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Article

Exploring the Potentials of Unplugged Activities—Developing Computational Thinking in Teacher Education

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Abstract

This paper explores the use of unplugged activities as a pedagogical approach for teaching computational thinking (CT) to student teachers at a Danish university college in the subject technology comprehension. Through an analysis of three cases—a toothbrushing routine, a political profiling quiz, and an interactive story creation—the study examines students' learning experiences and engagement with CT concepts and practices. The paper employs a methodological approach rooted in participatory observation and visual ethnography. Data collection includes video recordings, audio recordings, post-class interviews, and artefacts created by the students.

The analysis reveals possibilities as well as challenges experienced by students in their involvement in computational thinking activities, including algorithms, decomposition, and abstraction. These findings contest the oversimplified classification of activities as either 'plugged' or 'unplugged', suggesting that alternative factors hold more substantial importance. Subsequently, the paper explores the roles of self-efficacy and ‘be-greifbarkeit’ in students' learning processes, thereby elucidating how students' motivation and learning expectations, in conjunction with their tangible experiences and conceptual understandings, influence the development of their computational thinking competencies.

In conclusion, the study provides valuable insights for teacher educators, emphasising the need to consider the perceived complexity of the activity, including the students’ prerequisites for engaging with plugged and unplugged elements. It highlights the multifaceted nature of plugged and unplugged approaches, offering a nuanced perspective on their impact on students' learning experiences in the field of computational thinking.

Keywords: Unplugged Activities, Computational Thinking, Teacher Education, Technology Comprehension

Introduction

In the rapidly evolving landscape of education, the integration of computational thinking (CT) competencies has emerged as a critical component in preparing students for the challenges of the 21st century. Recognising the pivotal role that teachers play in fostering these competencies, the present paper delves into the exploration of unplugged activities as a pedagogical approach to facilitating the learning of CT in the realm of teacher education.

As technology continues to permeate every aspect of children’s lives, teachers are tasked with cultivating the ability to think computationally among students—competencies that extend beyond mere programming skills. CT encapsulates a broader cognitive framework, encompassing problem-solving, abstraction, generalisation, and the ability to dissect complex problems into manageable components (Bocconi et al., 2018; Shute et al., 2017).

While technological tools and programming languages are integral to developing CT on a more advanced level, the merits of unplugged activities—learning CT without the use of computers—have gained traction in educational discourse (Caeli & Yadav, 2020; Chen et al., 2023). Specifically, it can be argued that unplugged activities are particularly well-suited for fostering both self-efficacy and *be-greifbarkeit*, both of which are important for learning CT. Be-greifbarkeit refers to being understandable or graspable, both intellectually and tangibly. This paper explores the potential benefits and challenges of unplugged activities as a pedagogical strategy for nurturing CT competencies among future teachers. The activities reported on in this paper were designed to support and foster empowerment through self-efficacy and be-greifbarkeit, with the goal of improving the learning of CT in the context of the subject technology comprehension in Danish teacher education. In particular, the analysis focuses on students' experiences of be-greifbarkeit and self-efficacy as they emerge through these unplugged activities.

The paper explores local and situated CT practices in the subject of technology comprehension in Danish teacher education. It examines how student teachers develop and apply CT competencies in three distinct activities building on a combination of plugged and unplugged approaches. The empirical data are derived from a comprehensive collection of video observations during interventions, post-class interviews with student teachers, and an assortment of both analogue and digital artefacts created by the students. The analysis is driven by the following research questions:

> How can unplugged activities support student teachers' computational thinking in the subject of 'technology comprehension'?
>
> How do student teachers experience 'be-greifbarkeit' and self-efficacy participating in unplugged activities for learning computational thinking?

The paper discusses the potential of unplugged activities in fostering CT, ultimately contributing to the ongoing dialogue on teaching practices in the digital age.

Background

CT in Danish Teacher Education

Historically, teacher education has witnessed a gradual integration of information and communication technology, resulting in a pressing need to enhance and cultivate pedagogical digital competence among aspiring educators in Nordic countries (Tømte et al., 2015). Additionally, the realms of computing, critical analysis, and societal implications of digital technologies have recently been integrated into the digital education agenda and pedagogical digital competence (Lisborg et al., 2021). Consequently, educational strategies and policy initiatives have turned their attention towards programming and CT (Pajchel et al., 2024).

In 2018, the Danish Ministry of Children and Education initiated a pilot programme to test a new subject called *technology comprehension* at 46 schools. The programme ran from 2018 to 2021 (Ministry of Children and Education, 2023). Technology comprehension was introduced both as a separate subject and by integrating competence areas and learning goals into existing subjects such as Danish and mathematics. The curriculum was structured around four competence areas: digital design and design processes, computational empowerment, technological capability, and CT.

Simultaneously with the initiation of the pilot programme in schools, a national project in teacher education was also being developed. A module of 10 ECTS was developed between 2018 and 2020 and initially launched in 2020 at the University College Copenhagen (KP). This module was associated with the three largest subjects in teacher education: Danish, mathematics, and English. This meant that technology comprehension at the level of teacher education was implemented as new competence areas, learning goals, pedagogical ideas, and technology-focused exercises for existing subjects (Lisborg et al., 2021).

