Current conception of Computational Thinking at the K-12 classroom level curriculum

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Abstract. Aiming to contribute to the disambiguation of Computational Thinking (CT) concept the present work explores the conceptual interpretation of CT in widely known institutional and programmatic curricula. The paper explores the understanding of CT by the teachers as this is depicted in the pedagogical translation of the curricula into learning activities. More specifically, a directed qualitative content analysis was conducted on the set of learning activities of selected curricula, using a complex coding scheme, based on current theoretical conceptions of CT. The outcomes promote the understanding of CT's educational meaning, by unveiling the current content theory of CT formation as a school subject, as it is implicated in curricula proposed so far. The paper helps a more precise mapping of the general educational potential of CS, in comparison to CT, in K12 as well as the definition of relevant future research directions.

Keywords: Computational Thinking, Classroom Curriculum, Content Analysis.

1 Introduction

With the publication of the article entitled "Computational Thinking" [14], Jeannette Wing set out her vision of recognizing CT as a fundamental competency that all literate citizens should develop through compulsory education, to complement the three other core skills, that is, reading, writing, and mathematics. The wide spread of computational devices and CS applications may play a vital role in the success of such a venture. From that point on, extended discussion on the scope of the term got launched. No sooner had this discussion come to a close than various initiatives, as well as full curricula -geared towards the development of CT in education- emerged.

The interest of the educational community is therefore focused on the successful implementation of curricula and the effective use of scenarios. A key point to achieving these goals is the understanding of the relevant concepts by teachers. The present work constitutes an attempt to outline the conceptualization of CT as it is explicitly or implicitly presented through the curricula of K-12 education. Furthermore, the paper takes a cautious look at the expected conceptualization of CT by the teachers. The instructional events and learning activities that a teacher employs in his/her everyday practice and which formulate the classroom curriculum, constitute a projection of his/her interpretation and pedagogical translation of the programmatic curriculum [3],

[8]. Teachers' preparation is very significant for the development of the CT full pedagogical potential [17], [15], [2]. Recent research by Yadav, Stephenson and Hong [16] supports the view that pre-service teacher's education programs need to be redesigned, to develop teachers CT competences and prepare them to incorporate CT in K-12 classrooms.

For a systemic and sustainable integration of CT in formal education, resources that would first, persuade educational policy makers and later, allow teachers to integrate CT in the realm of their knowledge both in principle and classroom are required [1]. Although many initiatives have produced such resources and have been progressing to the integration of CS in education so far, CT and its relation to CS remain rather unclear and controversial. Yet, the early attempts of implementing CT integration in education have already been providing feedback information thus making the investigation of the interpretation of the CT dimensions by the teachers, possible.

2 Theoretical framework

According to Deng's view [3], a school subject is introduced at schools as a distinct representation of a content embodied in curriculum documents or materials (e.g. curriculum frameworks, syllabuses, textbooks, digital repositories of learning objects). Curriculum developers –often implicitly- apply a (subject dependent) theory of content, that is, a way of deliberately selecting, arranging, transforming, and framing the content so that it serves the educational purposes of a school subject. The theory of content is also applied in the process of selecting specific teaching, learning, and assessment methods for the corresponding school subject. Consequently, for an efficient teaching and the development of the full educational potential of a school subject, apart from familiarity with the content per se (Content Knowledge), teachers are required to have knowledge and understanding of the corresponding inherent theory of content as well as of the related curricular, learning and instructional issues (Pedagogical Content Knowledge) [13]. The exploration of both, CT theory of content and its understanding by teachers arises as a key research issue. Curriculum theory discerns three levels of curriculum-making: the institutional (or abstract/ideal), the programmatic (or analytic/technical), and the classroom (or enacted) [3]. The **institutional curriculum** expresses the desired, anticipated, long-term outcomes of the school subject in social, cultural and national levels [4], [5]. The **programmatic curriculum** describes specific content (topics, concepts, problems, case studies etc.) which have been selected and organized in a way that both, meets the institutional curriculum expectations, and is also consistent with the modern pedagogical approaches (e.g. inquiry, collaborative, interdisciplinary problem-based learning), as well as with the education research findings (Didactics of the specific subject matter). The programmatic curriculum, therefore, constitutes a set of technical and analytical documents for use in schools that incorporates a particular content theory. Finally, the transformation of the programmatic curriculum into instructional events and learning activities, at school, forms the **classroom curriculum**. Classroom curriculum is, therefore, mainly defined by teachers who are expected to have a good comprehension of the content of the programmatic curriculum in order to be able to interpret it and translate it into instructional and learning activities taking into consideration: a) the directions of the institutional curriculum, b) their students' existing knowledge and experiences and c) their school context. Thus, CT classroom curriculum concerns the development of teaching and learning designs (e.g. scenarios, scripts, lesson plans) and materials, aiming at engaging students in the construction of their own knowledge and competences related to CT, as well as the implementation of these designs in the classroom. The pedagogical translation concerns the development of educational experiences by selecting key issues (e.g. concepts, problems), their appropriate pedagogical representations, instructional and assessment methods and resources (e.g. class exercises, creative examples, careful explanations). Obviously, the classroom level curriculum is the key to a successful implementation of any institutional and programmatic CT curriculum, while the educational potential of CT is practically determined by the classroom curriculum.

