Computer Science

Development of Computational Thinking Curricula in Primary Schools

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1 Introduction

Digital literacy skills are needed to navigate in a modern world, influenced by computers and algorithms. Attention must be paid to teaching digital literacy in the curricula of our schools, to give students the knowledge and skills to interact effectively with digital technology. Currently, the digital literacy skills of Dutch primary school students are not adequate (DUO, 2021; Rooyen et al., 2021). Students do not understand digital technology enough to grasp the complete possibilities this technology enables, and do not understand the risks that are involved in its use (Klein Tank & Spronk, 2022).

The digitization of society brought about two important developments in digital literacy education: the actualisation of educational curricula in many countries, and the realisation that this education should include 'Computational Thinking'. The first development can be seen in the efforts that have been made to improve the Dutch educational curriculum. Currently, a comprehensive overhaul and actualisation of the curriculum of Dutch primary education is in progress, with digital literacy as one of the first priorities (Klein Tank & Spronk, 2022). The second development is apparent from the way Computational Thinking is included in Dutch education as part of digital literacy since 2014 (SLO, 2022a; Thijs et al., 2014). **Computational Thinking (CT)** is a way of thinking that applies concepts from Computer Science to problem-solving (Selby & Woollard, 2013; Wing, 2017), and its positive effects on digital literacy skills and social development (Kakavas & Ugolini, 2019) have been cited as reasons to include CT in the Dutch educational curriculum (Bocconi et al., 2016; Thijs et al., 2014).

These developments are culminating in the current effort of implementing CT in the Dutch educational curriculum, which is not yet completed (SLO, 2023). The first part of this implementation is the development of a standardised curriculum, which is currently being developed by the **Dutch expertise centre for curriculum development (SLO)**. Once SLO has defined learning goals ('kerndoelen') for digital literacy and CT, schools will be required to adhere to these goals in their educational curriculum (Ministerie van Onderwijs, 2016). The second part of this implementation is the teaching of CT in practice, which is done at only a small number of Dutch primary schools. Even though a majority of schools teaches digital literacy, only a small part explicitly includes CT in lessons (DUO, 2021).

These efforts of implementing CT education are made more difficult because of an overabundance of educational materials. As Dutch schools and teachers are generally free to choose their own materials, creating a comprehensive CT curriculum involves choosing from these offered materials. Dutch primary schools find that the excess of materials prevents schools from offering CT education (DUO, 2021; Voogt et al., 2019), and consequently most schools teach CT in an ad-hoc manner (Klein Tank & Spronk, 2022).

1.1 Rationale & Research Questions

Dutch educational institutions are preparing for the inclusion of CT in their curricula. To follow the progress of this, the status of digital literacy and CT education in primary schools has recently been monitored by various organisations, on their own initiative or directed by the Dutch government. The outcomes of of these studies show that schools have a lot of ground to cover, because students' CT skills are inadequate (Rooyen et al., 2021), and only 13% of schools use educational materials that are focused on CT (DUO, 2021). To help those schools without a comprehensive CT curriculum, this study seeks to learn what lessons can be learned from the schools that *do* already offer CT education.

The approach used in this study is understanding how schools and teachers choose and/or develop materials that are used in CT education, and how they use these materials in their educational programmes. This includes the methods of searching for materials, the filtering of relevance in the materials, and the stated goals of chosen or developed materials. From this follows the following research question:

- **How is computational thinking taught in primary schools, and how do schools select the educational materials?** [RQ1]

Then, it is important to understand how the currently available SLO material is helping teachers with CT education, or how it is lacking if teachers do not make use of it. Especially important here are the differences between the type of materials teachers expect, and what is actually provided. This gives the next research question:

- **What is the perception of teachers of available SLO materials, and how do they make use of it?** [RQ2]

Finally, the acquired understanding of the approach to educational materials and the use of SLO materials is used to identify key problem areas and obstacles that need more attention in the current efforts of implementing comprehensive CT education in all of Dutch primary education, specifically in how the SLO materials can be improved. This brings the final research question:

- **What lessons can be learned from the relation between schools' approaches and the SLO materials?** [RQ3]

This study will include interviews with parties involved in the development of CT material in several Dutch primary schools that offer CT education. Other included sources are documents concerning schools' approaches to CT education. Published SLO materials will be the final source. Further details on methodology are provided in section section 3.

1.2 Overview

After this introduction, first a literature review is included (section 2) where the current knowledge about computational thinking and the status of education are reviewed; next, the method of this study will be explained (section 3); then, the results of the study are reported on (section 4); finally, the last section (section 5) concludes by answering the above research questions, by discussing the limitations of this study, and by making recommendations for further study on this topic.

This bachelor's thesis was made in cooperation with Dr. Anna van der Meulen, my first supervisor, and Giulio Barbero, my second supervisor.

2 Theoretical Framework

In this section, the status of the literature around CT education is reviewed. First, in subsection 2.1, the term 'computational thinking', and the definition of it in the literature are discussed. Then in subsection 2.2 the status of CT education is discussed, including perspectives from policymakers and teachers, pre-teacher training, the importance of integrating CT into other courses, and existing challenges to the implementation of CT education. Next, in subsection 2.3, the current approaches to CT lessons are examined. This includes frameworks used to study CT and the relation of programming and CT. Then in subsubsection 2.3.1, the form and contents of CT educational materials are discussed, along with integration into other fields, and the approaches used to select materials for use in CT education. Finally, subsubsection 2.3.2 discusses assessment of CT skills, when applied in programming tasks and when applied in other fields.

2.1 Computational Thinking

The modern idea of computational thinking (CT) was introduced by Wing (2006) in an essay on the advantages that thinking like a computer scientist brings to other disciplines. Wing provided no exact definition, but from her essay and her further refining of the term (in Wing (2008); Wing (2014); Wing (2017)), it is clear that her intent is that CT is mostly a thinking skill: "*Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out.*" (Wing, 2014).

Educators and academics took up the concept as a means of promoting computer science to a more general audience. A more sturdy definition would help in this, and many have since attempted to derive this, as shown by Barr & Stephenson (2011) and Selby & Woollard (2013). As of 2019, Kakavas & Ugolini (2019) found in a systematic literature review that there seems to be no broadly accepted and adopted definition of CT. Still, even if is no agreement on the exact definition, some aspects that are frequently used in definitions of CT seem to point to a emerging consensus that CT should include that it is a thought process that makes use of the concepts of abstraction and decomposition (Selby & Woollard, 2013). This agrees with the broadly accepted view (Barr & Stephenson, 2011) that CT can be seen as an approach to problem-solving, similar to the intentions of Wing.

Programming is often included in CT education (Klein Tank & Spronk, 2022; Voogt & Brand-Gruwel, 2017), and sometimes taken as synonym for CT (Kakavas & Ugolini, 2019). However, it is not an essential part of CT (Kakavas & Ugolini, 2019; Voogt et al., 2019) but is only a tool that can be used in CT activities (Kakavas & Ugolini, 2019; Lodi & Martini, 2021).

In practice, CT is included as a domain in digital literacy in Dutch primary education (DUO, 2021; Klein Tank & Spronk, 2022), The Dutch national expertise centre for curriculum development (SLO) is responsible for curriculum development for this subject. For primary education, CT is defined by SLO as *"(re)formulating of complex problems using thinking skills and strategies in a way that allows computer technology to assist in solving them"* (SLO, 2022b). Topics included are data and text processing, decomposition, pattern recognition, abstraction, and algorithms. As this thesis focuses on CT education in Dutch primary education and performs a comparison to the SLO material, this is also the definition that will be used in this thesis.

2.2 Status of CT Education

Several factors have a role when it comes to implementing digital literacy education, relating to both teachers and the education itself. For example, good education requires teachers that are motivated and competent in their area of teaching (Bower et al., 2017; Kunter et al., 2013). Another factor concerns the implementation of CT education in the curriculum, which can be done through integration in other courses, or as a separate subject.