Computational Empowerment

While Nordic curricula encompass fundamental CT concepts, such as algorithms, abstraction, and decomposition (Bocconi et al., 2018; Pajchel et al., 2024), only Denmark and Sweden explicitly address computational empowerment and citizenship (Bocconi et al., 2018). The concept of empowerment can be traced back to community psychology and pedagogy in the 1960s. It focused on creating agency and opportunities for influence for marginalised groups in their own lives captured, among others, by the work of Paulo Freire (Andersen et al., 2023; Freire, 1968).

Linking the idea of empowerment to computing can be credited to Seymour Papert (1988). He was preoccupied with the notion of giving children the opportunity to create tangible products and provide students with agency through engagement with technologies. ‘The role that the computer can play most strongly has little to do with information. It is to give children a greater sense of empowerment, of being able to do more than they could do before’ (Papert, 1988, p. 5). His approach aimed to help students understand their own lives in a digitised society while learning computational skills to act back and create opportunities in their own lives.

Later, Brennan and Resnick (2012) emphasised the importance of creating connections between young people’s use and understanding of technologies, while acquiring the necessary knowledge to ask questions about them.

> we look for indicators that young people do not feel this disconnect between the technologies that surround them and their abilities to negotiate the realities of the technological world. Young people should feel empowered to ask questions about and with technology (Brennan & Resnick, 2012, p. 11).

What Papert (1980), Brennan and Resnick (2012) all point towards is how students’ computational empowerment demands an educative and pedagogical facilitation that allows the students to learn about the technologies surrounding them, feel a connection to them, and ask questions about these technologies through their use.

Computational Thinking

CT traces its origins to Seymour Papert's constructionist endeavours (Papert, 1980; 1988). CT was later termed in a pivotal article by Wing (2006) which reimagined the ideas defined by Papert. The most cited references on the definition of CT highlight the importance of understanding CT as a thinking process (Shute et al., 2017; Wing, 2010), where 'solutions are represented in a form that can be effectively carried out by an information-processing agent,' further emphasising the problem-solving approach (Wing, 2010, p. 1). Several definitions highlight the problem-solving approach, which involves breaking down complex problems into smaller, more manageable parts. Since the first definitions of CT, many have been added and developed (Ezeamuzie & Leung, 2021). This paper adheres to some of the ideas developed by Shute et al. (2017) who describe CT as a set of skills that can be applied across a wide range of domains and is not limited to computer science. They define it as a 'way of thinking and acting, which can be exhibited using particular skills' (Shute et al., 2017, p. 1), and they define CT as 'the conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers) with solutions that are reusable in different contexts.' (Shute et al., 2017, p. 1). They also suggest that CT skills are important for students to develop to be successful in the 21st century, identifying six key components of CT: decomposition, abstraction, algorithm design, debugging, iteration, and generalisation.

Unplugged Approaches to CT

The methodologies for learning CT are still lively debated (Ezeamuzie & Leung, 2021). One approach that has gained wide popularity and been the basis for curriculum development is an unplugged approach to understanding and working with CT (Caeli & Yadav, 2020; Chen et al., 2023). Bell et al. (1998) introduced the Computer Science Unplugged, aiming to foster interest in computer science by formulating specific and captivating unplugged activities explaining data, information, and computer code. Subsequently, these unplugged activities were recommended for K-12 curricula by the Association for Computing Machinery and were translated into various languages. Code.org later incorporated unplugged activities into its programmes (Caeli & Yadav, 2020).

The term 'unplugged activities' encompasses multiple variations, all of which share the characteristic of operating 'without a computer' (Bell et al., 1998; Curzon et al., 2014; Ford et al., 2017; Huang & Looi, 2021; Sentance & Csizmadia, 2017; Threekunprapa & Yasri, 2020). Building on this foundational definition, various interpretations have emerged, describing unplugged activities as involving the 'removal of the programmable machine' (Huang & Looi, 2021, p. 95), 'no use of digital devices', or 'nondigital' (Brackmann et al., 2017; Caeli & Yadav, 2020). Some even classify unplugged activities as 'kinesthetic or physical activities' (Curzon et al., 2014; Sentance & Csizmadia, 2017). In some cases, the physical aspect of unplugged activities aligns with the creation of 'active learning experiences', linking the physical aspect with active learning (Sentance & Csizmadia, 2017; Tsarava et al., 2017). Tying into this embodied learning some studies even specify that ‘students’ bodies form the core of the learning process’ (Città et al., 2019).

When unplugged activities are linked to learning processes on CT competencies, they often serve as an introductory approach because they require no technical skills. Although the consensus among the previously mentioned studies centres on unplugged activities being ‘without a computer’ and involving physical or active learning to some extent, there is considerable divergence concerning their relationship to programming. Some assert that unplugged activities cannot involve programming because of the necessity of a computer, while others define it to engage with algorithms without actual programming (Huang & Looi, 2021). Moreover, certain studies specifically elaborate on how unplugged activities can teach programming without computer usage (Threekunprapa & Yasri, 2020).

Ford et al. (2017) underscore the learning potential of unplugged activities, highlighting their minimal reliance on technological knowledge. Originally intended as an introduction to computer science, these activities facilitated swift introductions for learners lacking prior computer understanding or access to technology. Consequently, a recurring attribute emphasised in unplugged activities is their nonthreatening nature, serving as an effective initial step in developing a deeper comprehension of CT (Caeli & Yadav, 2020; Ford et al., 2017). Furthermore, motivation and engagement emerge as frequently highlighted features of unplugged activities, which are connected to the lack of requirements needed to engage with them (Tsarava et al., 2017). Occasionally, these are also associated with increased student confidence (Curzon et al., 2014; Ford et al., 2017).

