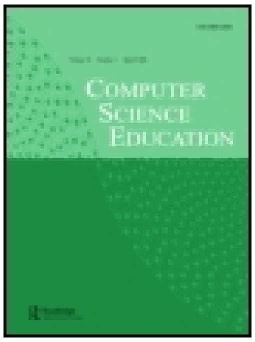

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Omnipresent yet elusive: Teachers' views on contexts for teaching algorithms in secondary education

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ABSTRACT

Background and Context: Although context-based teaching and learning has been investigated extensively in science education, little is known regarding the use of contexts for teaching CS in secondary education.
Objective: The aim of this study was to examine the characteristics of contexts suitable for teaching algorithms and to investigate teachers' considerations regarding those contexts.
Method: This study examines teachers' practices and reasoning concerning the use of contexts and is based on explorative, empirical research. Data were collected through semi-structured interviews with seven CS teachers and analyzed qualitatively.
Findings: The results of this study reveal several characteristics of effective contexts for teaching algorithms and show teachers' ambitions to address the variation within the student population when selecting contexts that advance students' algorithmic thinking.
Implications: The found characteristics may serve as recommendation for designing contexts. Development of teacher education and professionalization activities may benefit from the discussion of teachers' motives and concerns.

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Algorithms; algorithmic thinking; context-based education; secondary education; computer science teachers

Introduction

Improving students' meaningful learning is the goal of designing and applying new learning environments in education. A widely recognized and popular approach is to use authentic situations in which concepts are applied with the purpose of facilitating students' learning of conceptual content matter (Gilbert, 2006; Sevian et al., 2018; Taconis et al., 2016). In this paper, we refer to these situations as *contexts*.

According to Van Oers (1998), contexts support the "particularization of meanings" and brings "coherence with a larger whole" (p. 475). The idea is that introducing a new concept within a recognizable context provides for better understanding in two ways: first, the meaning of the concept is brought forward in more detail, thus eliminating ambiguities and second, a context can be used to tie the new concept to other concepts

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featuring in the used context. In addition to providing meaning to the abstract concepts, the use of contexts also aims to show students the relevance of new concepts.

In science education, the use of contexts has been described and investigated in depth (e.g., Bulte et al., 2006; Gilbert, 2006; King et al., 2008), and contexts have been confirmed to provide relevance and meaning to subject matter regarding science learning (Bennett, 2016). Moreover, many of the benefits of context-based education have been described in this literature. For example, contexts have been shown to be effective for motivating students (Bennett et al., 2007), increasing students' interest in science (Fensham, 2009), connecting school science with the everyday life of students (Bennett, 2003), promoting science professions as a future career for students, and increasing scientific literacy (Ültay & Çalik, 2012).

Considering the benefits of the context-based approach in science education, this approach has the potential to be effective for teaching computer science (CS) in secondary education, especially for teaching fundamental and abstract concepts such as algorithms. For a long time, the more fundamental concepts connected to algorithms and their analysis (e.g., efficiency) were exclusively taught in CS courses in higher education, where they are traditionally perceived as abstract and complicated (Schäfer et al., 2013). The same difficulties were seen after these fundamental concepts were introduced in secondary education (Gal-Ezer & Zur, 2002).

Algorithms and algorithmic thinking are seen as key concepts of Computational Thinking (Grover & Pea, 2018; Selby & Woollard, 2013). In recent years, the CS curricula for secondary education have been revised in many countries, which has given prominence to algorithmic concepts. Moreover, as research into digital literacy and computational thinking progresses (Lye & Koh, 2014; Voogt et al., 2015), further curriculum developments are expected and will even introduce algorithmic thinking in primary education. In his study of CS education in the school curricula, Passey (2017) argued that research is needed to examine approaches that support students' engagement with CS. Contexts may be useful to accomplish this aim because their use is assumed to provoke student engagement and interest (Gilbert, 2006; King, 2012). Therefore, the use of contexts to facilitate the teaching and learning of abstract concepts is undoubtedly worth exploring.

Until now, however, there has been a lack of research into the use of contexts for teaching CS in secondary education. Previous work on teaching CS using contexts has mostly focused on higher education (Cooper & Cunningham, 2010; Guzdial, 2010; Xu et al., 2008). In secondary education, the use of a context-based approach for teaching CS was addressed in the German project "Informatik im Kontext (IniK)" (Gramm et al., 2012; Koubek et al., 2009). The resulting IniK teaching units have a context-based orientation, with the intention to show the usefulness and relevance of CS topics. In their review of this IniK project, Knobelsdorf and Tenenberg (2013) suggested that further research is needed to investigate what makes a context "relevant" in the student's perception.

Furthermore, Pasternak (2016) investigated a contextualized teaching approach for a lower secondary education CS course. Results of his study suggested that teaching CS based on students' everyday life is possible. The only exception was that teaching programming in a specific context solely did not facilitate the learning of programming concepts. Therefore, Pasternak decided to temporarily leave the context out and instead teach programming “context-free” because students need to practice extensively to develop their programming skills.

In this study, we try to contribute to determining the characteristics of the contexts that are suitable for teaching fundamental concepts in CS, such as algorithms and the analysis thereof.

The field of CS has changed significantly over the past few decades, and consequently the discipline of CS education has also changed, as Tedre et al. (2018) described in their historical survey on the changing aims of computing education. Likewise, technological applications of CS have developed rapidly. The dynamic nature of CS poses challenges for both curriculum developers and teachers.

In the recent Dutch CS curriculum reform, concepts were specified explicitly but contexts were described in a generic way only, to make the curriculum more sustainable (Barendsen et al., 2016). Consequently, the selection of up-to-date engaging contexts was left to the teachers.

Moreover, because CS in secondary education is a relatively young subject and teaching materials are often “under construction”, CS teachers play an active role in further development of the subject. Many CS teachers tend to either select available materials themselves or develop their own teaching materials, and as such they play a key role in the selection of the contexts to be used in their classes.

This has driven us to investigate how CS teachers incorporate contexts into their teaching of algorithmic thinking. Moreover, by choosing a teacher’s perspective in studying context-based CS education, we aim to inform the design of professional development programs and other supporting activities for teachers.

This paper is organized as follows. We first provide the necessary background on contexts in science and CS education. Then, we formulate our research questions and describe the methodology that we have used in our study. We then describe our findings and we discuss the results. Finally, we present our conclusions, including a description of some of the potential applications.

Background

Context-based education

Contexts have been used in many subjects and a large number of studies have investigated the use of contexts for a range of content matter. In this section, we will refer particularly to existing research in the field of science education because the insights of these studies may contribute to our understanding of the use of contexts in CS.

A context-based approach in science education is characterized by the use of realistic contexts as a foundation for learning science with the purpose of providing relevance and meaning to the science content (Gilbert, 2006; Taconis et al., 2016). Context-based education encourages students to link science with the real world. For example, water quality is used as a context in the case study by Bulte et al. (2006). This unit for chemistry education has integrated different concepts that the students are required to know in order to test the quality of surface water in the neighborhood. By providing this context, the unit aims to contribute to the students’ understanding of how chemistry functions in society.

