Computational Thinking in Dutch Secondary Education

Nataša Grgurina

Teacher Education, Faculty of Behavioural and Social Sciences, University of Groningen
P.O. Box 800, 9700 AV Groningen, The Netherlands
n.grgurina@rug.nl

Abstract. We shall examine the Pedagogical Content Knowledge (PCK) of Computer Science (CS) teachers concerning students' Computational Thinking (CT) problem solving skills within the context of a CS course in Dutch secondary education and thus obtain an operational definition of CT and ascertain appropriate teaching methodology. Next we shall develop an instrument to assess students' CT and design a curriculum intervention geared toward teaching and improving students' CT problem solving skills and competences. As a result, this research will yield an operational definition of CT, knowledge about CT PCK, a CT assessment instrument and teaching materials and accompanying teacher instructions. It shall contribute to CS teacher education, development of CT education and to education in other (STEM) subjects where CT plays a supporting role, both nationally and internationally.

Keywords: computational thinking, situated learning, engaged computing, computer science

1 Present Situation

In 2006, J.M. Wing asserted that "to reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability" [6]. Educators recognize this need and inquire into the precise description of this concept and the ways to teach it. In 2010 in the United States, the National Research Council held a workshop on the nature and scope of Computational Thinking (CT). While there was a broad consensus on the importance of (teaching) CT, the workshop did not achieve a conclusive definition of this concept [4]. The Computational Thinking Task Force of CSTA did however suggest an operational definition of CT tailored to the needs of K-12 education. They state that:

CT is a problem-solving process that includes (but is not limited to) the following characteristics:

- *Formulating problems in a way that enables us to use a computer and other tools to help solve them*
- *Logically organizing and analyzing data*

- *Representing data through abstractions, such as models and simulations*
- *Automating solutions through algorithmic thinking (a series of ordered steps)*
- *Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources*
- *Generalizing and transferring this problem-solving process to a wide variety of problems*

These skills are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT. These dispositions or attitudes include:

- *Confidence in dealing with complexity*
- *Persistence in working with difficult problems*
- *Tolerance for ambiguity*
- *The ability to deal with open-ended problems*
- *The ability to communicate and work with others to achieve a common goal or solution [2]*

In the USA and the UK, teaching these CT problem solving skills does not get enough attention from policy makers and is hardly represented in school curricula [5]. In the Netherlands, the situation is similar [1]. The Computer Science (CS) course in the upper grades of secondary education seems to be a natural setting to introduce CT teaching. In this course students regularly collaborate on large practical assignments based or realistic problems in order to produce working solutions. For example, a typical assignment would require students to design a model of traffic lights for a busy crossing or elevators for an apartment building. Both these problems:

- Are open and can have various correct solutions;
- Come with a minimal specification, prompting the students to investigate the behavior of the system to be modeled and thus encouraging them to use higher order thinking skills;
- Originate from the *real world*: solving (modeling) them necessitates the use of information-processing agents – like those used within a CS course.

2 Research

Obviously, a number of aspects of CT can be recognized in regular CS teaching practice, albeit lacking coherence and not being explicitly specified as learning objectives in the CS curriculum. Therefore, we propose to conduct design research concerning the teaching and learning of Computational Thinking (CT) within the context of a CS course in upper secondary education in the Netherlands. This research will take four to six years and will result in a PhD dissertation.

2.1 Research Questions

We shall study the following issues:

1. What is an operational definition of Computational Thinking, tailored to the specific situation and needs of secondary education in the Netherlands?
2. How can students' CT problem solving skills be assessed?
3. What is a suitable pedagogical approach to teaching students and stimulating their learning of CT problem solving skills?

2.2 Method

It this research, a curriculum intervention (pedagogical approach, teaching materials and teacher education materials) and an appropriate CT assessment tool will be developed as a result of an iterative (cyclic) process.