The reason for including CT in the educational curriculum is different when viewed from the perspectives of policymakers and teachers. In many countries such as France, Poland, and the U.K., teaching CT will be, or is already legally established (Bocconi et al., 2016; Engelhardt & Balanskat, 2015). For policymakers in EU countries, the need for integration of CT in the regular curriculum rests on the assumption that CT skills and competencies transfer to other disciplines and real-world problems (Bocconi et al., 2016). In the Netherlands, CT is specifically mentioned as a way of preparing students for the digital world. Several studies show that in the Netherlands, most but not all teachers agree that teaching CT skills is necessary. First, a relatively recent representative survey of primary school teachers and school leaders showed that 66% percent of teachers agree on the need to educate students in digital literacy (DUO, 2021). Another recent study looked at Dutch online education during the Covid-19 epidemic, and found that teachers noticed that students' digital literacy was lacking and needed additional development (Rooyen et al., 2021). However, the same study found that teachers did not find that students were impacted by a lack of CT skills, and only 5% of respondents identified CT as an area that needed additional development. At the same time, creators of educational material are aware of the need for teachers to understand why CT is important (Rooyen et al., 2021; Tondeur et al., 2013). From these recent studies it is clear that Dutch primary school teachers understand the need for CT education. But to teach a subject effectively, teachers must be given the tools to understanding the subject (Bower et al., 2017; Kunter et al., 2013). The basic IT skills and solid pedagogical and didactic skills that are required are often lacking (Lloyd & Chandra, 2020). In many countries including the Netherlands, teachers are concerned that they don't have the necessary schooling to teach CT. For example, a recent representative survey in Dutch primary school education found that more than half of Dutch in-service teachers, and a quarter of ICT coordinators feel they would benefit from additional schooling in CT (DUO, 2021). This is not unexpected, given that CT is not always included effectively in pre-service teacher training. Yadav et al. (2014) observed that there was a lack of CT modules in pre-service teacher education for U.S. teachers. More recently in the Netherlands, Hebing et al. (2022) surveyed five teacher training colleges ("Pabo") on understanding of CT. As an additional factor influencing CT education effectiveness, Hebing found that pre-service teachers are troubled by the vague definition of CT, and that this uncertainty is a deterrent to actively approaching and seeking to understand the term. This is not limited to the Netherlands; studies in other countries have shown similar issues with pre-service teachers' understanding of CT. For example, Ata & Çevik (2020) surveyed more than 300 Turkish pre-service teachers and found that teachers perceived their own CT skills as inadequate. Similarly, Yadav et al. (2016) found that in the United States, teachers are hampered by a lack of computer science background, and more needs to be done to prepare pre-service teachers to teach computing principles.

It is clear that teachers are limited in teaching by their lack of understanding, and additional schooling is required. This need is recognised by both researchers and creators of educational materials. First, several studies have been done on effectively teaching pre-service and in-service teachers CT skills and knowledge. For example, Bower et al. (2017) looked at how teachers could be taught necessary knowledge. The authors found that teachers could quickly develop technological skills, knowledge, and confidence by using targeted professional learning. In another study, Lloyd & Chandra (2020) looked at teachers during the implementation of CT in the Australian primary school curriculum, and found that teachers would take up knowledge and skills relatively quickly while teaching. More recently, Greifenstein et al. (2021) identified key areas of CT knowledge and skills in which teachers perceived themselves as lacking. Greifenstein et al. found opportunities to improve teachers' knowledge, the main area being the integration of CT in other disciplines. Second, creators of educational materials have also noticed that teachers would need extra schooling to be able to teach CT effectively. Some frameworks were made specifically to prepare pre-service teachers without a computer science background for understanding computational concepts (Curzon et al., 2014; Yadav et al., 2011, 2014). Although these efforts were successful giving teachers knowledge to teach CT concepts, Yadav et al. found that this knowledge was limited to an "abstract" understanding, which made it hard to combine CT concepts with the subject matter of the teachers. Therefore, Yadav et al. and others (Voogt et al., 2015) have proposed that more attention should be paid to integrating CT concepts in other courses.

Researchers have noted that this integration is important, not just for the understanding of teachers but also because it has a positive effect on students. Many authors have acknowledged that CT should not be limited to the discipline of Computer Science, but also in other disciplines (Mohaghegh & McCauley, 2016; Voogt et al., 2015; Yadav et al., 2014). The foremost reason for this it that a) integration of CT into other courses helps both teachers (Yadav et al., 2014), and students (Mohaghegh & McCauley, 2016; Yeni et al., 2021) understand CT concepts better because they would be able to relate these concepts with their course practices. However, these authors all noted that research on this topic was still scarce. This scarcity can be explained by a relative surplus of literature about CT as a focused, separate subject. Kakavas & Ugolini (2019) performed a systematic literature review on CT in primary education, and found that most studies on CT education were done without integration in other courses. For example, recent work studied CT education through activities explicitly linked to CT, such as block-based programming in ScratchJr (Kyza et al., 2022) and physical programming of robots (Körber et al., 2021).

Several studies have shown that the factors named in this section (motivation, competence and preparation of teachers and implementing CT integrated or separately) impact and can hinder the implementation of CT into the wider educational curriculum. DUO (2021) reported that over three quarters of teachers structurally include digital literacy in their lessons. Teachers are generally aware of the four domains of digital literacy (Thijs et al., 2014) (ICT skills, media literacy, informatics, CT) but do not focus on these domains specifically. Parts of these domains are integrated in lessons in an ad-hoc manner, often without use of a constructive learning line or paying attention to students' progress. Rooyen et al. (2021) identified the main challenges with teaching CT as follows: 1) a lack of basic ICT skills in teachers and students hinders the effectiveness of CT education, 2) the relationship teachers have with CT negatively influences students' experiences, and 3) education aimed at the greatest common divisor is not enough for students that do not have the required basic ICT skills. Other studies have identified further challenges to effective CT education: 1) teachers' understanding of CT (DUO, 2021; Hebing et al., 2022; Yadav et al., 2016) and 2) time restraints experienced by teachers (DUO, 2021; Lloyd & Chandra, 2020).

Taken together, the literature indicates a good understanding of the status of CT education in primary education: teachers agree on the need for it but the implementation in actual teaching in practice is lacking. The main challenge to effective education from the perspective of teachers is their understanding of CT. From the perspective of how CT is taught, further integration of CT into other disciplines is identified as the main challenge because it has positive effects on teachers and students but most CT education is not integrated. Researchers in the field also call attention to this topic as an area where further research is needed.

2.3 Approaches to CT Lessons

With an understanding of current knowledge on the status of CT education in general, a closer look at CT lessons is possible. Aspects that are relevant here are as follows.

First, a method is introduced for studying CT through concepts and practices: terms that allow us to describe further knowledge more effectively. Then, the relation between programming and CT is examined, which is relevant because both terms are often used interchangeably in the literature and in practice (which is discussed below). For the concepts, the teaching goals that educational materials focus on are reviewed, as well as the topics that are used in them. For the practices, the different levels of application of CT in educational materials are discussed, along with the integration of CT in other courses. Next, assessment methods for CT skills are discussed, also when applied in programming tasks and when integrated in other courses. Finally, the topic most relevant to the research questions of this thesis is discussed, which is the knowledge of the approaches teachers and schools have when selecting or creating CT educational materials.

Brennan & Resnick (2012) developed an operational definition of CT by ways of a framework that separates aspects of CT into concepts, practices and perspectives. CT concepts can be seen as aspects that arise when approaching from a CT perspective, though Brennan and Resnick mapping concepts directly to blocks in the Scratch visual programming language. This gave the concepts sequences, loops, parallelism, events, conditionals, operators, and data. As the previous literature shows, and as is also noted by Brennan and Resnick, these concepts are about the knowledge that is required for CT based problem solving. The CT practices then are focused more on "the process of thinking and learning, moving beyond what you are learning to how you are learning"(Brennan

& Resnick, 2012). Brennan and Resnick define these as being incremental and iterative, testing and debugging, reusing and remixing, and abstracting and modularising. These practices are the ways in which the knowledge of CT concepts can be applied while problem solving. Finally, CT perspectives are the lens though which those doing CT view and interact with the world through application of CT concepts and practices: expressing is the way CT is used for design and self-expression; connecting is the interaction with others through projects and problems involving CT; and questioning revolves around the idea that CT empowers one to question their environment and find answers in this way. Though Brennan and Resnick developed their definition with Scratch in mind, the years after their introduction of the framework many researchers have used it in their own work (Kakavas & Ugolini, 2019). Fagerlund et al. (2021), in another literature review, show that while many studies do not explicitly fit within Brennan and Resnick's framework, but there is significant overlap. This shows that the distinction of concepts, practices and perspectives is an accurate and useful way of looking at CT, and it will be used further in this thesis to examine CT.