Although the practice of context-based education is usually more elaborated in science education, using real and diverse contexts is not a totally new idea in CS education. Some examples of the use of contexts that are relevant to students as real problems or issues from everyday life in CS education can be found in problem-based learning (Kay et al., 2000) or design-based learning (Kolodner et al., 2003). The previous work related to problem-based learning may provide some useful insights for the development of context-based learning in CS education. In this regard, King (2012) commented that both context-based education and problem-based learning highlight the importance of selecting contexts or problems that are relevant to the students' real lives. With problem-based learning, the students work on a problem that is "a challenging real-world task set in a realistic or authentic context" (King, 2012, p. 73). Likewise, in a study concerning foundation courses in CS using problem-based learning, Kay et al. (2000) reported "open-ended, authentic, substantial problems which drive the learning" (p. 113) as one of the characteristics of problem-based learning. In context-based education, these problems are used to provide meaningful learning environments to students and to relate the CS concepts to real-life. In addition, both problem-based and context-based approaches require concepts to be taught on a "need-to-know" basis, where new knowledge is needed to understand a particular context or problem. At this point, it is important to highlight that "not all context-based approaches are centred around a driving question, a problem or a project" (King, 2012, p. 73). Therefore, problem-based learning may be considered as a special case of context-based learning. This applies in particular for CS education, where authentic situations may be used for problem solving activities.

Problem-based learning has been utilized for CS education (e.g., in teaching theoretical computer science (Bednarik, 2004) or in a programming course (Nuutila et al., 2005)), resulting in greater motivation and more commitment from the students. Furthermore, the problem-based learning approach has been found to be useful in a programming course using game development (Martins et al., 2018). In a review of problem-based learning in computing education, O'Grady (2012) reported that the success of problem-based learning depends on good problems. However, the construction of these problems is hard and demanding for the teachers.

In the following sections, we provide an overview of prior work regarding the characteristics of contexts and the use of contexts.

Characteristics of contexts

To use contexts effectively, the first question is where useful contexts may be found and what criteria contexts need to meet to be effective for teaching and learning. Understanding the characteristics of contexts fitting the intended learning outcomes is a prominent topic in research on context-based teaching (Diethelm et al., 2011; Habig et al., 2018; Taconis et al., 2016).

Several studies have distinguished the types of contexts based on their source. In the German project "Chemie im Kontext (ChiK)", context-based teaching units have been developed based on questions from students' daily life, societal issues or science professions (Parchmann et al., 2006). Likewise, in a study on the design of context-based lessons by biology teachers, Wieringa et al. (2011) presented a variety of choices for the type of contexts and proposed a definition of context as "a realistic situation from students' own lives, from society or from professional or scientific practices" (p. 2439). Habig et al. (2018), in a study regarding the influence of context characteristics on students' situational interest, described the following three different "contextual framings": personal, societal and professional. These contextual framings correspond to the types of contexts as mentioned by Wieringa et al. (2011). The research by Habig et al. (2018) included the influence of contextual framings and the results of this research suggested that for less interested students, contexts from personal daily life settings are most effective.

In addition to investigating the source of contexts, previous studies have investigated other characteristics that play a role in determining effective contexts (e.g., Habig et al., 2018; Van Vorst et al., 2015). Van Vorst et al. (2015) reviewed the characteristics of contexts stemming from prior research, and suggested a framework with *authenticity* and *familiarity* of contexts as main elements. Authenticity involves being genuine and trustworthy. Authentic contexts might also be complex, consisting of many elements and relations between those elements. Habig et al. (2018) also acknowledged the role of authenticity. They pointed out, however, that "how 'authentic' a context is strongly depends on individual factors, such as how credibly the particular context is rated" (p. 1159). This highlights the difficulty in finding an effective context for a class of students.

Questions have also been raised on the role of familiarity for the effectivity of contexts. Some researchers emphasize the role of "common" contexts that are related to everyday life (e.g., Bennett et al., 2005), while others state that contexts should rather be related to uncommon or unique phenomena (e.g., Lubben et al., 1996).

Furthermore, Marks and Eilks (2009) introduced *controversiality* as a factor influencing a context's effectiveness. Building on the framework of science-technology-society (STS) education, Marks and Eilks (2009) developed a sociocritical and problem-oriented approach for chemistry teaching, suggesting that "the teaching approach must start with societally-relevant, current, authentic and controversial issues from within society" (p. 234). The significance of choosing a controversial context was confirmed in a case study of a lesson plan on shower gels and musk fragrances (Marks & Eilks, 2010). This context not only facilitates learning of the components used in shower gel and their chemical behavior but it also provides for a debate about the use of products and their potential effect on the environment (for example). According to the teachers who participated in this study, contexts should be authentic, controversial and *open for individual decisions* (Marks & Eilks, 2010).

Other research upholds the role of familiarity in determining characteristics of contexts. Diethelm et al. (2011) suggested *connection to students' everyday life* as one of the criteria for selecting contexts and advocated choosing contexts that have a "dinner-talk-ability"; that is, students will talk about the contexts and the lessons at home. Diethelm et al. (2011) recommended characteristics of contexts for the German context-based project "Informatik im Kontext (IniK)". This project featured "familiar" contexts, such as emailing and file sharing (Gramm et al., 2012). In the evaluation of the project, however, Knobelsdorf and Tenenberg (2013) concluded that such everyday life contexts are perceived as authentic and recognizable, but argued that at the same time it is unclear whether students are really interested in these contexts. Knobelsdorf and Tenenberg (2013) pointed out that the fact that students are surrounded by technology and use it daily does not automatically mean that they are eager to know how this technology works. Therefore, they suggested that a focus on *breakdowns* of devices or objects might create more interest for CS than just presenting the device or object as part of a familiar context. In a study with children aged 8–10 years old, Borowski et al. (2016) examined what contents and topics regarding CS interest 3rd and 4th grade students, and found that these primary school children are very interested in several areas of CS, especially computers and the Internet. However, we do not know of similar research in secondary education.

Although there is still a debate about the requirements of contexts, our literature review suggests that authenticity and familiarity are important aspects of the effectiveness of contexts. In particular, a "familiar" context reveals a connection to students' every day life but might not necessarily be interesting and engaging for students, therefore a "controversial" context might spark more interest.

Educational use of contexts

Several studies have investigated the use of contexts for teaching and learning, and also the effect of using contexts. Gilbert (2006) described the following four models in his seminal study on the nature of context in chemical education: (1) context as the direct application of concepts; (2) context as reciprocity between concepts and applications; (3) context as provided by personal mental activity; and (4) context as the social circumstances. These models differ in the way in which they contribute to meaning-making. For the first model, the context is used only as an illustration after a concept has been learnt. This model is used in a large number of courses, even if these courses are not presented as context-based (Gilbert et al., 2011). In the fourth model, context as the social circumstances, "the students and the teacher would see themselves as a 'community of practice', jointly working on a (series of) focal event(s) in a problem-centred way over a sustained period" (Gilbert et al., 2011, p. 824). Therefore, in this model, the context plays a much more prominent role in meaning-making because it defines the setting and the activities.

A number of studies have considered the effect of the use of contexts. Sevian et al. (2018) reviewed existing research on context-based learning and found that effects have been shown mainly in the development of interest in science (e.g., Bennett et al., 2007; King, 2012). Similarly, Bennett (2016) found that context-based approaches appear to have a positive impact on students' attitudes to science. In a review by Pilot and Bulte (2006) of five studies on context-based approaches for chemistry education in different countries, all of the studies were seen to report positive effects on students' experienced relevance when learning chemistry.

The existing research has demonstrated that the use of contexts is effective as a pedagogical tool to provide engagement and relevance. Furthermore, the aim of using contexts is to prepare students for participating in a rapidly changing knowledge society (King, 2012). Context-based teaching emphasizes that learning takes place in a cultural setting, and that meaningful activities play an important role in the development of higher order cognitive skills. This is in line with the sociocultural perspective of education (Vygotsky, 1978). Furthermore, the use of contexts is viewed as essential for enhancing scientific literacy. To acknowledge the relevant and motivational role of personal and social components in the enhancement of scientific literacy, Holbrook and Rannikmae (2007) proposed "that the teaching of science subjects is through context-based situations and not through the identification of essential content" (p. 1352).

