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1. Introduction

Today, children are growing up surrounded by versatile digital technologies [1,2], and at an early age, children start to form conceptions of how these technologies work and their basic capabilities [3]. Therefore, teaching children about digital technologies should consider children's initial mental models of the technologies [4], as well as the role the technologies play in children's everyday experiences [5].

This paper explores five- to seven-year-old children's concepts of computers, code, and the Internet. The rationale behind focusing on these concepts is grounded on the changed nature of children's digital life-worlds and recent curricular reforms. Computers that once were clumsy stand-alone machines have transformed into ubiquitous technologies, such as mobile devices (i.e., tablets and smartphones) and computer-integrated household devices (i.e., washing machines, refrigerators, and toys). Thus, it is important to study whether and how this development is reflected in children's concepts of computers. Additionally, whereas once games and movies were bought or rented from specialty stores, today they are downloaded, played, and watched online [1,2]. In other words, as the Internet is one of the meaningful life-worlds of 21st-century children, it is important to deepen our understanding of how they conceptualize this environment. Last, the "learning to code" agenda was recently introduced in school curricula across Western contexts [5,6]. The pedagogics of elementary programming for young children are in the emerging stage [5,7], and to develop appropriate and research-based methods, up-to-date knowledge of children's initial concepts of code and programming is needed.

These three concepts should be examined within the same study because thus far, children's conceptions of these concepts have been studied separately. As children's concepts of computers, code, and the Internet appear to be deeply intertwined, this division is artificial. This viewpoint is well illustrated when papers by Edwards et al. [8], Robertson et al. [9], and Sheehan [10] are compared. In all these papers, children expressed that they watched videos and played games when they used computers. However, in Edwards et al.'s [8] study, these activities were categorized as conceptions of the Internet, whereas Robertson et al. [9] classified these activities as children's conceptions of computers, and Sheehan [10] classified these activities as children's conceptions of computer programs. It appears that the research objective —not the content of children's answers—determines how the information is interpreted and categorized. More holistic approaches—such as the one used in this study—are needed to better understand children's conceptions.

1.1. Research questions

The research questions that guided the research process are as follows:

- What conceptions do five to seven-year-old children have about

a) computers,

b) code,

c) and the Internet?

- How are these conceptions related to each other?
- What are the foundations of these conceptions?

This study begins by summarizing the current state of research on children's conceptions of computers, code, and the Internet. Then, the research questions, data, and analysis methods are introduced. Then, the findings are provided. The paper concludes by discussing the implications of the study's findings for pedagogical practices and future research.

2. Background

2.1. Children's conceptual development

One of the most frequently applied frameworks for children's conceptual development is Vygotsky's [11] work on children's everyday concepts and scientific concepts. Everyday concepts refer to those that derive from children's daily practices and tool use [8,12]. When it comes to scientific concepts, two different interpretations can be found from previous research: Some scholars have demarcated scientific concepts as those that children are taught in school [12] whereas others have defined scientific concepts as children's rationales for how and why things work [8]. This study follows the latter approach which is commonly used in research on children's concepts of digital technologies [3,8,13,14]. In this interpretation, everyday concepts and scientific concepts are not treated as mutually exclusive categories but are understood to interact and work together for development [11,15]. In the chosen interpretation, a concept categorized as "scientific" does not have to be accurate. Put differently, instead of pinpointing the level of conceptual accuracy, the term "scientific" refers to a type of a concept that describes and explains the functional features of the phenomenon under discussion.

To form a scientific concept (accurate or not), children must identify cause-and-effect relationships, formulate hypotheses, make generalizations, and draw interpretations from their observations and experiences. All of these processes can be defined as higher-order thinking skills [16]. Thus, although children's scientific concepts may appear to us adults as simple and inconsistent abstractions of everyday experiences [17], deeming these concepts "naïve" or as evidence of "minimal" understanding [14] is disrespectful. Instead, these concepts should be treated as a valuable source of information regarding how children perceive and analyze their life-world.