Brennan and Resnick's framework was developed around a programming language, but it has been used in CT contexts that do not revolve directly around programming. Therefore, it is important to understand the relation between CT and programming. Programming is often included in CT education (Klein Tank & Spronk, 2022; Voogt & Brand-Gruwel, 2017), and sometimes taken as synonym for CT (Kakavas & Ugolini, 2019). However, it is not an essential part of CT (Kakavas & Ugolini, 2019; Voogt et al., 2019) but is only a tool that can be used in CT activities (Kakavas & Ugolini, 2019; Lodi & Martini, 2021). It is still useful as a tool because skills cultivated by programming transfer to CT (Guzdial, 2016, Chapter 7; Voogt & Brand-Gruwel, 2017). When CT education is done using a digital programming language, the language that is almost always used is the Scratch block-based visual programming language (Fagerlund et al., 2021; Lye & Koh, 2014).

2.3.1 Form and Contents of CT Materials

When considering the offerings of CT education in practice and in studies, it is helpful to look at the form and level of application activities involving the educational materials take place. The distinction of levels of application is useful because the different forms relate to different skills. Skills and knowledge in different levels of application can then be used in a constructive manner to build a better understanding of CT concepts (Saxena et al., 2020). Several studies have proposed categories through which to view educational materials, looking at different aspects of CT education. For example, Jeuring et al. (2016) conducted a literature review on programming lessons in primary education, and identified several levels of programming and program execution. Additionally, Yu & Roque (2018) created categories to organise kits in a survey on CT educational kits. Furthermore, categories for application of general CT skills are identified, by Dummer (2017) in a report on implementation of CT in Dutch primary education, and by Kakavas & Ugolini (2019) in a literature review on CT education in primary education. Table 1 lists a selection of categories of the previously named papers.

Table 1: Overview of levels of application according to authors

Dummer (2017)	Yu & Roque (2018)	Jeuring et al. (2016)	Kakavas & Ugolini (2019)
Plugged	Virtual (completely digital)	Programming (textual/visual)	Plugged
Hardware	Physical with/without electronics	Physical	Hybrid
Unplugged	Hybrid with/without tangible programming blocks	Unplugged	Unplugged

It is clear that while the category names differ, most authors classify materials based on two characteristics: whether the material has a physical aspect, and whether the material makes use of digital applications. Some authors use a more granular distinctions, but broadly all fit within three categories: 'Plugged', 'Unplugged', and 'Hybrid'. These correspond to activities involving digital technology on a computer, activities done without the use of electronic technology, and an area combining the two (using electronic hardware), respectively.

Delineating the boundaries between CT education focusing purely on computational concepts and education integrated in other courses is difficult (Voogt et al., 2013). CT education is implemented in practice within computing, cross-discipline, and even informal learning (Voogt et al., 2015). For learning computation, most material focuses on algorithmic thinking and not the wider CT perspective (Meyer-Baron et al., 2022). This agrees with the observation by Lye & Koh (2014) that CT education focuses more on concepts than practices and perspectives. For learning where CT is integrated in other disciplines, Barr & Stephenson (2011) gave various examples of how computational concepts can be applied in various courses (computer science, mathematics, science, language, and social studies). Later research shows that CT can indeed be integrated in many courses ranging from STEM courses such as science and physics, but also others such as geography, traffic and language (Grgurina & Yeni, 2021). CT has been integrated in language subjects (Jenkins, 2015; Sabitzer et al., 2018) and journalism (Wolz et al., 2011). Still, STEM courses are often named as areas where CT integration is relatively straightforward when compared to other courses (Sengupta et al., 2013). Examples are integration of CT into maths and science (Rich et al., 2020), maths (Herman Yu-Hin Leung, 2021), engineering (Sengupta et al., 2013).

Finally, the content of CT education is determined by the materials that are selected for usage. There exists relatively little literature focusing on this selection process, but it is known that Dutch primary schools find that the excess of materials prevents them from offering CT education (DUO, 2021; Voogt et al., 2019), and consequently most schools teach CT in an ad-hoc manner (Klein Tank & Spronk, 2022). This can be seen in that over half of Dutch primary school teachers don't use lesson plans to teach digital literacy (DUO, 2021). Additionally, only 13% of Dutch primary school teachers use educational materials that are focused specifically on teaching computational thinking (DUO, 2021). Literature reviews such as Kakavas & Ugolini (2019), Fagerlund et al. (2021), and Tang et al. (2020) show that studies are generally conducted with educational materials defined and chosen by the researchers. Some studies mention their approach to selecting educational materials (e.g. Körber et al. (2021) mentions using internet resources), but there is a lack of knowledge on the approach of teachers and schools for selecting materials.

2.3.2 Assessment of CT Skills

To see the effectiveness of CT education, teachers will need to make use of some manner of assessment. The literature on this topic focuses more on assessment of programming skills that coincide with CT skills than more general CT skills. Even less is known about assessment of CT skills when CT education is integrated in other courses.

Most knowledge and work on CT assessment is done for the CT aspects relating to programming This is shown by a relatively recent literature review on the available tools for assessment of CT skills, which shows that most studies on CT assessment tools and frameworks are focused on those developed for programming exercises (Tang et al., 2020). Assessment can be done by measuring positive effects on students' skills using these frameworks, but most frameworks and tools are limited to observations in a research settings (Lye & Koh, 2014). More recently, Fagerlund et al. (2021) give an overview of the frameworks and tools that are used to empirically measure effects of CT education by performing a literature review on assessment in studies using Scratch. Their research shows that assessment of CT is hard, even with the affordances programming languages like Scratch offer. Additionally, assessment was found to be most effective when teachers clarify intentions and criteria for success. Throughout the literature reviewed, Fagerlund et al. found several recurring rubrics used for assessment: difficulty rating, presence/frequency, description, correct answers, behaviour of programs, progression level, and self-evaluation. These rubrics are focused directly on skill and knowledge assessment, but other studies such as Sáez-López et al. (2016) note that assessment can be done also on creative aspects by looking at originality of students' submissions and communication styles.

Less is known about the assessment of general CT skills. In a systematic literature review on CT assessment, Tang et al. (2020) note that there are not enough assessment tools for general CT skills. Shute et al. (2017) observes the same, and also sees that as a consequence reliability and accuracy are issues. Most methods that are available are focused on algorithmic thinking, and not the wider CT perspective (Meyer-Baron et al., 2022). Exacerbating the problem a lack of assessment poses is the fact that most general CT skill assessment methods consist of pre-made quizzes which are hard to extend with new material (Dolgopolovas et al., 2015; Palts & Pedaste, 2017). There are however other ways to assess general CT skills developed, with Tang et al. (2020) noting that portfolios are used for skill and knowledge assessment, and surveys for disposition. Some more recent works have made efforts to resolve the lack of methods. For example Li et al. (2021) created a framework to be used for assessing the key concepts of CT.

3 Method

In this section, the design of the study and methods used are described. It includes information on the research setting and participants, the study procedure, the instruments used as well as data gathering, and the data analysis process.

3.1 Setting and Participants

The setting for this study was five primary schools with a variety of educational types (traditional public, Catholic, and Jenaplan) in the Randstad area in the Netherlands. The participants were one male, and four female employees of the schools, or contractors to schools, who described themselves as a 'main party' related to, or an 'important part of' the development of a CT educational curriculum at their school. Participants include two class teachers, one of which also functions as an IT coordinator; and three consultants to schools, also working as IT coaches for the school staff. All participants conducted lessons for children in primary school independently on a regular basis.

3.2 Procedure

Based on the research questions, the research setup was created with interviews and document analysis as research instruments (subsection 3.3), and thematic analysis used to analyse the gathered data (subsection 3.4). The research procedure was reviewed by the Ethics Review Committee of the Faculty of Science.