Contexts for teaching and learning fundamental CS concepts

The context-based approach might be promising for supporting the teaching and learning of fundamental computer science concepts, such as algorithms. In the problem-solving process, algorithms are an intermediate product between a problem and its solution as a working program. For teaching algorithms, the context-based approach has the potential to be effective because it offers (similar to problem-based learning (Ellis et al., 1998)) challenging problems to students to engage them in the learning process.

Algorithmic problem solving enables us to reason about solutions in an abstract way. The term "algorithmic thinking" is used to indicate the abilities needed to construct and understand algorithms (Futschek, 2006). Teaching algorithms and algorithmic thinking to students in secondary education is nontrivial, especially when it comes to analyzing algorithms and analyzing the computability or decidability of a given problem (Dagiene & Jevsikova, 2012). Students appear to perceive these topics as abstract and complicated (Gal-Ezer & Zur, 2002). Furthermore, students do not seem to recognize the relevance of the efficiency of algorithms (Ginat, 2001). One can speculate that this is because they are made to work on simple problems with small amounts of data in which running time is not an issue.

The context-based approach that is used in science education may be a promising option for CS. Indeed, applications of CS can be found in many aspects of students' daily life, connecting immediately to core CS subjects such as "networks" or "security". However, results from context related research in the science education community do not automatically transfer to CS because there are fundamental differences between CS and other science disciplines. For example, the omnipresence of computing contexts mostly stems from technically involved artifacts that are developed in the discipline itself rather than "natural" phenomena that exist independently of the science professional's activities. For CS education, contexts from professional practices may be found in the field of design, which is a prominent aspect of CS (Denning et al., 1989). Moreover, the construction of digital artifacts can be seen as a context in itself, such as for developing Computational Thinking skills (Voogt et al., 2015). This is apparent in studies where a Scratch programming environment is used to learn CS concepts (Meerbaum-Salant et al., 2013) or to teach abstraction in CS (Statter & Armoni, 2016).

The differences between contexts for science education and CS become even more apparent in the characteristics of contexts suggested for IniK (Diethelm et al., 2011). In addition to the already mentioned characteristic of "connection to students' everyday life", Diethelm et al. (2011) suggested four other characteristics: multi-dimensional (not only related to CS, but also to economical, ethical aspects etc.), width (societally relevant), depth (solid knowledge of CS concepts is needed) and stability (long-lasting context). The first characteristic, multi-dimensional, may be significant for CS because CS is inherently connected to other aspects of our lives or society. Moreover, CS applications seem to be interwoven with other fields and interdisciplinary subjects are common (e.g., bio-informatics, physical computing, computer graphics). Likewise, the characteristic "stability" may be exemplary for the unique nature of contexts for CS. Contexts in CS are rapidly outdated, which underlines the significance of long-lasting contexts. For example, in the study by Diethelm et al. (2011), an MP3-player is mentioned as a context that all students were familiar with. This has changed over the past years and now very few if any students own a MP3-player. Therefore, "stability" for CS contexts may be elusive or even nonexistent.

While contexts for CS might differ from contexts for science education, the use of a context-based approach might be effective for teaching algorithms. Given that the teaching of algorithms in secondary education is perceived as problematic, the use of a context-based approach might improve this teaching because of its contribution to giving significance and meaning. Traditionally, number-theoretic problems play an important role in contexts for CS, such as finding a maximum in a set of integers (Haberman et al., 2008). However, whether such contexts help to interest and engage students is debatable. In addition, most characteristic problems in CS are not as well-defined as such mathematical contexts. Rather, CS can be framed as a "science of information processes and their interactions with the world" (Denning, 2005, p. 27). Problems in CS are often quite open, requesting creativity to find solutions. Therefore, Romeike (2008) presented a teaching concept that focuses on challenges that provide students with choices by contextualization and personalization.

Therefore, although the context-based approach may be promising for teaching fundamental CS concepts, additional research is relevant to investigate the characteristics of the contexts that are useful for teaching algorithms.

Role of teachers

Teachers play an important role in educational innovations, reforms or changes (Janssen et al., 2013; Ryder, 2015). For any innovation to become successful, a thorough investigation into the knowledge of teachers is required (Verloop et al., 2001). To empower teachers in context-based chemistry education, Stolk et al. (2016) provided a framework discerning two aspects for which teachers need to be empowered, namely: teaching and designing of context-based teaching units. Stolk et al. (2016) examined to what extent such a framework empowers chemistry teachers for teaching and designing context-based education, and they observed teachers who taught a pre-developed context-based unit and developed new material collaboratively. This study concluded that teachers experienced difficulties when teaching context-based chemistry lessons and with creatively designing a new context. In addition, this study found that teaching a context-based unit does not sufficiently inform teachers to creatively design a new context-based unit.

According to Fensham (2009), teachers can be expected to be well-equipped to envision when contexts are relevant and engaging for their students. Moreover, Fensham (2009) suggested that it is easier for teachers to engage their students when the teachers use a topic that they have chosen themselves. However, our preliminary study indicated that teachers seemed to disagree – they pointed to their own limitations and suggested a more active role for the students in finding contexts (Nijenhuis-Voogt et al., 2018).

A match between concepts and contexts can be established in two methods: the teachers can either search for a context that suits a specific chosen concept, or they can start with an interesting situation and focus on all concepts playing a role in this context. The IniK working group used both methods when developing context-based learning arrangements (Gramm et al., 2012), starting with either context or subject matter. They concluded that although both of these methods might work well, it might be challenging to decide what subject matter to teach when taking a context as a starting point because some contexts are connected to a multitude of concepts.

Teachers' practices and considerations regarding teaching fundamental CS concepts with the use of contexts might be impeded by the fact that the concept of algorithms is difficult to teach (Dagiene & Jevsikova, 2012; Gal-Ezer & Zur, 2002; Ginat, 2001). Dagiene and Jevsikova (2012) suggested that simplified key issues of algorithms (e.g., computability) can be introduced in secondary education, as long as teachers are sufficiently qualified. However, this might be problematic because CS teachers come from a wide variety of backgrounds. CS is still a relatively new subject in education and CS teachers might have been retrained from elsewhere to teach CS. Hence, teachers without a CS background might lack the required content knowledge.

Aim of the study

Prior work provides evidence of a prominent role for teachers in selecting and using contexts, which indicates that a review of teachers' ideas is of interest. This study takes the practices and pedagogical reasoning of teachers who report using contexts as a starting point. By examining the teachers' reported practices and their reasoning, we aim to obtain a deeper understanding of the characteristics of context-based education for teaching algorithms. Consequently, this study addresses the following questions:

- According to teachers, what are the characteristics of the contexts that are suitable for teaching algorithms?
- How can teachers' considerations regarding the use of contexts for teaching algorithms be characterized?

Educational setting

In the Netherlands, CS is an elective subject in secondary education, in grades 10–12, for students aged 15–18. Less than half of the schools offer CS, and the number of schools with CS as an elective subject is declining. Schools discontinuing the subject argue that certified teachers are scarce. To become a certified CS teacher, a Master's degree in CS Education is currently required. From 1998–2006, teachers with a teaching degree in any other subject could obtain an additional degree in teaching CS by following a part-time training program for two years (CODI). Therefore, the population of CS teachers in the Netherlands is rather diverse.