Learning through Be-greifbarkeit building on Self-efficacy

Features of unplugged activities such as motivation, engagement, and confidence are connected to be-greifbarkeit and self-efficacy, as the former are viewed as indicators of the latter. These analytical concepts will later be used to analyse and discuss the empirical exploration of the potential benefits and challenges of unplugged activities in learning CT.

Building on the ideas of Papert and others, Katterfeldt et al. (2015) identify *be-greifbarkeit* and *self-efficacy* as key concepts essential for learning about digital technologies. *Be-greifbarkeit* builds on the double meaning of the German word ‘begreifen’, just as the English word ‘to grasp’ has a double meaning. The literal meaning of ‘grasp’ is to take, embrace or hold something, especially with one’s hand. However, to ‘grasp’ something can also mean to understand, to apprehend or making sense of something (Katterfeldt et al., 2015). In this context, be-greifbarkeit means understanding by grabbing and grabbing to understand. It emphasises the importance of tangibility and body interaction for understanding, building on Resnick and others’ idea of the importance of ‘objects-to-think-with’ (Resnick, 2017). Thus, be-greifbarkeit constitutes a relevant concept for comprehending the complexities of the embodied, kinaesthetic, and physical approach to learning inherent in unplugged activities.

S*elf-efficacy* refers to an individual's belief in his or her capacity to act and perform adequately in a given situation. The concept, originally developed by Albert Bandura in 1977, can be viewed as both a prerequisite for learning and a learning aim. It relates to students' attitudes towards learning content and activities. Self-efficacy constitutes the basis for the student to develop 'his and her personality and capacity according to own activity, power and experience to be able to change the environment' (Katterfeldt et al., 2015, p. 7). Katterfeldt et al. (2015) not only view self-efficacy as a factor that supports learning, but also as an element that fosters empowerment. This is especially relevant in a Danish context, where CT is not merely taught as a competence, but is understood as a competence that both facilitates and contributes to computational empowerment.

Methods

This paper investigates an introduction to CT with a focus on unplugged activities within a 10 ECTS technology comprehension course in a Danish teacher education program. The four lessons were designed as an introduction to CT within the context of computational empowerment, a core competency in the subject of technology comprehension. Computational empowerment and CT have previously been documented as two of the most challenging competence areas for in-service teachers to integrate effectively (Ministry of Children and Education, 2023).

The unplugged activities were designed on the idea that they would allow the student teachers to grasp the foundational concepts of CT without requiring prior technological skills. The class observed during the four-lesson introduction consisted of 9 female and 4 male first-year students. Through qualitative research methodology the lessons were documented using two video cameras, four dictaphones, and a digital still camera. At the end of the day, post-class interviews were conducted with the student teachers to gather insights into their learning experiences. Additionally, a collection of both analog and digital artifacts created by the students was gathered.

The methodological approach draws on fundamental ideas of participatory observation and visual ethnographic techniques to investigate both the linguistic and bodily practices of students as they engage with each other and technologies while learning about CT (Pink, 2007). During observations and filming, the students were asked questions and encouraged to comment on their actions. Additionally, group interviews were conducted with a focus on students' experiences of activities and learning outcomes at the end of the day. The students' own productions and materials created through the different activities were used as material elicitation devices in the interviews and informal conversations during the observations.

The use of video cameras during observations has facilitated revisiting these activities with technologies, enabling an in-depth examination of technological microprocesses during the analysis stage (Rehder & Møller, 2021). This data corpus serves as the basis for the analysis that informed this paper.

The analysis is guided by the theoretical assumptions of the benefits of unplugged approaches to introductory learning of CT, shaping the analytical lens used to examine and unpack the activities. It draws on concepts identified as essential in teaching and learning CT, which are described in the background section. Specifically, we focused on unplugged approaches in supporting motivation (Tsarava et al., 2017) and student confidence (Curzon et al., 2014; Ford et al., 2017). We also draw on theories of embodied learning through kinesthetic or physical activities (Città et al., 2019; Curzon et al., 2014; Sentance & Csizmadia, 2017; Tsarava et al., 2017). The analytical framework is further developed with insights from Katterfeldt et al. (2015) who expand on the concepts of self-efficacy and be-greifbarkeit. The data was then analysed drawing on content analysis, enabling the identification and examination of excerpts that align or diverge from the selected analytical concepts which was selected for further analysis.

In the following results section, three cases are presented with an emphasis on the analytical perspectives that set the stage for the subsequent discussion. In this first layer of analysis, each case is examined regarding the students CT learning processes as signs of be-greifbarkeit and motivation and engagement as signs of self-efficacy. In the subsequent discussion, a second layer of analysis builds on the case analyses. Here, the concepts of self-efficacy and be-greifbarkeit are applied to connect the three cases and explore their broader implications.