To search for potential participants, the site AlleCijfers.nl (*Informatie over basisonderwijs*, 2023) was used to select primary schools in the municipalities of Leiden and Delft, offering regular primary education. The websites for schools meeting the criteria were visited, and information such as school guides and information for parents were reviewed for mentions of CT or programming education. The schools that offered this were contacted by email through the addresses listed on the websites to ask for participation in this study. If a participant agreed to participate, an informed consent form was sent to be signed, giving information on the study goals, the setup for interviews and document analysis, and the handling of personally identifying information. The interviews were then planned, either in person or through a video call, and conducted only if informed consent was given through the form. As part of the interview, the possibility of providing documents was discussed, and if there were documents made available, these were later received through email.

3.3 Instruments and Data Collection

This study makes use of two main data sources: guided interviews and documents. For the interviews, a semi-structured form was chosen, which allows the interviewer to ask a mix of closed and open questions. A conversational guide was constructed, used for guiding the interview through several topics identified as relevant to the research questions. First, the participants' personal definition and understanding of the offered CT education, or the relation of the offered programming education to CT is discussed. Then the implementation of CT education at the participants' schools is discussed. The first part of this is the contents of lessons, including the inclusion of concepts and practices, as well as how concepts and practices are applied in lessons and assignments. The second part of this is the selection of educational materials, including sources used, the selection criteria used, and the creation of custom materials. Finally, the interview guide ends with a discussion on the success of CT education at the schools, including teachers' experiences, the expectations of students, and areas for improvement. The guide can be found in Appendix A.

Schools were asked to provide documents they used as part of their CT education. This included existing documents used to guide lesson contents, or documents written for that purpose. To be included, documents needed to be at least partly written by school staff, and as such unaltered copies of materials from other sources were excluded.

The resulting data consisted of five audio recordings of interviews, and six documents, five of Word format and one of Excel format.

3.4 Analyses

For the analysis of the data, thematic analysis (Braun & Clarke, 2006) is used. It is a versatile approach applicable to many study setups (Morgan, 2022). The method involves labeling relevant pieces of text with terms relevant to the research questions, extracting overarching themes arising from these labels, and summarising these themes. In this study, a reflexive approach is used, in which labels are created before the start of data analysis, but can be split into smaller parts or renamed if this fits the data beter (Morgan, 2022).

The first step of analysing the data consisted of transcribing the interviews. The contents of the interview are transcribed in an 'intelligent verbatim transcription' (Streefkerk, 2019), which means that stop words are excluded, and malformed sentences are fixed.

The second step consisted of selecting the relevant parts from the data. This was largely unnecessary for the transcribed interviews, as the contents broadly follow the interview guide. For the documents this step entails more: the relevant pieces of text could be included together with other, irrelevant pieces. The relevant pieces were those that mention CT education, programming lessons, or the schools' approaches to the former two. Examples of irrelevant sections are those related to internal school organisation or communication, or approaches to other courses. These pieces were removed and not included in the rest of the analysis.

The third step is the labeling of sections of text in the transcribed interviews and documents. A list of relevant terms, broadly matching topics included in the interview guide, was created as a starting point. During the analysis, a logbook was kept in which changes to labels were documented, allowing these changed labels to be applied to previously analysed data. Once labeling was complete, the labelled sections of text were extracted and organised per by label.

The fourth step is the search for themes that arose from the data and labels. In this step, labels are combined into potential overarching themes, and corresponding pieces of text were gathered together.

The fifth step was the evaluation and refining of themes. During this step, themes were reviewed on whether they really were themes that were present in all data, split up or combined if this represented the contents of the data better. Finally, themes were renamed to better represent the main essence of the theme.

The final step was the reporting on the themes. A summary of the contents, as well as level of consensus between participants and documents from different schools was written per theme. Particularly illustrative sections are quoted to provide examples of the themes.

4 Results

4.1 Interview Analysis

In total, four overall themes were identified in the interview data, relating to the teaching of CT and the selection and/or development of educational materials, and the perception of available SLO materials by teachers. Most of the themes identified seem to have a clear consensus between all participants. However, some differences in opinion exist in the details of the themes. This section reports and summarises the opinions and level of consensus surrounding these themes. The first theme is the request for support from organisations like the SLO, in the form of improvements to available SLO materials by providing specific materials and resources, such as accessible lesson plans and help in meeting educational goals. Then, the approaches to the selection of educational materials is discussed, including the finding, choosing, creating, and preparing materials; how the adaptability to the situation in the schools is an important aspect; and how integration in other lessons plays a part. Finally, one theme is that appears to be a limiting factor is the motivation and skill of teachers, where time constraints play an important role.

In reporting the opinions of participants, authors of the citations will be distinguished with labels I1 through I5. In the citations, the subject of anaphora is made clear by providing the meaning in square brackets, and the cutting out a diversion or explanation not relevant for the identified theme is denoted with '[...]'.

4.1.1 Request for Support and Resources

All participants agree that there are opportunities in what the SLO provides, with a general consensus that what is currently provided is not enough for most general primary school teachers.

All participants say they are aware of the SLO and its goals, and also of the information it provides. For example, I1 mentions that "*[the lesson plans] are based on SLO*", and I2 says that "*I am aware of the lesson contents of the SLO*". At the same time, there are several ways in which participants think the SLO can improve their materials: a clear and concrete description of goals to be met, descriptions of the important areas in education, and the use of checklists.

More clear and concrete goal descriptions First, there is a consensus that more concrete descriptions of goals would help teachers who teach CT lessons. Some participants mention the current available materials of the SLO, and how it is not concrete and concise enough, and some state that they hope the SLO will improve the published guidelines in this way. For example, one participant mentions that teachers don't know what to do in their lessons with vague descriptions of goals. They added that one way the information can be improved is to include practical examples of each of the goals. Multiple participants compare the SLO materials unfavourably to materials by other institutions, especially with regards to the clarity of the goal descriptions (I3: "*[another institution] worked out all goals much better and neat than the SLO, [...] they described the goals in much more detail*"). Others state that currently the work of creating a clear enough guideline falls to the teachers themselves.

More guidance in identifying important areas of education Apart from more concrete goals, the areas of interest are lacking. This is something that is mentioned by all participants. For example, one participant thinks that there is an opportunity to help teachers with less knowledge of CT get started (I1 "*It would be nice if you know which way you need to focus on. Now I know this after so many years of experience, but if you just start [...], there could be done more to make it easier*"). It follows that increased clarity of description would help teachers with knowing what they need to focus on in their education. Participants again mention that they have to reach out to other sources because of a lack of clarity. There is also a critique on how elaborate the material currently is, with one participant stressing that the curriculum description should fit on a single A4 page. All participants express that they hope the SLO steps in to provide this material.

Accessible lesson plans to help getting started All participants mention that the lack of accessible, readymade materials that allow teachers to get started quickly are a barrier to CT education. Practical examples are mentioned as a possible improvement (I1: "*with examples of how to implement it in practice, [...] that has the greatest chance of succeeding*"). Multiple participants again mention that they need to reach out to other organisations for lesson plans that are accessible and readymade (I2: "*Yes, we do run into [teachers not knowing what to do]. Then we use 'Digi Doener', which provided readymade accessible lessons*"), with others stating that they needed to make their own readymade lessons to help teachers with less knowledge of CT (I5: "*Most teachers, practically speaking, don't have knowledge [of CT]. If you make a curriculum [...], and you create lesson plans, teachers can do it*").

Checklists for lesson contents and goals As part of the additional guidance, participants all mention that checklists are useful, or even a necessary part in offering CT education. In this context, checklists are lists of topics and/or skills that can be used by teachers to check which parts of CT are included in their lessons. For example, one participant mentions that they needed to create checklists so that teachers would spent enough time on CT lessons. Others state that they currently don't use checklists, but want to have checklists because they allow teachers to make sure they include all required topics in their lessons (I1: "*We don't use it now, but it is a solution for looking at if we meet the goals, and allows you to check this on your own*"). Another participant mentions that assessment of students is hard because there is no list to check off their skills (I4: "*You want to assess, [...] but there is nothing on paper, and the curriculum is not there. You can't check it off of a list yet*"). While all participants agree on the that currently having checklists is useful, one participant relativizes their necessity (I4: "*The thing is, I wonder if it is even necessary to check off these things. [...] I think you have to look at skills, more than [checklists]*"). Of all topics where a request is stated for additional resources and materials, this is the only area where participants express explicitly contrasting opinions.