Respecting children's initial scientific concepts does not mean that it is not important or necessary to teach children about accurate scientific concepts. This understanding is necessary for children to develop mature concepts in which everyday concepts and (accurate) scientific concepts merge and for children to understand how scientific perspectives explain everyday concepts [10,12]. The Internet can be used as an example: The everyday concept of the Internet refers to the online activities that children carry out and observe, whereas the (accurate) scientific concept of the Internet refers to the understanding that the Internet is a complex technical and social system and a network of digital technologies that provides various services and socially mediated practices through the exchange of data [8,14]. Children who possess a mature concept of the Internet "understand that their practices and tool use when engaged with the internet involves a network of technologies sharing data designed and used by people" [8, p. 53].

One of Vygotsky's main arguments was that children's concepts do not develop independently but through social interaction [11,12]. This argument also applies to learning about digital technologies. Although statements about children being "native speakers of the digital language of computers, video games and the Internet" [18, p. 2] have been made, a body of evidence suggests that young children's learning about digital technologies is derived from intentional or unintentional tutoring from parents and siblings [1,8,19]. Sometimes, learning from others can take place accidentally, but children also try to actively synthesize the information they receive from adults and from their everyday experiences into coherent mental models [17].

2.2. Children's conceptions of computers, code, and the Internet: A literature review

The earliest attempts to understand children's conceptions of computers can be traced back to the 1960s [20] and the first studies that explored children's understanding of the Internet date back to the early 2000s [21]. Since then, both themes have been studied regularly [e.g. 3,14, 22]. This section provides an overview of the previous research the basic information of which is comprised in Table 1 and Table 2. As can be seen from them, all but one computer-related study is at least 10 years old [9], and Internet-related studies, in turn, have mainly concentrated on older children [8,23].

Table 1. Studies on children's concepts of computers (including programming)

Year	Study	Children's age	Reference no
1968	Wolfe	Seventh graders (exact ages not provided)	20
1984	Mawby et al.	8–12	24
1986	Hyson & Morris	4	25
1987	Hughes	6–12	26
1993	Denham	9–12	27
1995	van Duuren & Scaife	7–11	28
1998	van Duuren et al.	5–11	29
2002	Mumtaz	10–11	30
2003	Sheehan	6–10	10
2003	Jervis	7–11	31
2005	Jervis	7–11	32
2005	Turkle	2–14	33
2007	Hammond & Rogers	9–12	13
2008	Bernstein & Crowley	4–7	34
2008	Levy & Mioduser	5–6	35
2017	Robertson et al.	5–8	9

Table 2. Studies on children's concepts of the Internet

Year	Study	Children's age	Reference no:
2005	Papastergiou	12–16	4
2005	Yan	5–12	14
2006	Yan	9–13	36
2009	Yan	9–17	37
2011	Dodge et al.	K–2 children (exact ages not provided)	38
2012	Diethelm et al.	13–14	39
2017	Kodama et al.	10–14	22
2018	Oliemat et al.	4–8	23
2018	Edwards et al.	4–5	8
2018	Murray & Buchanan	10–12	40

In a recent review, Rücker and Pinkwart [3][1] identified the following types of scientific rationales from children's conceptions of computers: 1) Computers are intelligent, 2) computers are mechanical, 3) computers are omniscient databases, and 4) computers are programmable. Children also characterize computers according to what the children do with them, meaning that children understand computers as devices that can be used to play games, retrieve information, and watch videos [9], which in this study are understood as everyday concepts.