Results from Three Empirical Cases

In the following section, three cases involving plugged and unplugged activities are presented alongside the results. Each case includes a description of the assignment, an account of how the students engaged with the activity, and reflections gathered from follow-up interviews with the students. The three cases are as follows:

1) an unplugged introduction to algorithms,
2) an unplugged exercise acquainting students with flowcharts, and
3) a plugged interactive narrative assignment in Twine, a digital platform for interactive story development.

Case 1: Toothbrushing Procedure

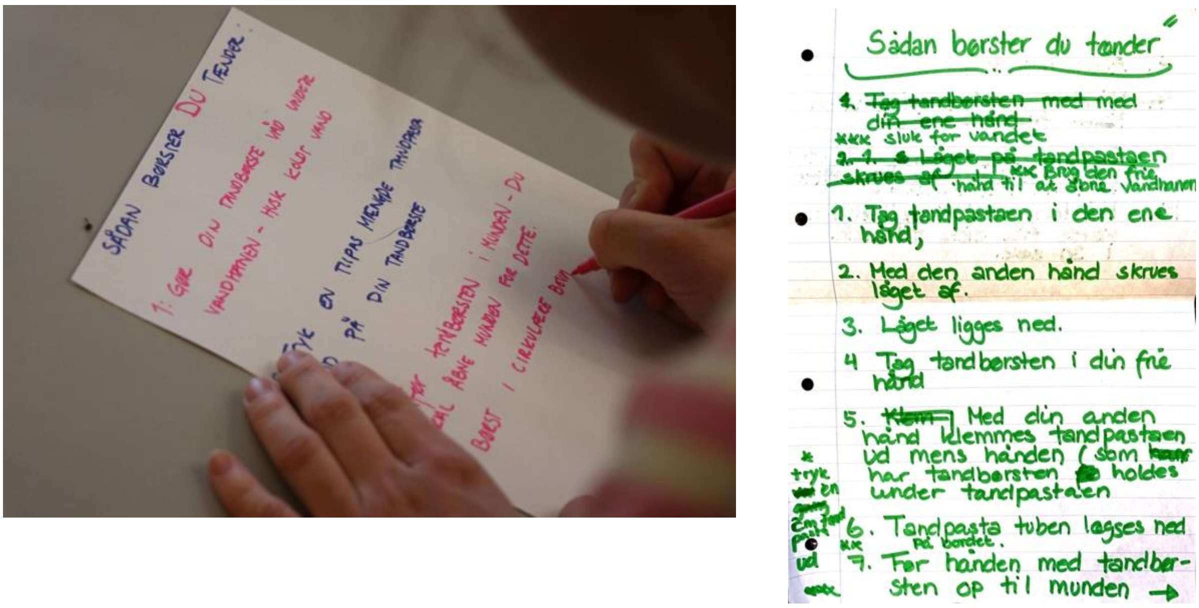
In the initial 20-minute assignment, the students were instructed to describe in detail how to brush their teeth and write instructions with a pen on a piece of paper. Subsequently, the instructions were to be followed very accurately by a fellow student. Finally, students shared and discussed their written instructions and their experiences with one another. The assignment outlined in the PowerPoint presentation was straightforward, as follows:

1. Describe in detail how to brush one's teeth.
2. Follow the instructions provided by a fellow student precisely.
3. Share and discuss your experiences.

The overriding intention of the activity was to introduce CT through an unplugged learning assignment, drawing on a familiar everyday routine. Specifically, the primary objective of the assignment was to introduce *algorithm* as a core CT concept and *pseudo code* as a representation of algorithms. Furthermore, the assignment aimed to encourage student engagement in CT through a playful activity and to support students' self-efficacy by demystifying the concept of algorithms. Additionally, it supported the CT competencies of decomposition and abstraction.

Overall, the students found the first part of the assignment straightforward, with all students producing lengthy and detailed descriptions of the process of brushing one's teeth (see Figure 1).

Figure 1. Toothbrush activity



In stage two, when the students had to follow fellow students' instructions, the lecturer emphasised the importance of only doing what was instructed and not assuming anything or 'filling in the blanks' with their knowledge about toothbrushing. This meant that it became clear that the written instructions lacked implicit information such as remembering to turn on the water, how to hold the toothbrush, how to insert it into the mouth, what movements to do with it when inserted into the mouth, how to put toothpaste onto the toothbrush, how much toothpaste to put on, turning the water off and so forth. For instance, one student read the instruction ‘put the toothbrush into your mouth’, and the other student then tried to put the *whole* toothbrush into his mouth. In general, the students demonstrated high levels of engagement throughout the activity.

In the subsequent short plenary discussion with the students, a key topic was the numerous details about toothbrushing that students had taken for granted when writing their instructions.

In the follow-up interviews, students once again noticed the contrast between the implicit nature of informal descriptions and the precision required in formal representations. As a student noted, ‘it was very nice to begin by doing an exercise with a toothbrush and discover that you didn’t have a good grip of it anyway, as you thought you had.’ (student 4). Overall, students reported that they had gained valuable insights into the importance of being explicit when writing algorithms.

On a broader level, the students articulated an understanding of how the activity enhanced their comprehension of CT. One student said: ‘Well, we set off with the toothbrush exercise that … in a very tangible way tells us what the idea of computational thinking is.’ (student 13) Another student linked the exercise to the practices of CT, demonstrating an understanding of key elements:

> You also used this … abstraction in relation to the toothbrush exercise. You had to simplify a procedure, truly down to step by step. … In that way, it is also to create abstraction. To simplify something that is so simple: A toothbrush process! (student 7)

Thus, the interviews indicate that the students clearly understood how the assignment supported their work with CT and how they were already familiar with key CT elements.