In the current curriculum at the time of the interviews, algorithms were not mentioned as an explicit concept. However, programming was included and therefore algorithms were indirectly addressed. This situation changed in 2019 when a revised curriculum was implemented. Under the new curriculum, the students are required to learn to develop algorithms for their own sake, to recognize and to apply standard algorithms, and to examine their correctness and efficiency (Barendsen et al., 2016). Anticipating this curriculum reform, several teachers have already started to explicitly incorporate algorithms in their classes. Because no preliminary teaching material was available, these teachers designed their own material and they selected a certain set of algorithmic concepts. Some teachers combined the teaching of algorithms with the teaching of programming.

Although context-based teaching as a specific methodology has not been included in the teachers' academic training, they are expected to be familiar with the notion of "context" because it is fundamental to the curriculum reform in the Netherlands. The new curriculum is disseminated to all teachers and it is regularly discussed during the annual conference of CS teachers.

Method

Participants

In this study, we examined the CS subject in pre-university education and we selected teachers who teach in that segment. The participants are seven teachers, who were recruited from regional networks of CS teachers and from attendees of the annual conference of the Dutch CS teachers' association. At the time of the interviews, not all of the teachers explicitly taught algorithms. Therefore, we selected teachers with experience in teaching algorithms. This aspect can be characterized as "critical case sampling" (Onwuegbuzie & Leech, 2007). They teach this topic because they are preparing themselves for the new curriculum (see "Educational setting"), and/or they are convinced that this is a crucial topic in CS and teach it out of their own enthusiasm. All of the participants reported using contexts.

In addition to selecting teachers with experience in teaching algorithms, we attempted to obtain a sample with maximum variation with respect to relevant teacher factors, such as years of teaching experience and prior teacher education, see Table 1. The participants' teaching experience varied between 1 and 20 years, and their educational background varied from CODI to a Bachelor's or Master's degree in Computer Science Education. The sample consisted of one female and six male teachers. All of the participating teachers developed their own teaching materials for either all of their lessons or for a specific topic in combination with a published teaching method or teaching material from the public domain. Because all schools in the Netherlands are bound to the same curriculum, we did not specifically select teachers from different regions, although the participating teachers work in five different provinces.

Table 1. Teachers participating in the study.

Teacher	Teaching experience (years)	Teacher background	Teaching materials used for teaching algorithms
1	16–20	CODI	own and from public domain
2	6–10	CS Education (BSc)	own and published material
3	6–10	student CS Education (MSc)	own, published and from public domain
4	6–10	CS Education (MSc)	own and published material
5	6–10	CS Education (MSc)	own material
6	16–20	CODI	own material
7	0–5	CS Education (MSc)	own, published and from public domain

Thus, we used a combination of “critical case sampling” (we selected experienced teachers) and “maximum variation sampling” (with variation in years of teaching experience and prior teacher education) as a sampling strategy (Onwuegbuzie & Leech, 2007).

We interviewed teachers until no new ideas were conveyed. This so-called data saturation (Boeije, 2010) was reached after interviewing seven teachers.

Data collection

The data were collected during semi-structured interviews, in which we asked for teachers’ practices and experiences when using contexts for teaching algorithms. Other interview questions aimed at eliciting teachers’ reasoning regarding the use of contexts. We did not ask specifically for “characteristics of contexts” because teachers’ knowledge about these characteristics is expected to be tacit. Instead, by asking what teachers “do”, “observe” and “consider”, we seek to collect a basis for extracting the underlying characteristics via a subsequent qualitative analysis.

The interview questions are listed in Table 2. The questions were used as a guideline for the interview. During the interviews, there was ample room for interaction and the interviewer formulated follow up questions based on the interviewees’ responses.

The first interview question and the corresponding subquestions aimed at eliciting the teachers’ experiences. In the second question, we asked for the teachers’ considerations for using contexts in their teaching. In the third question, we triggered teachers to think of other useful contexts. In the fourth question, we referred to different types of contexts that have been distinguished in the literature regarding context-based education. As there is debate regarding familiarity of contexts, we used a specific subquestion about the teachers’ ideas on contexts from students’ everyday life. In the fifth question, the teachers were given a small card with CS-related contexts (e.g., Internet, security, gaming) and contexts related to other school subjects (e.g., biology, math) as illustrations. This card with examples was handed to the teacher at the end of every interview. Most of the teachers valued the card but one teacher commented that this list with examples impacted the given response to the final question.

The interviews regarding the use of contexts lasted approximately half an hour. The interviews were audio recorded and transcribed verbatim.

Table 2. Interview questions.

	Questions
1	What contexts did you use when teaching algorithms and algorithmic thinking?
	How did you use the context? As an illustration for a concept or as a base for your teaching
	How did your students respond to these contexts?
	What was the effect of using this context?
2	Why do you use contexts when teaching algorithms and algorithmic thinking?
3	Can you think of other useful contexts for teaching algorithms?
4	Contexts might be arranged into three types: everyday life, societal and professional/scientific contexts. What preference do you think your students have?
	What would be advantages and disadvantages of a context geared toward students’ life?
5	What ideas do you think your students have regarding contexts from CS-related topics or from another school subject?

Data analysis

To investigate the teachers' ideas regarding context-based education for teaching algorithms, we examined what contexts the teachers mentioned as suitable for teaching CS in general, or specifically for teaching algorithms. In addition, we examined the teachers' responses about their practices, experiences and reasoning. As a first step in the analysis, repeated reading of the transcripts was carried out to develop an understanding of the data as a whole. By comparison of contrasting cases, the teachers' different practices and ideas regarding the use of contexts became apparent and significant quotes were marked.

The iterative coding process had two cycles. During the first cycle of coding, the data were coded by an open coding approach (Cohen et al., 2011). The units of analysis were coherent segments of data in which *contexts* were mentioned or in which a reference was made to *characteristics* of suitable contexts. In addition, we focused on those segments in which teachers expressed their *considerations* when selecting and using contexts for teaching algorithms. In this cycle, open coding allowed us to break up the teachers' interview transcript texts into small pieces, to compare them, and to then create main categories for the contexts that they mentioned, for characteristics of contexts and for teachers' considerations (Boeije, 2010). By examining the data this way, both positive and negative considerations for using contexts were found and were then rearranged into two distinct main categories: *motives* and *concerns*. The data were coded using Atlas.ti qualitative data analysis software. At the end of the open coding process, the codes were exported to Excel where they were checked, refined, and the codes with identical meaning were merged, which produced an updated code list.

To enhance validity and reliability, the codes were often discussed with the other researchers. In addition, one interview was coded by two researchers (the first two authors) to determine interrater reliability. At first, the resemblance between the codes used by both researchers was insufficient, due to the occurrence of codes that differed only slightly in meaning and also because of unitization problems (Campbell et al., 2013) where different segments of the text were selected for a particular code. After discussing the disagreements, the codes were checked, adjusted, and similar codes were joined. Afterwards, both researchers coded the interview separately for a second time to check the interrater reliability. Applying the simple proportional agreement method (Miles & Huberman, 1994) resulted in an interrater agreement of 94%. Eventually, all of the interviews were coded using the revised code list.

In the second cycle of coding, we examined the important concepts in the codes to be able to find characteristics of contexts and to characterize the teachers' considerations. We used axial coding (Cohen et al., 2011) and we assigned categories to groups of open codes covering the same concept. We associated the first-cycle codes with the new categories, and modified and elaborated the relationship between the categories and codes where needed. The new categories establish a higher-level classification within the main categories "contexts", "characteristics", "motives" and "concerns". The final set of categories and codes is listed in Table 3.

Our analysis aimed to capture the variation in the teachers' ideas regarding the use of contexts. In this respect, our approach corresponds to the phenomenographic approach, which focuses "on the variations in understanding across the whole sample, rather than on the characteristics of individuals' responses" (Tight, 2016, p. 320).