Help in meeting educational goals All participants mention that they want to meet educational goals. All participants mention that having the central education goals for CT ('kerndoelen' in Dutch) made explicit would help them personally. For example, one states that the goals would help them to improve the CT lessons and the CT curriculum they currently use (I1: "*I would like the kerndoelen, to integrate them, and look at what of our offering meets the requirements and what are we missing [...]*"). Others mention that having the goals would make explaining the need of CT in primary education to colleagues easier. Some have stepped in individually by providing their own version of the goals to be reached, for example by constructing an outline of the CT topics—that are published, in contrast with the central goals—per grade, and creating a checklist with the goals that teachers should aim to reach.

Other possible areas for improvement There are other areas that are mentioned as opportunities for the SLO to provide, but these are not mentioned by all. Multiple participants mention that the overwhelming amount of material offered through various sources is a barrier. For example, one participant describes that one would "*end up completely crazy*" (I4) if one looks for material and sees how much material can be found. Another mentions that the general primary school curriculum is already overly full, and having to delve into the CT materials is impossible because of time and effort constraints. The jargon used in the offered CT materials also seems to be counterproductive. Multiple participants mention that used language and jargon need to be simplified. For example, one participant mentions that the terms the SLO material uses are "*far too specific!*" (I4) for teachers with no relevant CT experience. Another states that some teachers are so unfamiliar with the term 'Computational Thinking' that they don't know how to pronounce it. Finally, some participants mention that explicitly identifying CT topics that are already discussed in class would help with the apprehension some teachers have because they doubt their expertise or ability to introduce yet another topic into their education. These areas were identified as areas where improvement is possible and wanted by only part of the participants. It has to be noted, however, that there is no explicit disagreement on any aspect of these areas, even if they are not identified by all participant.

4.1.2 Contents of CT Lessons

The content of CT lessons determines the materials that are used. The content of lessons—influenced of course by participants' own definition of CT—is relevant to include here to inform the other topics related to selection of materials. For the contents, all participants mention that programming is an essential part of the CT education toolbox. Algorithmic thinking is mentioned by all. For the levels of application, all participants mention that they use both plugged and unplugged practices in their education.

The place of programming in the CT curriculum All participants agree that programming is part of the CT toolbox. Some state this explicitly (I4: "*I think programming is part of CT*", I2: "*If you are programming, you are working with CT*"). Others do not say that programming is the same as CT, but they do state that programming is necessarily part of what they want to offer within their CT curriculum. One participant also notes that while programming is only *part of* CT, it is very useful. Furthermore, programming is identified as an activity that should be offered as part of CT education, to any students that are interested in it. Another mentions that sometimes students can get demotivated by the activities that are included in CT lessons, but programming is much more likely to interest children. However, one participants notes that programming, while part of CT, "*should not be the goal, definitely not in primary education*" (I4).

Algorithmic thinking One of the first things that participants mention when asked for the definition of CT is problem solving through algorithmic thinking. Sometimes algorithmic thinking is not named explicitly, but the comparable concept of step-by-step procedures is mentioned in that case.

Knowledge of concepts and practices Participants show a large variation in their understanding of the terms 'concepts' and 'practices' in the context of CT. All participants mention apprehension about using these specific terms, because of lack of understanding or disagreement on the way they are used and described. Some participants recognised these terms, but only after being provided with examples of what they entail. One participant, when presented with a list of the concepts that the SLO uses, states that her lesson plans don't incorporate those concepts specifically. Other participants, in contrast, are more familiar with the concepts and practices included in CT, and think they are important to incorporate in education. However, one participant notes that while the concepts are used, "*they are not goals, only tools*" (I4); specifically that students should be able to apply CT in their daily lives but the concepts should not be assessed on their own.

4.1.3 Finding and Choosing Materials

For the selection of educational materials for their lessons, participants name several topics. The search for, and selection of educational materials is influenced by a lot of factors. These include the choice of sources while searching for materials, and the selection criteria that are used to navigate in the large amount of different offered materials.

Sources of CT materials For the finding materials from sources, all mention that they look for materials on web sources. For example, one participant names websites as a resource for information and materials, but also for inspiration for their own lessons. LinkedIn is named, as are websites with an educational goal (I2: "*Code.org, Codeclass, Wikiwijs, Kennisnet*". Another source of information is the learning from colleagues. This is a dynamic that has is two-sided; one participant mentions using the posts of colleagues in the field on sites like LinkedIn to gather information, while another participant mentions that they are the one to provide information to colleagues (I2: "*I update my colleagues monthly with a mail on developments in the CT world*"). The use of trade magazines as source is mentioned by one participant: Vives (magazine on education innovation and IT), and KOS (magazine on digital education). Conferences are mentioned as a source by multiple participants, for example one partipant mentions the BETT conference in London (on education technology) as inspiration because the newest developments are presented there. Another one mentions an education technology conference held every year which is used to look for possible materials, because IT companies use the conference to present their new materials. However, it should be noted that one person thinks that while conferences are a great source of learning about available materials, you would learn more from visiting applied technology conferences than educational technology conferences (I4: "*You need to go not to an education conference, but to a conference with innovative technology in for example medical care*"). The reason this participant gives is that they think CT education should focus on the *application* of technology that involves CT, rather than CT as a separate skill.

Selection criteria For the selection criteria, one aspect is mentioned as important by all: adaptability and integration in the school situation. The participants mention many different criteria related to the adaptation in the school situation. For example, multiple participants state that they look at how the material can be integrated in the way the CT lessons are currently done at their schools (I4: "*I constantly keep in mind: how do I apply this in my own lessons?*"). Others think the materials should fit the goals that the teachers want to reach with CT education (I2: "*What do you have in the school? What can you do with it, how will we use it, is this what we were looking for?*"), while another looks at how the classes can be extended with materials. This can influence the choice on whether to make use of pre-made structural lesson plans covering all grades. Specifically, one participant states that they don't like to chose a method plan without adapting it, and instead "*you need to start the conversation, especially with these subjects research, and look for how it fits in your school and classroom*" (I4).

There are several criteria that are mentioned, but only by some. For example, costs are identified as a barrier by multiple participants (I2: "*I bought stickers [for a CT lesson], but that costs loads of money to buy constantly, so I stopped doing that*", I5: "*I would like to use more VR glasses, but they are too expensive*"). Another barrier mentioned by some is that effective selection of CT materials is hard without the knowledge on CT. For example, one participant states that while they have built up the required experience with CT over the years, others who have not will have trouble searching. Another criteria mentioned by a multiple participants is whether the material can interoperate effectively with the current materials in the schools.

Finally, there are some areas where opinions differ. The the inclusion of CT concepts and practices in the materials is one. For example, one participant states that they selected specific material because it addresses concepts and practices, while others do not look for concepts and practices at all when searching for materials. As discussed in subsubsection 4.1.1, some people have expressed the need for readymade, accessible lesson plans. But there are different opinions in whether readymade methods are a good idea in the end. Some use mostly readymade lesson plans, while others don't like to use them. Some think readymade plans can be used, but need to be adapted (I3: "*I don't like to just buy a method plan, and then you're done. You need to start the conversation, especially with these subjects research, and look for how it fits in your school and classroom*").

It is clear that the consensus is that there is enough material available, and there are many different criteria to select which materials to use. Most criteria are mentioned by all participants, but some participants name specific criteria that are not mentioned by others.

Creating materials Participants agree that now is not the time to create their own materials. All participants agree that there is enough material available to fill lessons, and several participants also give other reasons for not creating their own materials, either due to time constraints (I5: "*creating all your own materials costs a lot of preparation time. And that is completely unworkable*"), because the material they have available is saturated already (I4: "*I am complete. [...] I don't need any more*"), or because it is too soon in the planned implementation of CT in the school curriculum (I1: "*I'd like to develop my own material, but at this point I am busy with creating a structure, and look at 'what is available' before I get to creating my own materials. That is a next step*").