To sum up, this activity supports the assumption that starting CT work with unplugged approaches enhances student motivation. In this case, the students acquire an initial understanding of what is necessary in an algorithm to make it readable for a computer, which is practiced using pseudo-code. The pseudo-code is easily understandable for the students, and the exercise does not cause unforeseen or non-productive problems, which seems to strengthen their motivation and engagement.

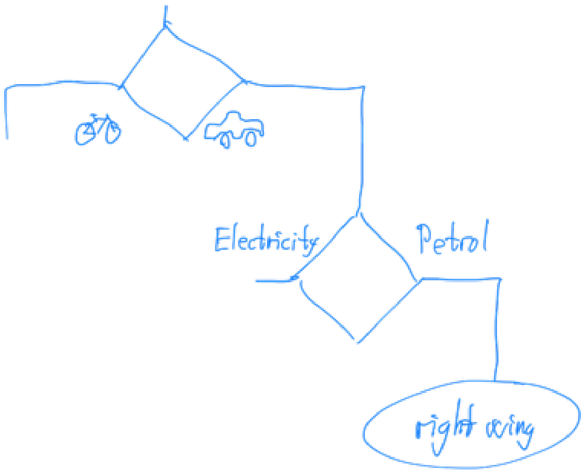
Case 2: Political Profiling Quiz

In the next assignment, students were asked to produce a political profiling quiz in the shape of a flowchart using a pen and paper in groups of three and four. The assignment was allocated 30 minutes and followed a simple three-part plan presented to the students:

1. Make a political profiling quiz as a flowchart using pen and paper.
2. Try each other's quizzes.
3. Share and discuss your experiences.

The objective of the quiz was to deepen the students' understanding of CT elements such as decomposition, abstraction, and algorithmic thinking, by incorporating multiple pathways using if-then-else structures instead of relying solely on simple step-by-step instructions, as in the first activity. For instance, a profiling quiz might begin by asking about the preferred mode of transportation: bicycle or car. In addition, if it was a car, ask if the car is electrical or uses petrol (gasoline), and then, if it is petrol, then conclude that the user's political view is right wing (see Figure 2).

Figure 2. Flowchart



To support their learning of CT, the unplugged activity was once again based on a familiar and significant phenomenon, a political typology quiz, while also introducing a new CT concept: the flowchart. Furthermore, the assignment was designed to help students explore the limitations and logic of CT and programming by demonstrating how results are generated from data. Additionally, it aimed to foster self-efficacy and promote empowerment through the demystification of the concept of a profiling algorithm. When the students began working on the activity, they appeared confident. However, it soon became evident that the assignment was immensely challenging for them. The students struggled to grasp the complexity of if-then-else logic and to apply it in the flowchart, which initially seemed like a straightforward task. One group attempted to overcome the difficulties by creating the flowchart on the floor and physically walking through its pathways (see Figure 3). They found the process of reducing a political profile to simple questions, while simultaneously managing the answers and their consequences in the flowchart, overly complex.

Figure 3. A flowchart on the floor

Another group gradually simplified the profiling task by reducing the number of pathways and outcomes in their flowchart. Consequently, the activity took longer than anticipated, with the students making numerous compromises to complete their flowcharts.

In the interviews, the students also pointed at the combination of the flowchart and the profiling quiz as being too complicated. As one student said: 'However, for me, that is also kind of a drawback in doing flowcharts. All the elements of left, middle and all that… I got kind of lost actually.' (student 3). Nevertheless, the students found the assignment meaningful, as it connected to issues of empowerment and digital citizenship. One student highlighted concern about the black-box nature of the political typology quiz and the potential for unknown data biases embedded within the algorithm. 'Multiple choice is not to be trusted, and we as users cannot see how it works.' (student 8). Another student linked the experience of working with the flowchart and understanding the consequences of various choices directly to the concept of empowerment as a countermeasure to manipulation. 'The flowchart thing … gives you a better understanding that you can be manipulated. … And then, you are already just a little bit, like, empowered.' (student 6). Manipulation was also mentioned by a student, who connected this to the black-box nature of the quiz:

> Well, if you don't know anything about it, manipulating you will be so much easier. Knowledge is what empowers you. This is exactly what this subject is meant to do. Make us empowered users. We have just worked with this in relation to democratic citizenship. It is truly, truly important that we are enlightened. (student 8)

These students connected CT to both empowerment and citizenship, which was also an objective of the exercise.

In summary, the students found the activity challenging, and it did not enhance their CT competencies to the extent originally expected. Gradually, the students lost confidence in their ability to complete the assignment satisfactorily, and in this sense, the activity did not support self-efficacy as intended. Nevertheless, the difficulty itself led the students to understand that representing a complex phenomenon is not straightforward. Consequently, they gained valuable insights into CT, particularly in the areas of abstraction, decomposition, and algorithm design. These insights are central to understanding the nature of the profiling quiz as something constructed and designed by someone. Thus, the activity facilitated the students' understanding of a normally black-boxed phenomenon. Moreover, in a broader context, it enhanced their self-efficacy as critical and empowered citizens.