3 Research Framework

The main scope of the paper is to explore the expected understanding of CT by the teachers as this is depicted in the pedagogical translation [3] of the curricula into learning activities. Towards this direction, directed qualitative content analysis [12], [10], [11], [6] on sets of learning activities of selected curricula-initiatives has been conducted, using a predefined coding scheme, based on current theoretical conceptions of CT (the review of the CT conceptions) and various educational dimensions. The directed content analysis uses an existing theoretical framework to determine the initial coding scheme while the results of the analysis validate or extend this theoretical framework [9] cited in [12]. Content categories in relation to pedagogy dimensions and CT concept disambiguation have also been defined. The analysis primarily aims at: (a) promoting CT conceptual disambiguation and (b) deductively confirming that CT concerns the application of CS to other school subjects and gain a better understanding of the nature of this relation.

More specifically, the analysis can potentially provide answers to the following questions:

- Are all the theoretical dimensions of CT represented in the classroom curriculum?
- Which other school subjects are utilized for the development of CT in schools?

Content analysis requires the selection of the unit of analysis to start. In this study, the unit of analysis is the learning activity design (or lesson plan, or learning scenario, or learning script) that explicitly addresses CT for the K-12 grades.

To build the collection of learning activities designs we first collected a set of curricula and initiatives concerning CT in K-12 education which made clear reference to the term and relevant concepts, as well as activities that include core dimensions of CT, without referring directly to the term. The sources were filtered based on their quality, intentional focus on CT and their role as models for many other less known initiatives. The final set of curricula and initiatives as well as the numbers of the corresponding learning designs/scenarios that were selected for analysis, are summarized in table 1.

Table 1. CT learning design sources included in the analysis.

Source	Selected learning designs
Teaching London Computing	21
Barefoot Program	14
CS Unplugged	14
Computational Thinking Toolkit by ISTE and CSTA	9

The sources presented in Table 1 contain many learning scenarios from which 58 –the ones that more strongly responded to the criteria defined above- were selected for further study and content analysis.

3.1 Defining the coding scheme

In a directed content analysis, the coding process requires a predetermined categorization matrix (coding scheme). In this study, the coding scheme was developed with respect to a) the union of CT dimensions that are proposed by the various initiatives b) pedagogy features (learning, teaching methods, social mode, unplugged or on the computer), c) interdisciplinary features (related subject matter other than CS). To serve the analysis purposes the authors used a number of dimensions, only a subset of which, the ones mentioned in the research findings section, are presented here below.

a) CT Dimensions. CT is analyzed to several dimensions by the various learning scenarios providers. The authors tried to find correspondences and define the union of these dimension schemata, in order to use them as coding categories. The exploration of the distribution of scenarios throughout these dimensions and the relationships among them will provide crucial information for the understanding of CT at the classroom curriculum level. The following dimensions were identified: *Algorithmic Thinking – AL, Problem Decomposition – PD, Abstraction – AB, Data Representation – DR, Logical Reasoning – LR, Generalization – GE, Representation – RE, Modeling – MO, Simulation – SIM, Pattern Matching -PM, Evaluation – EV, Problem Translation – PT, Data Analysis – DA, Automation – AUT, Testing – TE, Understanding People – UP, Sequencing – SE, Data Collection – DC.*

b) Curriculum Subject. As CT is supposed to concern the application of CS in other disciplines, the relevant scenarios are reasonably expected to be interdisciplinary. The authors used the scenarios' curriculum subject as another coding dimension to confirm the above CT conception. Furthermore, the distribution of the scenarios to the various subjects could reveal subjects that are not represented at all, or others that are more common and popular. Finally, the inspection of the potential problems and concepts of each subject used in the scenarios will result in information concerning the extent of the scenarios designers' understanding of CT. The category elements of this coding dimension include school subjects (e.g. Mathematics, Science, History).

c) CT Tools: Includes the titles of software and/or hardware that are used/proposed in the scenarios (e.g. Scratch, Robotics Kit, Unplugged).

4 First Findings-Discussion

The content analysis of the CT learning scenarios reveals interesting findings, concerning the pedagogical translation of CT into classroom curriculum [3], some of which are summarized here below.