Integration in other lessons Integration is mentioned as an essential part of CT education by most. All participants already use integration of CT in other lessons in their education, and one person describes a wish for further integration because the current integration is lacking (I2: "*If they teach [CT], it is framed as 'here the teacher comes to give a single lesson'*"). Similarly to how adaptability to the situation in schools is mentioned as a factor when choosing materials, ability to integrate is noted to be important for educational materials (I4:"*So mostly, how do I use it for algebra, mathematics, Dutch language. I always keep in mind 'how can I use this for that?'*"). Most participants note that integration of CT in other lessons works better than giving separate CT lessons, for example by showing students understand what CT can be used for in their lives. One participant even states that integration in other lessons needs to be done, otherwise CT education will never be effectively implemented.

Other reasons are given for the importance of integration of CT in other lessons. One participant notes that integration could help improving teachers' motivation (I3: "*SLO and Kennisnet are used, but people get demotivated because it is too much [...] and if you could combine it with current lessons. That has the greatest chance of succeeding.*"). Other participants note that time constraints can be alleviated (for example, I4: "*integration is important, because otherwise if we include it in the schedule everyone would say 'I don't have time for this'*"). Another person mentions that integration could help bring the lessons of other courses up to date the standards of today (I4: "*a very nice way to make lessons more fitting in today's world*"). The stated advantages differ, but there is overlap and I see here that most have articulated clear reasons for their opinion on the importance of integration.

4.1.4 Motivation and Knowledge of Teachers

The motivation, knowledge & skills, and available time of teachers is identified as a barrier to CT education by all. Most teachers are not knowledgeable and skilled enough. This is the one topic all participants agree on, and emphasise during the interviews. To start, multiple participants note that teachers are sometimes completely unaware of CT (for example, I5: "*[...] most teachers,* *practically speaking, don't have knowledge of [CT]*". All participants subscribe to the idea that more education is needed for teachers. For example, one participant hopes that teachers will educate themselves ("*[...]I hope that some teachers will take the time to educate themselves in [CT]*"). This lack of knowledge is identified as a problem by all participants. Teachers have trouble understanding SLO materials, they are apprehensive about their competence and won't do CT lessons (I4: "*This is where competencies of teachers come into play. If they are not adequate, there is apprehension, and they won't do [CT lessons]*")

These problems can be alleviated somewhat according to participants. For example, one person mentions that integrated CT lessons can help with introducing CT lessons even if teachers' skills are inadequate (I5: "*most teachers, practically speaking, don't have knowledge of [CT]. [...] if you make an [integrated] curriculum with a robot, and you create lesson plans, teachers can do it*"). Identifying which areas are already included in teachers' lessons can help put fears about extra time costs CT would introduce to rest (I4: "*If you identify, and tell teachers 'you're already doing programming', you're already doing it'. Then that would sooth fears*").

Apart from normal teachers, a person with the responsibility of CT education can be introduced in schools. The opinions differ on whether a single person is enough for this. One participant thinks that creating a curriculum should be a group process (I4: "*it cannot be done by a single person, not even the school leader. A working group needs to be created, with teachers from different grades, who will determine the direction to follow*"). Others think that having at least one person tasked with working on the CT curriculum is already a very important step (I3: "*A great development is that every school has at least someone with knowledge on IT, who has some working hours apart from their normal teaching to do things with [CT]. That is a direction we went to a couple of years ago, and I welcome it*").

4.2 Document Analysis

As part of the document analysis, six documents from two schools were analysed that were used in schools to guide their CT education. Not all schools created or used documents. In total, three schools expressed that they used documents to guide their education. However, one school did not create these documents but gathered various lesson plans from other sources. As these do not inform on the school's approach to their CT education, they will not be included in this analysis. Consequently, documents from two schools are included. The authors of the documents will be distinguished by labeling citations with D1 and D2. In the citations, the subject of anaphora is made clear by providing the meaning in square brackets, and the cutting out of a diversion or irrelevant explanation is denoted with '[...]. For documents using tables or visually placed forms of text, the relevant parts are summarised instead of directly quoted, in order to preserve context.

Description of documents First a short description will be provided of the materials used. The first school uses documents to directly guide CT lessons. There are two documents listing specific educational materials, which are divided into plugged, unplugged or hybrid activities, and connected to specific grade levels. There is also a lesson plan describing plans for when to work with specific materials. These documents as a whole discuss digital literacy, but also contain parts specifically discussing CT. The second school used and made available for analysis four documents. One is a single lesson plan similar to the one the first school uses, and three others are ambition, policy, and vision plans for future school years. Again these documents all discuss digital literacy as a whole, but contain parts specifically discussing CT. An overview is provided in Table 2.

Table 2: Documents analysed

Description
D1: Structured lesson plan connecting materials to concepts and grade levels
D1: Planning for digital literacy lessons (unfinished, a work in progress)
D2: Explanation of digital literacy terms and a structured lesson plan
D2: Description of specific goals regarding the implementation of digital literacy education
D2: Description of policy and approach to policy regarding digital literacy education
D2: High-level description of the vision and aspirations regarding digital literacy education

Some extra context needs to be mentioned: there is a difference in the way the documents are meant to be used. For school D1, the documents were made by an IT coordinator responsible for CT education in the school, for personal use. The consequence is that the documents mostly describe the contents of CT lessons. In contrast, all documents made available by school D2 except for the lesson plan were used for internal communication and planning of future education.

4.2.1 Lesson Plans

The lesson plans are the single type of documents used in both schools.

CT Concepts and Programming Both relevant areas of the documents are formatted as a table, and both identify separately several aspects of CT which broadly match 'concepts' of CT. For example, both mention thinking in steps, instructions, and thinking in binary. Both also mention programming separately from the CT concepts, with ScratchJr and Scratch being used.

Brands of Educational Materials Both documents mention specific brands of CT educational materials, such as Beebots, Bluebots, and Microbits. These are mentioned for use in specific grades in both documents, but not linked to the concepts described earlier.

Levels of Application of CT The final aspect in which both documents are similar, is in the inclusion of all levels of CT application at the level of plugged, unplugged and hybrid, corresponding with the levels of application that were chosen to be used in this study. Lessons consisting of programming in the block-based programming languages Scratch and ScratchJr are plugged activities, fully digital. All further brands of CT educational materials are hybrid, combining digital electronics with physical effects. Finally, both mention unplugged activities. D1 uses books and board games such as 'Scratch Unplugged', a physical representation of the Scratch programming language. D2 describes activities that involve CT but are unplugged such as 'playing grocery store' and the 'peanut butter challenge', the latter of which is also mentioned by D1.

4.2.2 Ambition, Policy, and Vision Plans

The remaining documents are all provided by school D2. The themes that appear here are the education of teachers by the educational team, the definition of CT, helping teachers identify the ways in which they are already including CT in their lessons, and finally the integration of CT into other lessons.

Staff Responsibilities First, the documents state that it is the responsibility of the educational team to do research and educate other teachers on the topic of digital literacy, and consequently CT. They state who is responsible for ensuring CT education is offered correctly: "*educational goals of the SLO are implemented. The IT team ensures that the educational goals are integrated in the projects*", "*The grade coordinators ensure that the year planning includes two weeks of CT for each grade*". A further example is found in giving the IT coordinator the responsibility of "*innovating related to CT, planning in hours for this purpose, and keeping the rest of the school up to date*".

Education of the teacher team Also stated in the documents is how teachers are educated in CT by the educational team. For example, a stated goal is that all teachers in will be educated on what CT entails, by having the educational team raise awareness of what CT related activities are done, or planned to be implemented at the school. Specific time frames are specified for when teachers will be educated. For example, in the next school year (2024-2025), the documents mention that study days will be organised to educate teachers in CT, and to provide inspiration and examples for CT lesson plans. Two educational platforms are named, which were mentioned during the interviews as providing readymade lesson plans (Digi-Doener and Edu Winkel app).

Definitions of CT-related Terms The SLO definition of CT is explicitly used for D2's definition in both documents where it is mentioned. Consequently, CT is correctly identified as a separate aspect of digital literacy, and digital literacy and CT are listed in a section on the importance of 21st century skills. A reason given for this importance is that it gives children experience with modern technology: "*We think it is important to give the children guidance on how to get started by themselves with practical IT skills and CT*".

Identifying CT-related content already implemented The importance of identifying the areas in which CT is already included in lessons is mentioned: "*CT is already done in kindergarten. It is important that teachers are ware of what they are already doing. Like laying patterns, playing grocery store, building in the crafts area, and smartphone games".