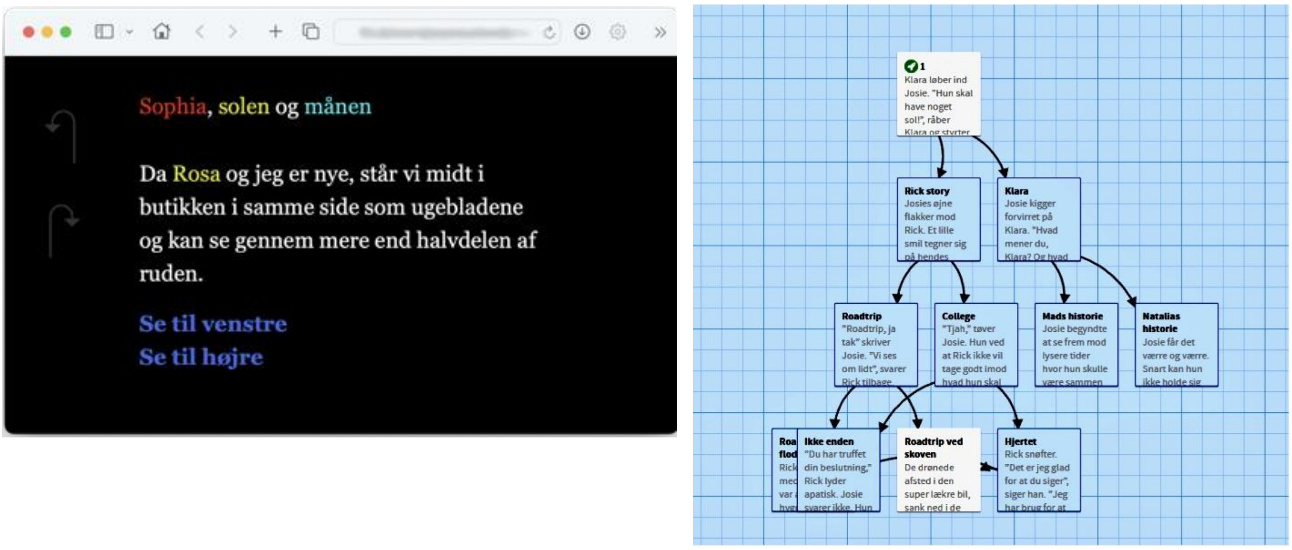
Case 3: Interactive Stories in Twine

In the final assignment, the students were asked to reinterpret a passage from a novel by producing an interactive story. Before the lesson, the students had read *Klara and the Sun* by Kazuo Ishiguro, which is told from the point of view of Klara, a solar-powered 'Artificial Friend' who is chosen by Josie, a sick child, to be her companion. During class, the students were told to select a passage and construct different alternative 'story paths' with the selected passage as the starting point. The result had to be written in Twine, an open-source digital tool for telling interactive stories. The default format for text in Twine is Harlowe which is a markup language with programming features. The students had no prior experience with Twine or Harlowe, and they were asked to use at least three different Harlowe codes. The students worked in groups of three and four, and the activity lasted an hour and 15 minutes.

The learning objective of the activity was to foster an emerging understanding of more complex CT competencies, particularly abstraction, decomposition, and algorithmic thinking. Additionally, the activity introduced *markup language*, offering an example of computer code. It also aimed to connect two representations of multiple pathways based on user input: the visual, unplugged representation of the flowchart and the textual, plugged representation of the Harlowe code. By anchoring the activity in the students' storytelling and their engagement with the novel, the goal was to inspire and stimulate their motivation.

Overall, the students were very engaged in the storytelling, in the creative activity. Most students were acquainted with physical books featuring multiple story paths, and storytelling is, of course, also a well-known activity. Furthermore, having found *Klara and the Sun* moving and thought-provoking, the students seemed to pitch into the assignment with great enthusiasm and confidence. Each group produced lengthy and complex stories, with some even incorporating images and videos (see examples in Figure 4).

Figure 4. Examples of interactive stories using Twine



Although the final product was a digital Twine project, most groups drew on additional tools. For example, while all groups made use of the computer-generated graphs of the 'Passage View' of Twine to obtain an overview of the story paths, some groups also drew these paths on a piece of paper, thereby connecting to the previous activity involving flowcharts. Regarding the articulation of the actual text, some groups wrote directly in Twine, whereas others produced drafts on paper or in Microsoft Word, again drawing on additional, more well-known tools. Interestingly, these tools included both unplugged (pen and paper) and plugged (Microsoft Word) tools.

In the follow-up interviews, the students expressed enthusiasm about the activity. One student said: 'It was a cool way to work, I think. I could really see how you could use it in the future with your own students.' (student 6). Other students were equally delighted:

> I think that's also what I got the most out of today, in relation to the flowchart. … Not that you needed to use your brain more or less. I think maybe it's just because I understand it better now. (student 4)

> And it was actually a lot of fun. … And when you're working with Twine, you're kind of tuned into how to do it, and then all of a sudden, it's just there… and you programme it. … what you're learning here is programming. (student 13)

Thus, the students expressed a strong grasp of the activity and conveyed confidence in their ability to express their intentions by means of the digital tool.