Table 3. Coding scheme with core categories for answering the research questions.

Main categories	Categories	Codes
Contexts	Contexts mentioned by teachers	The contexts that were mentioned by teachers are grouped into themes. These are listed in Table 4
Characteristics	Connected to students' everyday life	Students become more interested if a context is realistic
		Recognizable contexts provide more meaning
		Students become more motivated if a context is relevant
		Selecting a context based on students' interest
		Contexts selected by students are closer to their interest
	Matching specific students' interests	Selecting of contexts is dependent on specific group of students or varies per student
	Appropriate for algorithmic concept	Selecting a context appropriate for the algorithmic concept to be learned
	Omnipresent	Contexts for CS education can be found everywhere
Motives	Fostering students' learning	Using contexts to engage students in the learning process
		Using contexts facilitates students' learning
		Using contexts to support meaningful learning
		Using contexts to enable students to transfer knowledge
	Bridging school learning with everyday life	Connecting algorithmic thinking with students' everyday life
		Empowering students' computational thinking
	Meeting varied needs and interests of students	Employing different contexts intended for different students or student groups
		One single context is never interesting for all students
	Advancing algorithmic thinking	Illustrating a concept by using contexts
		Students learn to apply concept in multiple situations
		Use contexts to stimulate students' thinking before they start coding
Concerns	Limitations of contexts	Dealing with limitations of an everyday life context
		Context is not qualified to discuss all aspects of a concept
		Context for algorithms risks being too complex
	Concerns regarding teachers' capacities	Choosing contexts is a difficult process for teachers
		Selecting different contexts intensifies teachers' workload

Results

In this section, we first describe the different contexts that were mentioned by the teachers during the interviews. All of the teachers answered with examples of contexts when they were asked which contexts they used when teaching algorithms and algorithmic thinking. Therefore, it is evident that all of the teachers made use of contexts when teaching this specific topic.

In addition, we describe the characteristics of the contexts and the teachers' considerations regarding the use of contexts as elicited through the interviews. As mentioned earlier, we found both positive and negative considerations. To explicate the diversity, they were labeled *motives* and *concerns*, respectively. The description is organized according to the main categories and categories listed in Table 3. The teachers' quotes were translated from Dutch into English. The teachers are referred to by "Ti", where "i" stands for the number of the interview.

Table 4. Contexts mentioned by teachers.

Themes	Contexts	Types
Using computer	Log in to access email; Sort incoming mails; Search engine; Sorting of search engines results; Check correctness of email address; Count words in a text	Everyday life
Gaming	Playing games on a computer or game console	Everyday life
Internet application	Use of Internet; WiFi reception	Everyday life
Security	Public transport chip card; Hacking into systems;	Everyday life, Societal,
Professional		
Route-planning	Google maps for own use (e.g., for newspaper distribution, which is sometimes done by students on their bikes); Route-planning for a snowplow; Route for fish trap fishermen	Everyday life,
Professional		
Digital creativity	Tinkering with Gamemaker; Exploring Lego Robot	Everyday life
Make, design, develop	Design websites; Make web applications; Develop games; Build a search engine; Develop software	Professional
Social media	Social media; Facebook	Everyday life, Societal
Other school-subject	Combination with music; Combination with Physics; Languages; Automatic translation	Everyday life, Societal,
Professional		
Task without computer	Sorting of classmates based on length; Searching in pile of cards; Solving puzzles	Everyday life
Real world analogies	Soccer team; Police; Phone book; Stocking shelves;	Societal
Digital artifacts	Vending machine; A robot disassembling explosives	Societal
Professional problems	An existing problem of real business; Task scheduling in pizzeria	Professional
Research	String matching for DNA research; Research on page rank algorithm	Professional

Contexts mentioned by teachers

To illustrate what contexts the teachers referred to when discussing their use, an overview of these contexts is given in Table 4. Contexts have been grouped into themes. In addition, the different types of these themes are listed. Following the example of ChiK (Parchmann et al., 2006) and context-based biology education (Wieringa et al., 2011), this type refers to the source of the context: contexts from students' everyday life, societal contexts (with relevance for a society) or professional/scientific contexts. To more easily visualize the context themes and the types, the themes are also displayed in a triangle, see Figure 1. The corner areas correspond to the three types of contexts. Placing a context is not always obvious because it might differ per person, depending on any involvement with a context. For example, for a student working in a supermarket, a context like "Stocking shelves" might fit into the *Everyday life* theme. In this paper, the decision where to place a context was made based on the generally applicable characteristic of the context. In this case, "Stocking shelves" would fit in the *Societal* theme. Furthermore, some context themes ("Social media" and "Route planning") do not completely fit in one of the three types and are instead represented on the axes between *Everyday life* and *Societal* or *Professional*. Other contexts ("Security" and "Other school subjects") are related to all three types and are displayed in the center area.

What stands out in the table and the figure is that most of the contexts that were mentioned are associated with students' everyday life. Although societal and professional contexts were mentioned, the teachers described many more contexts related to the students' lives.

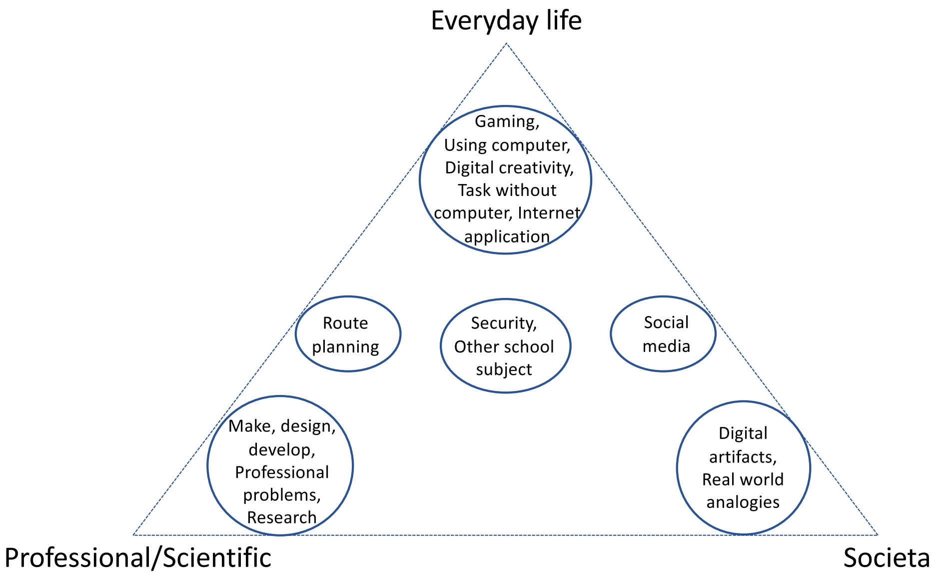

Figure 1. Context themes in relation to context types.

In addition to the contexts, we have selected examples of quotations in which the teachers mentioned the contexts that they used during their lessons. For example, one teacher described how he attempts to show his students the relevance of efficient algorithms:

> "*Let us assume we have a table with all users with a Hotmail-account, a couple of years ago that used to be 420 million, but nowadays Gmail has more than a billion. And imagine that when you try to log in, there is a linear search action to check whether you are listed in that table with the password you entered.*" (T6)

Another teacher mentioned how context rich programming environments work well, as opposed to specifying flowcharts:

> "*We program in a context rich environment or in a more playful environment like Lego robots or Gamemaker, and these things make it more fun for students. They enjoy working with Arduino's and so on. But the moment you directly focus on algorithms, like writing a flowchart, they are less interested.*"(T5)

Another teacher reported to take students outside the classroom:

> "*So you don't stay in your classroom and demonstrate something on the smart board. For example, in the new curriculum, finite-state automata are addressed. Then, we told our students: 'let's go to the vending machine in the cafeteria and let's see if we are able to describe its actions'.*" (T2)

Furthermore, a teacher reflected on the nature of CS in selecting contexts:

> "*CS is about solving problems for humans. So that is my context, it should be a problem of a person that gets solved. Like a robot who disassembles an explosive so that no human gets killed.*" (T7)

What stands out in this response is the focus on problems, which underlines the relationship between context-based education and problem-based learning.