The conception of *computers as intelligent machines* refers to an animistic understanding in which computers are seen as agentive and conscious artifacts that engage in independent thinking. Such concepts are found in the oldest and the most recent research papers and expressed by children of various ages [9,20]. According to Turkle [33], such concepts are formed when psychological reasoning dominates physical reasoning: The more complex and opaque the technology, the more likely children rely on psychological reasoning when they explain the technology's functional capabilities [33,35], and the time spent with computers strengthens children's psychological reasoning if no alternative explanations are provided [26]. Nevertheless, contrasting findings have been provided by previous research. The most prominent example is Bernstein and Crowley's [34] study in which four- to seven-year-old children ranked computers low in intelligence and psychological characteristics. This discrepancy may have been caused by methodological differences, as, unlike in other studies, Bernstein and Crowley [34] asked children to compare computers with people who, in turn, were ranked high in intelligence and psychological characteristics. Additionally, the questions asked of the children may have had influenced their answers. For example, Robertson et al. [9] asked children whether they think that computers want to do things and think like humans. As noted by

[1] There was also a fifth category in Rücker and Pinkwart's [3] categorization: Computers are wired networks. However, in this paper, this category is included in the computers are mechanical category due to the notable overlap of the themes.

Vosniadou and Brewe [17], children can read such questions as prompts of the implicit demands of the questions.

Children also reason that *computers are omniscient databases* that have all the answers to everything stored in their memory [4,28,39]. Depending on the study, such a concept is more or less common with the youngest children. Mawby et al. [24, p. 30] described how children "spoke as if computers know specific facts, such as the product of 23 times 45, rather than having general algorithms that generate specific answers to specific questions," a feature that was most prominent among the youngest participating children (eight-year-olds). In contrast, none of the five-year-old participants in a study by vanDuuren et al. [29] believed that computers have the answers typed in. Given the methodological differences between the studies, it is impossible to point out exact reasons for these contrasting findings.

Some children consider *computers to be mechanical,* as the children equate computers with other mechanical devices, such as refrigerators [9], or make clear distinctions between computers and things the children consider biological, namely, people and animals [34]. In both cases, the children (four- to seven-years-old) relied on categorization- and classification-based reasoning by sorting based on similarities (computers are like refrigerators) or differences (computers are not like people). In addition, young children conceptualize computers as wired networks [9,24,31]. These conceptions suggest that the functions and nature of computers are—to a notable extent—described and analyzed by relying on their physical features. In addition to wires, children name electricity, batteries, plugs, monitors, and keyboards as essential features of a functional computer [9,10,13, 25,26]. One explanation for the prevalence of these components is that they are either visible (i.e. wires, keyboard, and plugs) or familiar to children from other devices (i.e., batteries and electricity) [3].

Computers are also conceptualized as *programmable machines* that receive commands from humans [9,28,33]. Even young children are usually able to name examples of their everyday use of computer programs, including playing games, using a word processor, and using drawing software [10,28]. However, the scientific conception of computer programming requires a conception of computers as something that can be programmed [3]. It appears that children, especially young children, do not have this conception. For example, almost half of the six- to 10-year-old children in Sheehan's [10] study were not able to answer the question, "what are computer programs?" Similarly, none of the five- and eight-year-old participants in van Duuren et al.'s [29] study were able to explain what programming is. Instead, they either claimed not to know or described what their favorite software applications were. Although the conception of computers as programmable machines—which can be considered the most complex and accurate scientific conception—is most common among older children, it appears that children rarely come up with the idea of programming by themselves but have been told about it or have engaged in programming-related activities [10,26,28,30,32,33,35].

Research on young children's technology use suggests that although children use Internet-based services (i.e., play online games and watch programs and movies from on-demand services) regularly, they have little to no understanding of the scientific concepts of the Internet or what it means to be "online" [1,38]. The few scientific—but not necessarily accurate—concepts that have been identified by previous literature are the Internet as a big central computer, the Internet as a network of two or more computers, the Internet as a network of computer networks, and the Internet as a giant search engine [4,8,40]. Such concepts are typically expressed by older children (10- to 16-year-olds).

Younger children, in turn, use slightly different rationales. Four- and five-year-old children in Edwards et al.'s [8] study conceptualized the Internet by referring to its mechanical features. They, for example, noted that electricity or wires are required for the Internet to function properly [8]. As discussed, the prominence of such features relates to their visibility (wires) and general familiarity (electricity) [3]. Another finding by Edwards et al. [8] was that children often possess tool-based concepts in which the Internet is understood as a feature of the device they use for [see also 4,23,37]. Last, some children (five- to eight-year-olds) in Oliemat et al.'s [23] study conceptualized the Internet as a connection that is needed to download games and stream videos, to give two examples.