To sum up, all groups were successful in writing interactive stories in Twine, and they found the assignment to be motivating. Whereas the new plugged resource, Twine, produced challenges for the students, it did not significantly affect the students' remarkable engagement with the task or their apparent experience of competence.

Discussion

The three cases illustrate the complex interplay between plugged and unplugged activities in teaching CT in education. This discussion will link the findings from these cases and examine the broader implications across all three.

Supporting CT

The aim of the activities was to support student teachers' understanding of CT, particularly through the application of unplugged activities. The three activities involved a variation of CT competencies, and the students addressed the computational problems of the activities in different ways.

The concept of *algorithm design* (Shute et al., 2017) was particularly prevalent in the first and third activities. Brushing one's teeth can easily be perceived as a step-by-step recipe, and even though the interactive story involved a more complex structure of separate story paths, the students were supported by the well-known linear structure of the narratives of each story path. In the case of the profiling quiz, however, there was no sequential structure to support the construction of the algorithm design (the flowchart); the students had to construct the structure themselves which proved difficult. In both the profiling quiz and the interactive story activity, the students produced visual unplugged representations of the algorithm structure, but in the profiling quiz activity, the representations apparently provided insufficient scaffolding. Even the group creating the flowchart on the floor and walking through it had problems keeping track of the algorithm design.

All the activities involved breaking down a complex problem into smaller parts, thus involving *decomposition* (Shute et al., 2017). However, the process of decomposition varied significantly across the different activities. In the toothbrushing activity, the sequence of concrete actions provided an accessible structure for breaking the problem into smaller parts through an iterative process, aligning with the concept of decomposition (Shute et al., 2017). In the interactive story activity, different narrative paths usually began identically, and when the stories parted, the ramification was a natural breaking up of each path. In both cases, the activity itself provided assistance regarding possible decompositions. In contrast, how to break down the problem of profiling through a profiling quiz turned up as much more difficult. This might stem from the fact that the students had to decide for themselves how to produce concrete questions that revealed political convictions. Additionally, the solution had to be expressed in the form of a flowchart, a representation that were unfamiliar to the students. Regardless, in the unplugged profiling activity, the students found decomposition markedly challenging.

Finally, *abstraction* was employed and developed in diverse ways. For instance, abstraction was utilised to simplify descriptions of the toothbrushing activity to emphasise the most important parts. Additionally, the activity drew attention to the simplifications made in descriptions of procedures for humans; details were left implicit because humans normally understand the specific context—which computers do not. In this way, the unplugged activity was used to demonstrate something important about (plugged) computer programming. In the profiling activity, it proved difficult to create a clear-cut abstraction regarding political conviction, not least on the basis of a few simple questions. Furthermore, the model had to be expressed in an unfamiliar language, the flowchart. Finally, in the interactive story activity, the visual representation of the story paths functioned as a valuable model of the story paths—regardless of whether it was in Twine, 'plugged', or on paper, 'unplugged', or a combination.

Self-Efficacy and Be-greifbarkeit

As outlined in the background section, both self-efficacy and be-greifbarkeit have the potential to become tools for unpacking students' learning processes, which is why the assignments were designed to promote these aspects (Katterfeldt et al., 2015). In the toothbrushing activity, the students were familiar with the actions they were tasked with describing. They already had bodily and sensory experiences of what it meant to brush one's teeth which provided them with a basis of be-greifbarkeit in the task. This familiarity continued to be the reference, drawing from prior experiences, and was supplemented with the physical toothbrush given to them as part of the workshop. In the profiling activity, some students attempted to create be-greifbarkeit by laying out the flowchart on the floor and physically walking around it. Others attempted to draw visual representations with pen and paper. However, these efforts did not help them much. This suggests that physical interactions with materials during the workshop or prior bodily experiences can enrich be-greifbarkeit, but alone, they are not sufficient for students to successfully solve the given task.

In the toothbrushing activity, the same familiarity, which was enabled by physical references and bodily experience as be-greifbarkeit, also reinforced their belief in their ability to manage the task (Caeli & Yadav, 2020; Ford et al., 2017). This created self-efficacy allowing them to expect positive results. In the political profiling activity, the students initially displayed great confidence in their ability to successfully address it. They understood the task, and the political profile quiz were familiar. However, the complexities of producing a profiling algorithm combined with an unfamiliar and highly formalised representation, the flowchart, proved difficult. As a result, the students became increasingly challenged, which led to a decline in their self-efficacy. In the interactive story activity, the student expected the task to demand their full attention, since the activity involved plugged programming in a seemingly unfamiliar environment, but it turned out to be easier than expected. Even though they had no prior experience with the application, Twine seemed to facilitate the process and even assist in creating choices and alternative stories.

Furthermore, the user interface of Twine resembles the interface of text editing applications familiar to the students. This seems to suggest that the activity could support a sense of self-efficacy and empowerment through the experience of being able to design, create, and 'have a voice' using digital technology.

Computational Empowerment

Computational empowerment and CT are, as previously described, strongly connected in the Danish curriculum, where they are linked to the concept of citizenship (Bocconi et al., 2018). In the cases, computational empowerment is more specifically connected to certain aspects of CT, and the students appear to develop a strengthened sense of empowerment through self-efficacy.

In the toothbrushing activity, the idea of empowerment can be connected to the concept of self-efficacy, as the students ended up feeling empowered with a sense of strengthened self-efficacy when they were able to create the initial algorithm design of a simple toothbrushing routine as an entry into understanding how computers function.