Characteristics of contexts described by teachers

The data analysis of the CS teachers' reported practices and their reasoning regarding selecting and using contexts revealed several characteristics of contexts for teaching algorithms. According to CS teachers, a context should be "connected to students' everyday life", "matching specific students' interests", "appropriate for algorithmic concept", and contexts for CS are "omnipresent". In this section, we explain each characteristic separately.

Connected to students' everyday life

According to the participating CS teachers, a context for teaching algorithms should be connected to students' everyday life. Different conditions have been reported by teachers, as follows: a context should be realistic, recognizable, relevant or appealing. All of these conditions express the need for contexts to be connected to students' life or to their interests. Whether a context is perceived as recognizable or relevant depends on the student's interest and background but, in general, a context from students' lives or interests is expected to be useful. Moreover, several teachers mentioned that they encouraged the students to come up with their own contexts, pointing to the limitations of their selection of contexts because their selection might be based on their own interest and knowledge.

First, the teachers mentioned that a context should be **realistic** because it increases students' interest and because a realistic context provides better understanding of a concept. Second, the teachers described how they select **recognizable** contexts from students' life to connect the lessons to the students' reality. Given that the students are often only users of digital artifacts such as apps or computer systems, they are not necessarily concerned about their inner workings. By using recognizable contexts from their daily life, students start to understand them better . As teacher T3 mentioned:

> *"They do find it interesting to know why for example, with page rank, asearch result is at the top of the list, what causes that?"*

Furthermore, the teachers reported that students become more motivated if a context is considered **relevant** and they observed that contexts help to see the relevance of a topic. For example, teacher T6 mentioned that:

> *"If you can provide reasonable explanations that demonstrate the relevance of something, that works pretty well."*

Moreover, the teachers described how they select **appealing** contexts based on students' interest to captivate the students' attention. More playful contexts, such as robots or game development, are considered to be appealing for students.

Matching specific students' interests

Whether a context is useful or not depends on the students in a class. The teachers described the variations between the individual students' responses to the contexts:

"And one student has more connection with that than the other. One student says: 'I really enjoy knowing all these things' while the other will respond like 'oh well, I don't care about that'." (T3)

In addition, the teachers reported that they select different contexts based on a specific group of students, their level, age and so on, or based on the track that the students have chosen:

"During class activities, I start with a context from students' everyday life, how does this work? There are also societal or professional contexts, but when you are a class 4 student [with 2 more years of secondary education], you have no relation with a profession. You have just chosen your track, but what further education you will follow or what profession is related to that study, that is something most students [in class 4] do not know yet." (T2)

Furthermore, the teachers try to take the gender of the students into account, as teacher T7 described:

"*I think a context should be appealing for girls*."

Appropriate for algorithmic concept

The teachers select contexts that are appropriate for the algorithmic concepts that they will teach. When teaching algorithms, they use contexts as illustrations. Teacher T5 reported:

"The context should be very suitable to explain the concept." (T5)

Regarding this issue, the teachers referred to other topics in CS where they follow a different approach and select contexts first, as teacher T2 described regarding teaching networks:

"Then you can work from a context, because, well, at home the WiFi-network just works, except for the attic where there might not be WiFi reception, that is a classic context." (T2)

Based on this context of a malfunctioning WiFi-network at home, different concepts can be explained.

Omnipresent

The selection of the contexts should be a natural process because a context for CS can be chosen from many different areas. As teacher T6 mentioned:

"*Computer science is the only school topic concerning everything*"

implying everything can be chosen as a context. Asked whether teachers can think of other useful context for teaching algorithms, teachers commented that an "*almost infinite number of topics*" (T4), or "*billions of options*" (T7) can be used. As teacher T3 described: "*I think CS is in just about anything*".

Teachers' motives for using contexts

The analysis regarding teachers' practices and considerations revealed several motives for using contexts. In particular, the participating CS teachers use contexts to foster students' learning, to bridge school learning with everyday life, to meet varied needs and interests of students and to advance algorithmic thinking.

Fostering students' learning

The teachers described how they use contexts to engage students in the learning process. In addition to using contexts as pedagogical tool to provide engagement, the teachers mentioned cognitive aspects as motive for using contexts. The teachers use contexts to facilitate the learning process as a recognizable context prepares students for an understanding of what is taught. In this regard teacher T2 mentioned:

> "*You start with a context, in doing so, you will deal with the concept and once that has landed, you can delve deeper into the concept, so they know the direction you want to go, that was illustrated by an example.*"

The use of different contexts supports transfer of knowledge because it enables the students to see that algorithmic concepts can be applied in multiple, varied situations.

Bridging school learning with everyday life

The teachers use contexts to show the connection with situations in students' life, such as route planning algorithms for distributing newspapers or the route of a snowplow. Teachers argued for the use of "real" problems as contexts because students will understand that these problems need to be solved efficiently. Moreover, the teachers reported that they see contexts not just as a means to support the understanding and to show the relevance, but also as an end in themselves. The teachers hope to deepen their students' understanding of the practical realities of the use of algorithms in their daily life:

> "*For all these different things they apply [in their daily lives], they can imagine there is an algorithm behind it [...] So that is what I would like them to think about, that they change the way they look at or consider these things.*" (T3)

Meeting varied needs and interests of students

When using contexts, the teachers make an effort to activate diverse students and therefore they have to take the differences between students into account. A single context is never interesting for all of the students in a CS classroom, as shown in the following example:

> "*When you use a search engine as context, some students will be interested: 'Is that something I can influence and how does it work?' They might be interested in the first step but when you would really examine the underlying code (which is undoable for Google's search engine), only a small group of students might be interested because everyone else will drop out.*" (T4)

In addition to considering differences in interest, the teachers mentioned that they take into account the different capabilities of their students. The teachers realize that a context might complicate the cognitive load. As teacher T4 mentioned:

> "*The context was limited to make it manageable for all students in the class.*"

Advancing algorithmic thinking

The teachers appeared to be focused on the concepts that the students have to learn as they start with the learning goals for their students and select supportive contexts, for example:

> "*We have chosen sorting algorithms, Dijkstra's algorithm and the algorithm of the Chinese postmen, after that we selected contexts for these algorithms that also are in line with students' interests. Because everyone sorts, everyone knows a route planner and distributing newspapers or the route of a snowplow, for these you can imagine that they need to be efficient.*"(T2)

The teachers reported that they encourage their students to think about where they can apply their new knowledge or skills.

Teachers' concerns regarding the selection and use of contexts

The teachers were concerned about the limitations of contexts for teaching algorithms and they also expressed their hesitations about using contexts in their teaching.

Limitations of contexts

The contexts should not be too complex because that hinders the learning of new concepts, as teacher T7 reported:

> "*I think you should choose one thing where they can be challenged and the challenge should not be in the context.*"

Some contexts are too complicated and they need to be reduced to support the learning of a new concept, such as Google's search engine or Facebook's algorithms. The teachers also reported that a context might not be qualified to discuss all aspects of a concept, or that specific concepts are easier to teach with standard algorithms instead of using an appealing context. Although a context from students' life might be interesting and recognizable, this type of context might be too limited or it might not be challenging, for example:

> "*The disadvantage would be that you rush to solutions they already know or already see and that you do not challenge them to think outside the box.*"(T7).