To conclude, previous research has identified that children have various concepts of computers, code, and the Internet. The different concepts are not mutually exclusive, and children can possess conceptual blends that are combinations of two or more concepts [3]—a phenomenon familiar to non-technology-related concept research as well [17]. In addition, there are no unambiguous explanations behind how these conceptual categories emerge. Depending on the study, factors such as historical context [3], quantity of computer use [26], quality of computer experiences [28], and the age of the children [29] have been named as possible factors leading to the development of different concepts. Furthermore, these factors appear to be more interlinked than independent. For example, Yan's [14] study results suggest that the quantity and quality of children's online experiences are related to children's age: The younger the children, the more filtered and regulated their Internet use [41]. This may explain why younger children have a narrower understanding of the Internet than older children [37]. Synthesis of previous research also suggests that data collection methods, for instance, the questions asked of children, play a role in shaping children's concepts.

3. Method

3.1. Participants, data, and data collection

The data consists of drawings produced by and interviews conducted with 65 five to seven-year-old children from five preschool groups from northern Finland. Table 3 presents basic information regarding the age and gender distribution of the participating children.

Table 3. The participating children

	Girls	Boys	Total	Total %
Five-year-olds	6	2	8	12 %
Six-year-olds	26	22	48	74 %
Seven-year-olds	4	5	9	14 %
Total	36	29		
Total %	55 %	45 %		

The teachers of the preschool groups were attending to an in-service training course—in which I acted as a trainer—and volunteered to collect the data as part of their course assignments. Having teachers to implement the data collection instead of an outsider-researcher was believed to provide the children a safe and familiar environment to express their views [42]. Written consent to participate in the study was requested from the municipal education departments as well as from the children's guardians. Moreover, oral consent to participate in the study was requested from the children. From an ethical point of view, it was crucial that the children were informed of the objectives of the research project and knew who was carrying out the study [43,44]. As I was not able to visit all the groups in person, I sent every group a personal video greeting in which I introduced myself and explained why I was interested in hearing their thoughts. I also emphasized that if the children agreed to give their drawings as data, then the original drawings would be returned to them right after I made digital copies of those drawings. Later, I sent another video to the children in which I expressed my gratitude for having the opportunity to study their drawings and interviews. The data collection was conducted from January to February 2017.

Children's drawings are a useable tool for knowing what children are telling us and gives us adults a chance to take a glance to their thinking and understanding of the world [45]. Drawing can be described as a child-centered data collection method, as it is an enjoyable and beneficial activity for most children [46]. Children are often interviewed based on what they have drawn. The strength of combining visual and verbal narration is that by using the drawing—or some other visual medium—as a mediating tool, different parties can understand each other's thinking by creating a transitional space in which their thoughts and ideas can be externalized into concrete form [47]. Drawings and interviews are a commonly used form of data in research regarding children's understandings of technologies [10,31,48].

In the context of the present paper, a procedure known as the draw and tell conversation method (DTC) [49] was applied to explore the children's conceptions. In DTC, children are first given a specific art directive that reflects the study purpose. When the drawing is ready, a conversation facilitated by an interviewer is carried out. In this case, the directive was the following:

> Your task is to draw how computers work. What are the different parts that computers contain? What is inside the computer? You can also write if you want.

More questions about computers, code, and the Internet were included in the interview sheet. To obtain rich data [50], the children's conceptions were explored using various trigger questions summarized in Table 4.

The questions were designed to be as open and non-descriptive as possible because the way questions are asked influence children's explanations [9,17]. For example, in Robertson et al.'s [9] study many children stated that computers are programmed with "computer chips," a concept they had been introduced to in the previous section of the interview. The children's answers were written down on the drawings and on an interview sheet [42,45].

