example, metaphorical clashes [68], epistemic controversies [36], or counterpartying semiotics forms. As an example of epistemic drivers, there is an ongoing debate that could be titled "CT and programming". There are many scenarios in which CT positions itself differently in relation to programming and CS. These different dispositions of CT could be as follows:

- (Solely related to programming) *is the step that comes before programming; based upon our studies of interactive media designers;*
- (Partially related to programming, related to other disciplines) *is the systematic approach of not just computer science, but many other subject areas, and careers, as well; is a skillset for many disciplines, and for a computational world; is both central to computer science and widely applicable throughout education and the workforce; from a math and computer science perspective, to one useful for all subjects;*
- (Not related to programming, related to technologies and digital literacy) *is the prerequisite skill for understanding the technologies of the future;*
- (Not related to programming, related to problem solving) *is an approach to tackling challenging questions and ambiguous puzzles; is a problem-solving process;*
- (Not related to programming, related to cognitive development and creativity) *is an expressive or creative process.*

Regarding the controversies grounded in multimodal semiotic forms, we could classify them as follows. Mainstream discourse labels CT as (1) a set of advanced competences, focusing on the internal structure and considering educational methodology definitions. Such resources usually depict CT in the form of diagrams, illustrating its internal parts and possible applications. This is usually supported by video recordings of lessons or lectures with links to parts of the curriculum, sufficiently formalized and grounded in the methodological universalities incorporated in the resource. Some of these resources link to members of the CT network related to the educational aspects of CT. Another important part of the discourse designates CT as (2) a methodological approach focused on advances in cognitive development. Such resources usually portray CT through "skillful" learners, usually emphasizing their digital literacy by illustrating the accompanying digital

tools or technology elements and connections to other knowledge domains. This is usually supported by videos or descriptions of various hands-on and other developmental activities that are less formalized and grounded in the presenter's expertise. Networking includes links to service providers, communities, and tools for feedback and experience sharing. Other forms may include resources focused on (3) educational policy and marketing aspects. Such resources usually portray CT indifferently or in relation to the product, services, and activities they promote. Networking is mainly related to product and services descriptions, including links to retail websites and marketing tools. Some illustrative examples of printed educational materials on computational thinking are presented in Figure 1.

Figure 1. Computational thinking educational materials (Retrieved with permission from: https://www.icompute-uk.com/Downloads/iCompute-CT-diary.pdf, accessed on 10 December 2021; https://teachyourkidscode.com/what-is-computational-thinking/, accessed on 10 December 2021).

6. Conclusions

Summarizing the study, we can formulate the answer to our main question: What are the tendencies in the development of the CT phenomenon? As already mentioned, the phenomenon itself is a complex entity with a sophisticated structure, therefore some adapted approaches have been applied when studying it, especially in the context of such a comprehensive topic as futures studies. We observed different storylines such as: "CT as an advanced educational skill"; "CT as an advanced competence for a new-age citizen"; "CT as a mental enhancer"; "beyond the CT"; "enhanced CT"; "CT for the smart kids" and "CT for holistic development", analyzing the discourse presented in terms of the semiotic and socio-technical networking agencies of the CT phenomenon.

By observing how meaning-makers identify themselves and what their ideological commitments are, we can draw the following conclusions. First, (1) CT has a strong agentive potential, enabling a wide spectrum of opportunities, from individuals to institutions and virtual resources. However, the focus is on meaning-making identities related to educational activities, and other forms of meaning-making identities are, in our view, underestimated. For example, business, the medical community or political institutions are underrepresented in the discursive landscape of CT. Further, (2) although the ideological commitments behind the narratives are represented and refer to democratic values, the declared ideological values "inducted" namely by CT are mainly underrepresented. The proclaimed ideological declarations mostly refer to general declarations related to critical aspects of educational policy. CT specific ideological commitments are mostly limited to societal and personal benefits and prospects related to acquisition of (i) digital literacy and (ii) some universal competences in general and specific problem solving. This is partially

due, as shown earlier, to the narrow representation of the meaning-makers, leaving a wide range of ideological issues outside the discursive landscape being described.

Further, it could be concluded that the transformative potential of CT is sufficiently revealed in the discourse. However, it can be seen that a limited number of transformation directions are presented, although such directions mainly focus on cognitive and societal aspects, leaving other directions partially under-represented. Considering the transducing potential of CT, it is clearly evident that the transducing potential of CT is underestimated. The reason for this may be the complex nature of the phenomenon, which requires addressing not only material, but also virtual and transcendent entities. However, the ongoing process of societal transformations associated with changing and refocusing the priorities of individual–society relations may be responsible for the tendency in the evolution of CT from a well-presented transformative semiotic agency to an increasing future role of CT as a semiotic transducer. Historically, the motivation for introducing CT is to improve human cognitive abilities based on some advanced techniques and competences related to computers and computer science. The next step is to improve these abilities, including more advanced techniques and competences, e.g., AI thinking. This is basically the same direction: improving the human being to better communicate with machines. However, what about the reverse direction: improving machines in order to improve communication with humans? Indeed, following Hayles [70], for example, the question can be asked: what are machines in a posthuman society?