Regarding the comprehension of the CT concept by the learning scenarios designers, the analysis concluded that some CT dimensions appear to be much more popular than others. This indicates a rather conservative perception of the CT concept by the designers, according to which, CT is primarily viewed as being identical to Algorithmic Thinking and some relevant dimensions. More scenarios are needed in various dimensions such as Data Analysis, Pattern Matching, Modeling, Simulation, Automation and People Understanding. It therefore appears that the current understanding of CT by the scenario designers leaves an important range of scenarios out. Thus, the teachers' and/or educational designers' understanding of CT is susceptible to significant improvement. It's worth mentioning that Systems Thinking is not considered as a CT Dimension in the analyzed initiatives despite the fact that is mentioned as such in other sources [7]. This is a programmatic curriculum level omission since Systems Thinking is a key contribution of CS for problems solving and the study of complex dynamic systems.

As for the curriculum subject dimension, the analysis of the sample scenarios shows that most of them combine CT with Mathematics, a significantly smaller number involve Arts and Language, while dramatically fewer are the scenarios relating to other school subjects such as Science and Social Science. This limitation supports the argument that in order for CT to unfold in all its aspects, CT instructional/learning designers need to collaborate in interdisciplinary teams. In addition, further research, focused on the exploration of CS impact in other disciplines is necessary, in order to highlight the CT factor. The analysis of the connections of CT dimensions to the various School Subjects reveals that a common way to connect the various disciplines with CT dimensions passes through the data collection and analysis paths. Surprisingly, pragmatic curricula do not include significant CT dimensions, such as Systems Thinking and Digital Citizenship, areas of significant CS applications that should affect general education.

Finally, the tools/resources study reveals a significant shortfall in educational key technologies, e.g. educational robotic kits, automation, specific programming languages and mobile programming.

Taking into account the main findings of the content analysis it appears that, during the process of their transformation into learning scenarios, both the conceptual content of CT and its dimensions are limited enough, in terms of how the concept has been formulated, in the institutional and programmatic curricula. Furthermore, interdisciplinary groups of learning designers and systematic mapping of the scenarios to unfold the scope of the concept.

References

1. Barr, V., Stephenson, C.: Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? ACM Inroads 2(1), 48-54 (2011). doi: 10.1145/1929887.1929905.
2. Cuny, J.: Transforming Computer Science Education in High Schools. Computer 44(6), 107-109 (2011). doi: 10.1109.MC.2011.191.
3. Deng, Z.: The formation of a school subject and the nature of curriculum content: an analysis of liberal studies in Hong Kong. Journal of Curriculum Studies, 41(5), 585-604 (2009). doi:10.1080/00220270902767311.
4. Doyle, W.: Curriculum and pedagogy. In P. W. Jackson (ed.), Handbook of Research on Curriculum, pp. 486–516. Macmillan, New York (1992).
5. Doyle, W.: Constructing curriculum in the classroom. In F. K. Oser, A. Dick & J. L. Patry (eds.), Effective and Responsible Teaching: The New Syntheses, pp. 66–79. Jossey-Bass, San Francisco (1992).
6. Elo, S., Kyngas, H.: The qualitative content analysis process. Journal of Advanced Nursing, 62(1), 107–115 (2007).
7. Easterbrook, S.: From Computational Thinking to Systems Thinking: A conceptual toolkit for sustainability computing. In M. Höjer, P. Lago & J. Wangel (eds.), Proceedings of the 2014 conference ICT for Sustainability, pp. 235-244. Atlantis Press, Amsterdam (2014). doi: 10.2991/ict4s-14.2014.28.
8. Fesakis, G. & Serafeim, K.: Influence of the familiarization with "scratch" on future teachers' opinions and attitudes about programming and ICT in education. ACM SIGCSE Bulletin, 41(3), 258-262 (2009). doi:10.1145/1595496.1562957.
9. Hsieh, H., Shannon, S. E.: Three approaches to qualitative content analysis. Qualitative Health Research, 15(9), 1277–1288 (2005).
10. Krippendorff, K.: Content Analysis: An Introduction to its Methodology. Sage Publications, London (1980).
11. Neundorf, K.: The Content Analysis Guidebook. Sage Publications Inc, Thousand Oaks, CA (2002).
12. Seker, H., Guney, B. G.: History of Science in the Physics Curriculum: A Directed Content Analysis of Historical Sources. Science & Education, 21(5), 683–703 (2012). doi:10.1007/s11191-011-9416-6.
13. Shulman, L. S.: Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4- 31 (1986).
14. Wing, J.: Computational thinking. Communications of the ACM, 49(3), 33-36 (2006).
15. Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., Korb, J. T.: Computational Thinking in Elementary and Secondary Teacher Education. ACM Transactions on Computing Education, 14(1), 1–16 (2014). doi:10.1145/2576872.
16. Yadav, A., Stephenson, C., Hong, H.: Computational thinking for teacher education. Communications of the ACM, 60(4), 55–62 (2017). doi:10.1145/2994591.
17. Yadav, A., Zhou, N., Mayfield, C., Hambrusch, S., Korb, J. T.: Introducing computational thinking in education courses. In Proceedings of the 42nd ACM technical symposium on Computer science education, pp. 465-470. ACM, New York, NY (2011). doi:10.1145/1953163.1953297.