Integration of CT content in other lessons Finally, while it is clear that there is a lot of attention to CT education, it is not integrated in the rest of the curriculum: "*We plan a week of*

CT education every year for each grade. The other [digital literacy] goals are included in projects". This corroborates the relative lack of integration in the curriculum that was stated in the interview.

5 Discussion & Conclusion

The goals of this study were understanding the approach schools that currently teach CT have to their educational materials, understanding how teachers view SLO materials, and identifying lessons that can be learned from this. To reach this understanding, staff at various primary schools that offered CT education were interviewed, and schools were requested to provide documents they used to guide their education. The participants in interviews were the main people responsible for developing the CT curriculum at their school, and provided extensive information about their experiences in building the curriculum. By analysing the interviews, several themes were identified which appeared in the experiences of all participants. While not all schools provided, or even used documents in their approach to education, the documents of those that provided them were analysed in a similar way. The results of this analysis allow us to answer the research questions for this study.

5.1 Approaches to Teaching CT and Selecting Educational Materials

The first research question revolves around the teaching of CT in primary schools and the approach to the selection and use of educational materials for this purpose: "**How is computational thinking taught in primary schools, and how do schools select the educational materials?**".

Teaching of CT The exact form of CT of how CT is taught differs greatly between schools, but some important commonalities can be found. For one, it is clear that most schools give the responsibility for creating the CT curriculum, and for keeping up with innovations in the field to a single person. This person was the one to be interviewed in all cases. Consequently participants were knowledgeable on the topic of CT, and worked out the CT curricula at their school competently. However, the knowledge, skills and motivation of other teachers is clearly a large barrier to effective CT education. Participants mention that in their experience, some teachers are not even aware of CT. Furthermore, teachers who doubted their own competence can be hesitant, meaning that CT lessons are not done at all. No large differences in definition and contents of CT educations were identified between participants and the literature. For example, all participants consider programming to be part of, but not equivalent to CT. Similarly, all participants mention algorithmic thinking, or the comparable concept (Selby & Woollard, 2013) of step-by-step procedures as one of the first skills when asked what CT is to them. The approach of involving 'concepts and practices' in CT education, used often in the literature, is less clearly apparent, with some participants needing examples before recognising terms, while others explicitly use the terms when thinking about the CT lessons they create. The documents analysed support this, with the lesson plans provided by two schools connect specific educational materials to concepts and practices. Although many studies were done on teacher education, including the development of several frameworks for educating teachers in CT, the general lack of knowledge and skills apparent in both this study and the literature suggests that the implementation of this education is not yet adequate. The literature also mentions a lack of basic IT skills in teachers, which could be a cause for the inadequate knowledge of CT among colleagues as expressed by the participants. This lack of IT skills might also negatively impact neighbouring fields of education making use of IT.

Finding Materials It is clear there are a lot of factors influencing the selection and use of educational materials. One of these is the sources used to find the materials. Participants all mention they use multiple different sources, so it is clear that they do not think one source provides an adequate amount of suitable materials. Also apparent is that the SLO is not mentioned as a source for educational materials, although it is used to gather general information on the topic of CT. Sources providing material explicitly focused on CT are named, such as Wikiwijs (freely available lesson plans, including for CT). But participants are proactive in their search for materials, and also look into sources that are not explicitly focused on CT. Examples include LinkedIn, trade magazines, and conferences. It is clear that to the participants, these sources provide added value over more traditional sources for educational material. The wide variety of sources used for finding educational materials could be contributing negatively to the time constraints of teachers, as navigating many different sources costs a lot of time. Additionally, with non-traditional resources the quality and completeness might not be clear to teachers: checking for this costs extra time, and might not be possible for teachers that do not have enough knowledge of CT. Furthermore, the time and effort it costs to find materials might be a larger hurdle if the motivation of a teacher is already low. Consequently, it is understandable that both participants and the literature identify time constraints as an important barrier to effective education.

Selection of Materials The overabundance of materials available was stated to be a barrier to choosing educational materials in both the literature and by participants. However, all participants have developed extensive selection criteria to narrow down the selection. The most important criteria is the ability to integrate materials into the school situation. The manner in which this integration is wanted differs in details. For example, participants mention fitting materials in the current manner of education, suiting student skill levels, helping to reach educational goals defined by the school, and extending existing lessons. The integration and adaptability is mentioned as a reason for not using readymade lesson plans by educational publishers, although on the other hand the ease-of-use of materials such as these is also considered. The ability to be integrated into lessons of other courses is also a very important criterium, because most participants think that such integration is essential for effective CT education. Further criteria mentioned are purchasing/licencing costs, ease of use and integration with other technology. The literature showed that a focus of materials on the greatest common divisor of students negatively effects CT education. Participants do not mention this aspect literally, but it is included in the criteria of suiting student skill levels. This suggests that one way in which the focus on the common divisor affects education is the increased time costs and required knowledge to select the right materials; and teachers without enough knowledge and time might choose materials that do not suit all students' skill levels.

5.2 Perception and Use of SLO Materials

The second research question concerns the relation that teachers have with SLO materials: "**What is the perception of teachers of available SLO materials, and how do they make use of it?**".

It is clear from the interviews that the current approach to CT education participants have is not always supported by the SLO, and sometimes even hindered by it. The SLO material seems inadequate to support 'normal' primary school teachers who have no experience with CT. When asked to identify areas for improvement, participants often express hope that SLO materials will be improved in some manner, or compare it unfavourably to materials made by other institutions. Wishes are expressed for more concrete descriptions of the learning goals, and more guidance on what areas of education to focus on. Publishing checklists containing educational goals and topics to include in lessons could help with this. So there is the general idea among all participants that SLO materials could be expanded.

However, at the same time a need for more accessible and less elaborate materials is expressed. For example, the amount of information made available by the SLO can be overwhelming, similar to how the overabundance of offered materials hampers the selection of materials. The use of jargon makes materials less accessible. The participants interviewed have enough experience to be at least acquainted with terms related to CT, but general primary school teachers are not as knowledgeable.

5.3 Lessons Learned

The final research question focuses on what conclusions we can make from the previous two research questions: "**What lessons can be learned from the relation between schools' approaches and the SLO materials?**"

From the interviews, lack of knowledge, skills and motivation of teachers is identified as an important barrier to effective CT education. It is also clear that there are various ways to fix or make up for the lack. For one,when competence is inadequate institutions such as the SLO can step in by providing materials that empower inexperienced teachers. Readymade lesson plans and more accessible materials can help teachers that are less knowledgeable or skilled with CT lessons. Checklists would allow teachers to check for themselves if they are meeting goals and discussing all topics. Documents in the form of concrete examples of how topics can be implemented in lessons can prevent teachers feeling out of their depth. Furthermore, educating teachers is a possible solution, as participants state that they are already learning from others or educating other teachers themselves. The ambition, vision and policy plan documents from one school show that the education of the teaching team can be structurally included in the school organisations. Collaboration between teachers of varying backgrounds while working on creating a CT curriculum would help in this case. This would allow experienced teachers to share their expertise with others, stimulate conversations about implementations of CT in multiple other courses, and create opportunities to work on guiding documents that can be used as a handhold during the implementation of CT into the wider educational curriculum of the school.

There are also opportunities for the SLO to help teachers navigate the overwhelming amount of offered educational materials. This could include example lesson plans such as those provided by the schools as part of this research. Such plans would combine solutions to many of the identified issues of current SLO material: such lesson plans are accessible, allow teachers to get started quickly, and also implicitly show what the areas are that the education should be focused around.

Finally, the aspect of motivation is something that should not be discounted. Participants in this study were generally very motivated, and the literature shows that this generally holds for most primary school teachers. Most participants worked on their curricula individually, but understood the importance of CT education and were able to built extensive, complete CT curricula while overcoming all identified barriers. Some participants were class teachers that took up the responsibility for the CT curriculum. But this raises the question of what happens to CT education if no one steps up? It is possible that less motivated teachers are not able to create an effective educational curriculum for the aforementioned reasons. Therefore, we should do our best to explain the importance of teaching computational thinking skills to both our teachers and students. One possible improvement might be found in policy: the inclusion of CT as a mandatory part of the general educational curriculum in many different countries suggests that policymakers already understand the importance of CT. It might be helpful for the motivation of teachers for policymakers to be more proactive in communicating to teachers why CT is so important that it is a mandatory part. Another can be found in the education of teachers. Both the literature and this study show that lack of knowledge can cause lack of motivation. Consequently, better education of teachers might increase motivation. This can be done for example by improving the education pre-service teachers receive on the area of CT, which is a topic that is the literature shows is currently taught inadequately.