Concerns regarding the teachers' capacities

Our analysis of the teachers' responses revealed that they might need support when using contexts for teaching algorithms. Several teachers did not feel confident and responded with quotes such as "*I do not know*" or "*I think it is tough*", revealing their hesitancy. Using contexts is seen as difficult, especially for teachers with less teaching experience. The teachers expressed that suitable contexts are hard to find. Moreover, the teachers are concerned that finding good contexts intensifies their workload, especially if they want to use multiple contexts for their students, as in the following example:

> "*I would love to have more contexts … but I didn't get around to it.*" (T7)

Furthermore, using a context that is linked to another subject, such as bio-informatics or mathematics, has consequences for teachers who lack content knowledge.

Discussion

Prior work has investigated the characteristics of effective contexts for teaching science. Because teaching CS in context has focused mostly on higher education, little is known, in general, about the use of contexts for teaching CS in secondary education and, in particular, about teaching algorithms through the context-based approach. The main aim of this study was to explore teachers' ideas regarding the characteristics of effective contexts and their considerations about the use of contexts for teaching algorithms.

In this section, we first discuss the findings related to contexts and their characteristics. We then reflect on the teachers' considerations, specifically regarding variation between students, complexity of contexts for algorithmic concepts, and the need for multiple contexts. Finally, we present the implications of our study, and we describe limitations and future work.

Characteristics of contexts for CS education

During the interviews, the teachers mentioned several of the contexts that they use during their lessons. The teachers described contexts, such as an existing problem of a real business. This context is a typical example of context-based learning that could, for example, be connected to a shortest path algorithm. This context could also serve as an example of a problem for problem-based learning. This finding illustrates that some contexts can be used as problems for problem-based learning, as described in the background section. Likewise, problems that are known from earlier studies on problem-based learning (e.g., game development) were mentioned as contexts by teachers. However, in accordance with the observation of King (2012), our study found that not all contexts are problems because the teachers mentioned, for example, playing games or social media.

In the background section, we reported that several studies have identified different types of contexts based on the source of contexts. However, our findings show that these types may not be completely distinguishable. Several of the contexts mentioned by the teachers could fit into more than one type, as illustrated in Figure 1. This particularly applies to the context of *making* or *developing* digital artifacts, which is a typical context for CS education. In Figure 1, this context is displayed as "professional/scientific context" because it is closely connected to professional practices. However, artifacts such as websites and apps are often used by students and, therefore, may be part of the theme "Using computer", which is related to "Everyday life". Furthermore, developing websites, web applications or games can serve as a context for explaining CS concepts, but it is at the same time a typical learning activity. Even though the used typification was effective for providing more insight into the contexts used by teachers, classifying contexts into a type proved difficult for the reasons given above.

Although the different types may overlap occasionally, the teachers in our study predominantly mentioned contexts from their students' everyday lives, as shown in Figure 1. The teachers in our study had varied considerations about these contexts. On the positive side, teachers mentioned that they used contexts for bridging school learning with everyday life, in particular to make the students understand the applications of algorithms in their lives. In addition, the teachers reported the advantages of using contexts from students' everyday life because they facilitate recognizing the importance and relevance of the content that is being taught. On the negative side, the teachers commented on the limitations of everyday life contexts. These contexts are interesting and recognizable, but they may be less challenging and may hinder the process of broadening the students' perspectives. This limitation might be prevented by using contexts from society or from professional or scientific practices. However, these contexts were not often mentioned, or were only mentioned as contexts that are interesting for some students but not for all (e.g., for contexts from professional or scientific practices).

The teachers' reported practices and considerations suggest the following potential characteristics of contexts for teaching algorithms: contexts should be connected to students' everyday life (realistic, recognizable, relevant and appealing), matching specific students' interests, appropriate for the algorithmic concept, and contexts for CS are omnipresent. Although the present study aimed to find the characteristics of contexts for teaching algorithms, the teachers occasionally also reported experiences with using contexts for teaching other topics of CS. Therefore, we argue that these characteristics are also relevant for contexts to teach other concepts of CS.

These results corroborate the suggested criteria for contexts for the IniK project (Diethelm et al., 2011). In particular, the teachers in this study and Diethelm et al. (2011) stress the connection to students' lives and expect contexts to be realistic, recognizable and relevant. Furthermore, they both emphasize that contexts should be supportive for learning CS concepts. Therefore, contexts should be used that require an in-depth understanding of the CS concepts. Diethelm et al. (2011) also suggested multi-dimensionality and width as characteristics. Although we did not explicitly find these characteristics, the participating teachers reported that contexts for CS are omnipresent, hinting to the multi-dimensionality and width of effective contexts.

In contrast to Diethelm et al. (2011), our findings revealed the need for contexts that address the variation between students as the teachers acknowledged the differences between students. A possible explanation for this might be that teachers have to deal with this reality regularly. On the other hand, Diethelm et al. (2011) suggested stability as characteristic of contexts. The findings of the current study do not support this aspect. Although teachers would benefit from teaching material with contexts that do not need to be updated constantly, they might be used to the fact that they teach a fast changing subject.

These findings raise intriguing questions regarding the nature and function of the characteristics that we have found. We would suggest that these characteristics may serve as a recommendation for designing contexts. Curriculum developers or teachers may realize that the effectiveness of contexts is dependent upon several, sometimes seemingly conflicting, characteristics. Some of the contexts mentioned by the teachers, such as searching in a phone book, may be very appropriate to address the concept of efficiency of algorithms because it is useful for explaining the difference of efficiency of search algorithms. Meanwhile, it is not related to students' everyday life because it is unlikely for a student to use a phone book nowadays. Furthermore, a context such as searching in a phonebook or a pile of cards can be used as a direct application of concepts, which is the definition of the first model of Gilbert (2006). However, such a context serves only a limited purpose.

In the discipline of science education, previous studies evaluating the characteristics of contexts come to inconsistent results. Some research has focused on authenticity and familiarity (Van Vorst et al., 2015) while other research has pointed to controversiality (Marks & Eilks, 2010). The findings of the present study reveal the need for "realistic" contexts, which confirms the notion of "authenticity". In addition, the notion of "familiarity" was supported by our findings, which suggested that contexts should be "recognizable". However, our teachers complemented these characteristics with the idea that students differ in many aspects. Hence, this variation needs to be addressed when selecting contexts.

Knobelsdorf and Tenenberg (2013) suggested that contexts should focus on breakdowns or failures because a breakdown or failure in the interaction of a device will be a more interesting context to students than the device itself. This was observed in the reports of the teachers in our study, but only indirectly. For example, when using a context for teaching networks and referring to "the classical context" of problems with WiFi when someone is in the attic of their house, the suggestion was made that the fact that the WiFi did not function made it a relevant context.

Variation between students

The participating teachers expressed the desire to use a context to engage and interest students during lecturing, and they mentioned "fostering students' learning" as one of the main motives to use contexts. However, the teachers seem to be worried about the possibilities for engaging a complete class using a single context. They felt the need to address the variation within the student population, and emphasized the need to select contexts that meet the varying needs and interests of their students. Therefore, our findings point to the importance of employing different contexts intended for different students or student groups.

As mentioned in the Background section, Knobelsdorf and Tenenberg (2013) suggested that more research is needed to find what CS students perceive as relevant. Our findings confirm that relevance is an important aspect. The teachers try to select and use relevant and recognizable contexts, but they realize that this is dependent on students' different backgrounds and experiences. This is in line with the conclusion by Habig et al. (2018) that when designing context-based learning environments, the "individual characteristics of learners have to be considered" (p. 1172). Moreover, the teachers in our study also mentioned the consequences for their lessons as they reported to prefer to give students options; hence, the students can choose a context that is interesting and relevant to them.