In the political profiling activity, the students attained an initial understanding of CT concepts as they experienced how a profiling algorithm is structured around nonneutral and heavily normative interpretations of simple and banal questions. Here, they began to explore the algorithms that determine democratically important political profiles, influencing voters and, as such, the democratic voting system. This connects to the idea of empowerment, as Brennan and Resnick (2012) describe it where understandings of technologies and having the knowledge to ask questions about them allow students to negotiate and understand the realities surrounding them in the technological world.

In the interactive story activity, the students could be seen as attaining computational empowerment by expressing themselves with technology through computer models, as they created the interactive story in Twine which can be linked to Papert's initial ideas. Here, the students experienced agency and empowerment by actively engaging with technologies to create products (Papert, 1980).

These activities demonstrate how computational empowerment can be fostered through carefully designed CT tasks that align with students' developmental stages and the broader goals of citizenship education. By engaging with abstraction, algorithms, and critical reflections, students not only developed key CT competencies but also gained confidence in navigating and questioning the digital aspect of their everyday life.

Unplugged Activities

Applying a straightforward definition of 'unplugged' as 'without a computer' or 'nondigital', the first two activities were entirely unplugged, while the interactive story activity was part plugged, part unplugged. Nevertheless, they all related to computational practices and expressions.

As is often the case, the unplugged activities served as an introduction to CT on the premise that they require no technological or programming skills. However, the findings of this study indicate that the significance of using or not using computers is not a crucial factor in itself. Although the students used 'plugged' resources such as Microsoft Word and the text editing features of Twine without much effort in the interactive story activity, they found grasping the 'unplugged' flowchart activity challenging. In other words, it is important to make a clear distinction between 'requiring no technological knowledge' and 'unplugged'. Some unplugged activities might require expertise in an unaccustomed technical language (such as the flowchart), whereas activities involving a computer might come across as straightforward and uncomplicated, perhaps drawing on existing competencies with computers.

Although unplugged activities are often related to kinaesthetic or physical activities, which are ascribed introductory capabilities, the physical activities do not always seem to help the students (Curzon et al., 2014; Sentance & Csizmadia, 2017). In the political profiling activity, the students created a flowchart on the floor, engaging in bodily interaction with the complex task, yet this did not result in a greater understanding. In contrast, bodily experiences and interactions with the toothbrush created some apparent advantages for the students in the first activity. This finding points to the fact that kinaesthetic or physical activities alone do not seem to make a difference or provide an advantage, which is further illustrated by the non-kinaesthetic, plugged Twine activity.

A final element of the unplugged approach to CT is the expected advantages in relation to the creation of self-efficacy among students. In the toothbrushing activity, this is exactly what was expected to be the outcome; they would approach the new CT competencies with an activity that had a non-threatening nature as an initial step in developing comprehension of CT (Caeli & Yadav, 2020; Ford et al., 2017). This activity was designed to create increased confidence, and this was also expected to be the case in the political profiling case which was a well-known phenomenon and unplugged in the design (Curzon et al., 2014; Ford et al., 2017; Tsarava et al., 2017). However, the confidence quickly plummeted, which first rose again in the partly plugged activity at the end.

Although the unplugged approach to learning CT, in some cases, has lived up to its potential, it has also proven to be more complex. In investigating the consequences of using unplugged environments as a basis for CT activities, it was clear that the students' relation to and knowledge about different technologies, as well as the complexity of the technology and the language that the students are required to utilise, are equally important factors to consider.

Conclusion and Implications

This paper has highlighted the multifaceted role of unplugged activities in teacher education for learning CT. By examining three cases of student teachers engaging in unplugged and plugged activities, the findings underscore the nuanced interplay between these approaches.

While unplugged activities are often heralded as accessible and non-intimidating entry points for learning CT, this paper demonstrates that their success is contingent on various factors, including the students' prior knowledge, the complexity of the tasks, and the pedagogical design of the activity. This challenge the assumption that unplugged approaches are inherently more effective or accessible for introducing CT. Instead, the paper suggests that the success of unplugged and plugged activities lies in the alignment with learners' prior knowledge and the scaffolding provided to bridge gaps in understanding. Designing CT activities requires careful consideration of the tools—whether plugged or unplugged—and the complexity of the skills and conceptual understandings they demand.

From a broader perspective, the paper offers insights for teacher education programs aiming to integrate CT. First, the binary distinction between unplugged and plugged should be reevaluated in favor of a more fluid understanding of how different tools and approaches can complement each other. Second, successful CT education requires balancing task complexity with pedagogical support, ensuring that activities are stimulating yet accessible. Lastly, fostering self-efficacy remains a foundation of successful CT education. Activities should be designed to enable learners, allowing them to gradually build their understanding of CT in both plugged and unplugged contexts, connecting abstract theory with practice through activities stimulating be-greifbarkeit.

Future research could explore the impact of combining plugged and unplugged activities on student teachers' CT competencies, as well as the role creating self-efficacy through activities promoting be-greibarkeit by leveraging well known tools and contexts. Additionally, investigations into how such approaches impacts the subsequent teaching practices of these future educators could provide deeper insights into the transformative potential of unplugged and plugged approaches to CT in education.

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