5.4 Limitations of the Study

Although this study adds valuable insights to the literature, the goal was not to get results that would be generalisable for primary education in the Netherlands as a whole; a sample size of five is consequently not enough for this purpose. Additionally, the number of schools providing numbers was small even within the sample. Additionally, the selection of participants took no efforts to prevent sampling bias; the sample of participants studied is a convenience sample. The schools considered to be included in the study are located entirely around two neighbouring cities. Furthermore, participants taking part in this research were those who were both interested in CT and had the time available to conduct an interview. There is also a large variance between the functions of participants, from IT-coordinators to external contractors, but nothing is known about what functions appear more in the population. The topics that were mentioned during the interviews were also limited by both the guiding document and time constraints during the interview. For example, many opinions around identified themes were mentioned only by some participants, but it is possible that those who did not mention them did so because they could not think of it at the moment, or did not have enough time. The combination of a convenience sample with motivated participants in this study created the impression of a generally positive outlook on CT education. However, less motivated, or time-constrained participants could have more negative views on CT education, which are not present in this study.

5.5 Further Research

Further research can be done to understand the topic of this study better. Already barriers and opportunities were identified, but a study which is able to generalise all Dutch primary schools could identify the areas named most often which could be prioritised. Methods for conducting a more generalisable study are e.g. sourcing participants from a wider geographical area, or increasing the number of participants. Furthermore, the interview guideline could be made more extensive to include topics learned during this study, so that all participants have at least spoken about all topics.

This study gives rise to areas of interest for future work. Integration in other lessons was already identified in the literature as an essential aspect of CT education with a lack of research on the topic, and participants in this study also endorse the view that integration is important. This study shows that the lack of skills, knowledge and motivation of teachers is a large barrier to effective CT education, but participants have already been working on educating their colleagues. Further studies could look at how best to educate general primary school teachers. Finally, once the development of the curriculum is finalised, the status of SLO materials could be revisited because a lot might have changed since.

5.6 Concluding Remarks

It is necessary to prepare our students for life in a digital world with the necessary skills, of which CT is an important part. The education programme for teaching CT in Dutch primary schools is not yet optimal, but still a work in progress. To help schools without a comprehensive CT curriculum, this study sought to learn what lessons could be learned from schools that *do* already offer CT education. The findings will benefit researchers and creators of educational content, by having identified barriers and areas of opportunities that schools and teachers experience in their implementation of CT education. We hope that this thesis can be a starting point for further research and educational material development, to empower schools and teachers and teach our students CT effectively.

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A Interview Guide

Type: semi-structured interview

Inleiding

- Voorstellen interviewer en mentor/begeleider
- Verzamelen toestemmingsformulier.
- Ga een aantal vragen stellen die te maken hebben met onderwijzen van computational thinking + uitleg. aan de leerlingen wordt gegeven.
- Informatie is vertrouwelijk.
- Interview zal ongeveer een half uur tot drie kwartier duren
- Zal een geluidsopname van het gesprek gemaakt worden, nadat toestemming is gegeven.
- Bij het beantwoorden van de vragen kunt u eigen leerlingen in het achterhoofd nemen.

Wat is Computational Thinking?

In het geval van 'programmeeronderwijs':

Als er enkel programmeeronderwijs gegeven wordt, willen we weten of de leerkracht/schoolleiding bekend is met het concept van computational thinking.

> Wat verstaat u onder programmeeronderwijs?

- Bent u ook bekend met 'computational thinking'?
  - Zo ja,
    - Wat valt er volgens u onder het geven van computational thinking onderwijs?
    - Waarom biedt u dit onderwijs aan?
  - Zo nee, (. . . uitleggen)
    - Herkent u onderwerpen en vaardigheden in het programmeeronderwijs dat u geeft terug?

In het geval van 'computational thinking onderwijs':

Als wel expliciet 'computational thinking onderwijs' gegeven wordt, willen we weten wat dit inhoud en waarom.

> Wat is uw definitie van computational thinking?

- Hoe zou u computational thinking onderwijs beschrijven?
- Waarom heeft u gekozen voor computational thinking onderwijs, in plaats van enkel programmeeronderwijs?

Hoe Ziet het Onderwijs Er Uit?

Hier beginnen we met bovenstaande open vraag over hoe lessen eruit zien.

> Kunt u vertellen hoe een programmeerles eruit ziet?

> Welke **onderwerpen** (begrippen/concepten) komen aan bod?

- Hoe komen die onderwerpen terug in de lessen?
- In welke volgorde worden deze concepten behandeld?
  - (vervolgvraag) Waarom die volgorde? Is de volgorde opbouwend?
- (als deze niet genoemd worden) Herkent u de [[Computational Concepts]] zoals sequenties, loops, parallellisme, conditionals (voorwaardelijke stellingen), operatoren, data?

> Kunt u vertellen over de **opdrachten** die de leerlingen doen?

- Als er opdrachten zijn om te maken, welke vaardigheden worden hiermee ontwikkeld?
  - (vervolgvraag) Zijn er opdrachten gekozen om specifieke vaardigheden te oefenen / bij te brengen?
- (als deze niet genoemd worden) Herkent u de [[Computational Practices]] zoals experimenteren en ontwikkelen, testen en debuggen, hergebruiken en ombouwen, abstraheren en modulariseren?

Keuze voor Lesmateriaal.

Hier zijn we geïnteresseerd in de redenen voor het kiezen / ontwikkelen van onderwijsmaterialen zoals lessen, opdrachten, en thema's die gebruikt worden in de programmeerlessen.

> Welke **onderwijsmaterialen** gebruikt u?

- Als zelf ontwikkeld:
  - Hoe heeft u deze materialen ontwikkeld?
  - Wat was de reden dat u het materiaal zelf ontwikkelde?
  - Heeft u ook nagedacht over het gebruiken van bestaand materiaal?
- Als bestaand gekozen:
  - Hoe heeft u deze materialen gekozen?
  - Wat was de reden dat u dit materiaal koos?
  - Heeft u ook nagedacht over het ontwikkelen van eigen materiaal?

Succes

Hier gaat het nu over de indruk van de betrokkenen op het onderwijs. Hier halen we met name uit wat er goed gaat en waar nog verbetering mogelijk is.

> Wat is uw algemene indruk van het **geven van** dit onderwijs?

- Hoe ervaart u zelf het geven van de lessen?
- Hoe denkt u dat het onderwijs door de leerlingen ervaren wordt?

> Lukt het om het **lesplan** te volgen?

- Kloppen de verwachtingen die er van de leerlingen zijn?

  - (vervolg als niet genoemd) Specifiek: lukt het vooraf vastgestelde onderwerpen te behandelen, en vaardigheden bij te brengen?
- Hoe toetst men of deze verwachtingen kloppen?
- Lukt het om alle leerlingen mee te nemen in de lessen?
  - Lukt het alle leerlingen om op niveau te blijven, en vooruitgang te boeken?
  - Zijn / blijven alle leerlingen gemotiveerd en geïnteresseerd in de lessen?

Wat is uw algemene indruk van de **effecten van** het onderwijs?

- Wat is het belangrijkste aan dit onderwijs?
  - (vervolgvraag als niet genoemd) Welke doelen of effecten vind u het belangrijkste van dit onderwijs?
- Welke aspecten bent u heel tevreden over?
- Ziet u nog punten waar verbetering mogelijk is?
  - Wilt u meer ondersteuning vanuit instanties/schoolleiding etc.?
  - Komt u tijd te kort; zou het onderwijs beter worden met meer beschikbare tijd?
  - Zijn er aspecten van het onderwijs die u zelf belangrijk vindt, maar die missen in het beschikbare door instituties ontwikkelde materiaal?
- Zijn er dingen die u anders zou willen hebben, maar niet mogelijk zijn in de huidige opstelling?

Heeft u algemene opmerkingen of extra informatie?