In the Netherlands, all students in upper secondary education have the option to choose CS as an elective subject as long as their school offers CS education. Consequently, some students come from a science-track (with classes in physics, chemistry or biology) while others follow a society-track (with classes in history, geography or economics). This might explain why Dutch CS teachers underline the issue of student variation. However, we expect that similar variations can be found in other countries.

The perceived variation in interests of students might be a consequence of the variation in topics that CS entails given that it is based on mathematical, scientific, and engineering traditions (Tedre & Sutinen, 2008). Because the students might not be interested in all three aspects, it might be possible to offer several contexts from the different traditions.

Prior research (Fensham, 2009) has suggested that the selection of contexts could be left to teachers because they are expected to have a good understanding of what is interesting and engaging to their students. The CS teachers that participated in this study hold a different view in that they pointed to their own limitations and proposed that the students should have a more active role in selecting contexts. Although this might be demanding for students, it could advance the transfer of knowledge and be more engaging for them. It would therefore be interesting to examine ways to develop contexts in collaboration with students.

Complexity of contexts for algorithmic concepts

The teachers in our study stated that using contexts facilitates sense-making of the new content matter, and they indicated that contexts that are appropriate for the algorithmic concepts should be selected. At the same time, they expressed concerns that contexts for teaching algorithms (e.g., a search engine) can be far too complex and may hinder the learning of new concepts. Furthermore, the teachers mentioned that algorithmic concepts are difficult to learn for students; therefore, they did not want to "overload" their students with complex contexts. Guzdial (2010) concurs that when additional knowledge about the context is taught, it might distract students and time spent introducing the context might delay the learning of content that you are aiming to teach. Therefore, it is relevant to monitor the cognitive load of a context as an effective context might foster the learning while an ineffective context might be a hindering factor which interferes with the learning. However, it is important to differentiate between the three types of cognitive load: intrinsic (regarding complexity of information), extraneous (imposed by instructional procedures) and germane (concerning learner characteristics) (Sweller, 2010). Teachers may be concerned about the intrinsic cognitive load of the algorithms related to (for example) a search engine. Yet, the cognitive load may be manageable by reducing the extraneous cognitive load by treating the algorithms on a higher level of abstraction.

Although teaching complex and abstract concepts such as efficiency of algorithms is supposed to benefit specifically from the context-based approach, our study suggests that for teaching algorithms, it might be difficult to find suitable contexts. A possible explanation for this is that there are many situations in students' daily life that could make the teaching of algorithms more engaging and relevant, but these contexts may seem too comprehensive and algorithms in such a context may be viewed as too complex to use in secondary education. Therefore, these complex contexts may need to be decomposed and may need to be presented differently, focusing only on those components that are relevant for teaching algorithms. Because decomposition is another aspect of Computational Thinking and a skill that is needed for designing digital artifacts, it might be useful for students to observe this decomposition.

These findings point to the need to investigate ways to control complexity when working with relevant but comprehensive contexts.

Need for multiple contexts

As mentioned earlier, the teachers in our study emphasized the need for multiple, varied contexts because of their desire to engage many students, and to meet the needs and interests of all of the students. Multiple contexts are also needed to show that concepts can be used in multiple situations. The participating teachers prefer not to use a single ("central") context for students to work on throughout a longer period of time, as is often proposed in literature regarding a context-based approach for science education (Gilbert et al., 2011; Taconis et al., 2016).

The teachers' suggestion to use multiple contexts might be caused by differences between CS and science education. In science education, contexts are valued for providing coherence, which is achieved by integral tasks that take place over several lessons. However, the lack of coherence may not be the primary goal of using contexts in CS education. The focus of learning CS in context is on providing students "with a sense-making perspective on the subject matter" (Knobelsdorf & Schulte, 2007, p. 66), where students learn in realistic situations with real problems.

Implications

Although the current study was conducted in the context of teaching fundamental concepts such as algorithms, we argue that our results provide insight into the use of contexts for teaching CS in general and even for teaching in a broader sense. The results of this study revealed several characteristics of contexts for teaching CS: contexts should be connected to students' everyday life, matching specific students' interests, appropriate for the algorithmic concept, and contexts for CS are omnipresent. These characteristics may serve as recommendations for curriculum developers as they should consider the authenticity and familiarity of contexts, but also take into account the variation between students. Moreover, the teachers' considerations point to the benefits and the impediments of using contexts. These findings may help us understand the complex nature of selecting and using contexts for teaching fundamental aspects of CS. This study suggests the need for decomposing complex contexts because useful contexts for teaching algorithms might be comprehensive and complicated. In addition, our results indicate that teachers need significant support to give them the confidence to be able to select and use contexts. Given that prior studies have shown the important role teachers play in educational change (Janssen et al., 2013; Van Driel et al., 2001), this finding has important implications for developing adequate teacher education or supporting teacher professionalization.

Limitations and future work

All of the participants in this study are Dutch teachers, which could be seen as a potential limitation. However, because we used a combination of "critical case sampling" and "maximum variation sampling", our research offers valuable insights in the diverse ideas of Dutch teachers. Further studies regarding teachers' ideas in other countries would be worthwhile.

The small sample of participating teachers allowed us to explore these teachers' ideas in depth. However, it would also be interesting to include a quantitative study focusing on the findings of this study. We specifically selected teachers with experience in teaching algorithms and we found considerable concerns regarding the use and selection of contexts. More research is relevant to explore the relation between teachers' knowledge of algorithms and their concerns regarding using contexts for teaching algorithms.

Furthermore, as the participating teachers suggested, it would be worthwhile to investigate how to design contexts in collaboration with students. In addition, because contexts for CS are mainly used to provide meaningful education, further work is recommended to examine the possibilities of a more prominent role of contexts in providing coherence in the CS curriculum.

Conclusion

The aim of this study was to examine the characteristics of the contexts that are suitable for teaching algorithms and to investigate teachers' considerations regarding the use of contexts. Our research may contribute to the knowledge regarding context-based education for CS because it addresses a number of knowledge gaps indicated by prior research into CS in context, such as research into IniK. It is remarkable that the teachers reported that the contexts for CS are omnipresent and at the same time they also described that contexts may be elusive. The contexts for CS can be selected from various areas because CS is inherently connected to many aspects of our lives or society. However, it may be difficult to find effective contexts that are connected to students' everyday life but at the same time are appropriate for algorithmic concepts, and address the variation between students.

We have been able to identify a number of themes that might contribute to the education and professionalizing of CS teachers. The teachers' responses reveal that teachers will likely benefit from support for selecting and using contexts for teaching algorithms. The teachers in our study appear to be concerned about the complexity of relevant and appealing contexts. Therefore, it is recommended that further work should examine how these contexts can be reduced to make them useful for teaching algorithms in secondary education. Furthermore, because a single context is never recognizable and appealing to all of the students in a class, it is recommended to use multiple, varied contexts to meet the needs and interests of all students.

In addition, this study has shown that finding the right balance when selecting and using contexts is challenging for teachers: a context from students' everyday life that is recognizable and relevant may contribute to foster students' learning. However, these contexts might be too complex and may distract the students from learning algorithmic concepts. Interestingly, the teachers in our study often describe two aspects of the selection process: on the one hand, they would like to use many contexts for different students, while on the other hand they are concerned about the increasing workload for themselves when they need to find varied contexts. Finding a balance seems an important aspect of selecting useful contexts.

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