The first phase of the research is dedicated to obtaining an operational definition of CT. In the second phase, an instrument for the assessment of students' CT will be developed. The results of these two phases will yield the data for the pedagogical approach that will be developed in the third phase of the research: a curriculum intervention for students as well as accompanying teachers' instructions will be developed and tested in a pilot. In the fourth phase, the effects of the curriculum intervention will be assessed in an experiment on a larger scale and the final version of curriculum intervention (i.e. teaching materials) will be developed.

Phase 1

Essential aspects of CT will be described, based on the CSTA definition of CT, existing teaching materials and additional literature. This draft definition will be presented to a number of experienced CS teachers. Their pedagogical content knowledge (PCK) pertaining to aspects of CT described in the draft definition will be established using content representation framework [3]. This will yield a final operational definition of CT tailored to the needs of CS course in Dutch secondary education.

Phase 2

The CT description obtained in phase 1 will be used to develop an instrument for the assessment of students' CT problem solving skills. After consulting with experts, both nationally and internationally, and necessary modifications the author will test this instrument for usability and reliability in her own classroom while teaching CS using suitable sections of regular teaching materials. The findings will lead to final adjustments of this instrument. At the same time, the students' learning will be observed through video and sound recordings of individual and collaborative work, semi-structured interviews and other qualitative methods. Special attention will be paid to the difficulties students experience, misconceptions, use of CT skills and visibility of problem solving strategies.

Phase 3

The findings of the phases 1 and 2 will contribute to the development of teaching materials for students and instructions for teachers (in the form of a course for teachers). The design of students' materials will be based on the idea of working with concrete problems in real world situations (situated learning). The curriculum intervention includes programming and modeling using freely available software.

After consultations with national and international experts (and possible modifications), these teaching materials will be tested by a small number of teachers who will report their experiences and findings through questionnaires and interviews. This will lead to further adjustments of the teaching materials.

Phase 4

The experiment will take place in some dozen schools. Using the CT assessment instrument mentioned earlier, the effect of curriculum intervention (i.e. teaching with newly developed teaching materials and an associated pedagogical approach) on students' CT problem solving skills will be assessed and compared to CT problem solving skills of the students in control groups who were not taught CT problem solving skills explicitly. This will also lead to further adjustments of teaching materials.

3 Results

There has not been much research on (the effects of) teachers' instructions on CT problem solving skills of their students. This research will provide an assessment tool to make students' learning of CT visible, together with a validated assessment instrument to measure students' computational thinking. Furthermore, teaching materials for students and accompanying teachers' instructions will be developed.

Since CT can be viewed as a form of situated learning, the results of this research will be interesting for scientific research into situated learning in related STEM subjects.

New insights into teaching and learning CT will help teachers to prepare their students more adequately for life in our modern society and for effectively applying CT professionally, regardless of whether ICT plays a central role in their occupation or not. Teacher training departments will be equipped better to prepare future (CS) teachers for their jobs.

Besides the contribution of this research to the growth of the body of CS pedagogical content knowledge in general, it will mean to the author a further development of the pedagogical approach she has been practicing in her classes for years and which has convinced her more and more that that CS is not an isolated art but one that facilitates learning and understanding in other disciplines.

References

1. Barendsen, E., Zwaneveld, B.: Informatica in het voortgezet onderwijs - voorstel voor vakvernieuwing (Notitie voor KNAW) (2010)
2. CSTA, `http://csta.acm.org/Curriculum/sub/CompThinking.html` (last checked 1/31/2013)
3. Loughran, J., Berry, A., Mulhall, P.: Understanding and developing science teachers' pedagogical content knowledge (2006)
4. National Research Council (US). Committee for the Workshops on Computational Thinking. Report of a workshop on the scope and nature of computational thinking, Natl Academy Pr. (2010)
5. Schnabel, R. B.: Educating computing's next generation. Communications of the ACM, 54(4), p. 5 (2011)
6. Wing, J. M. Computational thinking. Communications of the ACM, 49(3), pp. 33–35 (2006)