Examining the CT identity in relation to the reflective type of identity, it could be concluded that reflective identity is an underrepresented aspect in the discursive domain of CT. Although it is claimed that the aim of the meaning-maker is to promote *students to grow as computational thinkers* or educate students *to solve problems as computational thinkers*, such declarations are rare and usually remain undisclosed. The reason for this may be related to the position of CT as a cognitive (virtual) artefact [71], a mental enhancer. One could observe its explicitly presented structure, a set of well-defined and documented techniques aimed at enhancing cognitive abilities for the task process and other activities. However, it should be noted that entities such as cognitive artefacts have different claims to their effectiveness, observed from the perspective of the developer (educator) and the user (student). If the former sees it as an advanced tool or method, the latter may consider it as just another tool, which may lead cognitive degradation as a result of its use [71]. This could be one of the reasons why CT identity is presented mainly from the pedagogical side (educators) and not from the learner's side. At the same time, this could be due to the complex nature of the phenomenon, so that the learner is involved in such activities unconsciously, and CT is introduced mostly implicitly (as a "black box" for the learner).

Observing CT from a metaphorical perspective leads to conclusions on the importance of further study of this phenomenon in this direction. An in-depth disclosure of the metaphorical nature of CT will allow for tuning the tendencies and directions of its constitutive development, because its metaphors are the agentive entities that "[. . .] create new personal and strategic pathways [. . . ,] constitute reality [. . . and] are foundational in disrupting the present, unlocking alternatives, and creating new futures" [72]. The current situation can be referred to as a "metaphorical starter", as it could be observed that a metaphorical landscape is underdeveloped. This is a largely undirected and unconscious process, possibly caused by the inherited semiotic nature of CT, as its metaphors "have to be seen as integral parts of *semiotic processes* containing other signs than metaphors and other types of signs than verbal signs" [73]. Understanding the importance of developing the metaphorical domain of CT is growing (see, for example, [67]), but it is directed towards appropriate educational technologies rather than understanding the phenomenon of CT per se. As a conclusion, it can be stated that it is to be expected that CT will further develop in the direction of revealing its metaphorical instance.

Observing the agentive feature of CT in relation to the mediation of relevant socio-technical networks, we can conclude that CT declares rather immature positions in the respect to the material and semiotic relations in the socio-technical networks it mediates. Al-

though various forms of networks that integrate institutional, virtual, and personal entities and artefacts emerge, develop, and are supported by the phenomenon of CT, we observe, that the structure and constitution of such networks are mostly hidden and descriptions are fragmentary and not always supported by heterogeneous connections. It is well seen that driving controversies are mostly epistemic in nature and could be observed as an ongoing debate related to the impact of positivistic and pragmatist viewpoints on educational issues. The positivist account is based on CS tradition, supported by incorporated methodological universals, while the pragmatist approach, in contrast, "performs at the opposite side", promoting creativity, hands-on, unplugged, and other semi-formal and community linked methodologies. The former could be named a "top-down" approach, as is relies on political power and related directions, while the latter is a "bottom-up", social and community-oriented approach focused on the common good and personal development perspectives. However, the other forms of controversies are not yet clearly presented. Regarding the STS position as opposite to the "traditional" positivist claim that "reality is constant and that we share the same reality-world" [49], it advocates a "flat" and pragmatist view of the issue. It could be argued that it is this assertion of "flatness" that is underestimated as a driver of the CT controversy. This includes underrepresented semiotic or metaphoric forms. However, the emergence of this tendency is observable mostly in connection with the already mentioned Maker Movement or the progress in the positioning of CT in relation to STEM and engineering education (see e.g., [25]).

As a limitation of this study, it may be noted that all of the sources we reviewed were written in English, which narrows the discourse to English-speaking narrators. A broad search in other languages, which is important for the search for non-systemic narratives, is positioned as a further study.

The narratives we have selected constitute a kind of "first floor" of information based on CT-related content and focus on semiotic and related critical aspects. This information is presented and studied from a generally unstructured set of resources, which makes it difficult to develop ontological (information science) or taxonomic considerations that might be of interest to consider. Therefore, as noted earlier, at this stage we focus on the epistemic, semiotic, and sociocultural aspects of the development of the phenomenon. Nevertheless, this ontological perspective can be promising for consideration (in terms of the futures studies). Nevertheless, we consider its realization a really difficult task. We have to go up to the "second floor", to the meta-level, which provides an understanding of the development of the emergent structure of the phenomenon. The problem here, however, is that such a structure will evolve into a new synthetic structure resulting from the corresponding synthesis, which makes the task of such study and subsequent generalization quite difficult and could be positioned as a direction for further study.

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