Table 4. Interview questions

Topic	Questions
Computers	What are computers like? How do computers work? What can be done using computers? What have you done using computers? How do you know these things?
The Internet	What is the Internet? How does the Internet work? How can you use the Internet? What can be done using the Internet? What have you done using the Internet? How do you know these things?
Code	What do you understand about code? What do you understand about coding? What do you understand about programs? What do you understand about programming?

3.2 Analysis

The analysis process was guided by an abductive approach, in which the researcher moves between and combines inductive reasoning and existing theoretical models to develop new ways of theorizing the phenomenon under investigation [51,52]. In practice, the data was analyzed via monotype mixed analysis (MMA) [53]. In MMA, the data—be it qualitative or quantitative—is analyzed by using both qualitative and quantitative methods. The use of MMA requires that qualitative data is altered into a form that can be analyzed statistically and that quantitative data is transformed into a form that can be analyzed qualitatively [41]. This mixing can be characterized as a combination of measurement and interpretation [54] that allows rich and comprehensive views of the phenomena under investigation to be constructed. In the present study, transforming the data meant quantifying the occurrence of how often different types of features related to computers were drawn and mentioned, and these frequency counts were then converted to percentages to calculate the frequency effect size [55]. However, a high frequency was not a requisite for certain conceptions or themes to be meaningful, as from an interpretative point of view, what is not found in the data is as important as what is found.

Interpretative analysis was carried out by reading the data—both the drawings and interviews—by applying the method of constant comparison [56]. The comparisons were made in three levels: 1) within the data from the individual participants; 2) between the data from different participants, and 3) between the data and theory. These levels were more overlapping than sequential by nature. Comparison within the data from the individual participants means—for example—that the children's explanations of what could be done using computers were compared with their explanations of what could be done using the Internet. Put differently, if a child commented that a computer could be used to buy things, it was investigated whether she or he understood that this particular activity required an Internet connection (see Section 4.1.3 for further discussion). Comparison between the data from different participants refers to how interpretations made from the data from an individual child were compared with the data from others to identify possible patterns or “special cases.” One example is the notion that children who had encountered problems with Internet connection appeared to have a more accurate scientific concept of the Internet than others (see Section 4.2 for further discussion). Comparison with the data and theory refers to how all data-driven interpretations were compared with previous research on children’s conceptions of digital technologies to identify similarities and differences.

4. Findings and discussion

In this section, the findings of the study are provided. The section is divided into two subsections: The first subsection (4.1.) focuses on the question of what the children thought computers, code, and the Internet were (i.e. the children’s scientific concepts of computers, code, and the Internet). The second subsection (4.2) examines children’s conceptions of what can be done using computers and the Internet (i.e. the children’s everyday concepts of computers, code, and the Internet). The findings related to the foundations of children’s concepts and knowledge are discussed within these two sections.

4.1 Children’s conceptions of what computers, code, and the Internet are

4.1.1 Computers

The term “computer” typically referred to either a desktop computer or a laptop computer for the children: 46% (n=30) of the children drew or mentioned a laptop, and 40% (n=26) of the children drew or mentioned a desktop. In nine cases, it was not possible to identify the type of the computer. Only one child drew a tablet computer, and 25% (n=16) of the children named tablets as a distinctive form of technology when asked how one could use the device to connect to the Internet. None of the children expressed that computers could be found in other forms of technology, such as cars, washing machines, or toys. Unlike in earlier studies, conceptions of computers being intelligent machines [9] or omniscient databases [4,24,28,39] were rare and rather indicative by nature: 8% (n=5) of the children explained that computers could be used to seek information with no references to using the Internet, which suggested that these children believed that information was located inside the computer (see Section 4.2 for further discussion).

Only two drawings contained information about how computers might look inside. In both drawings, the child had drawn a square shape with wires inside it and referred to the drawing as the interior of the computer (see Fig. 1). However, using the drawings and interviews, it was impossible to determine which part of the computer the drawing referred to.

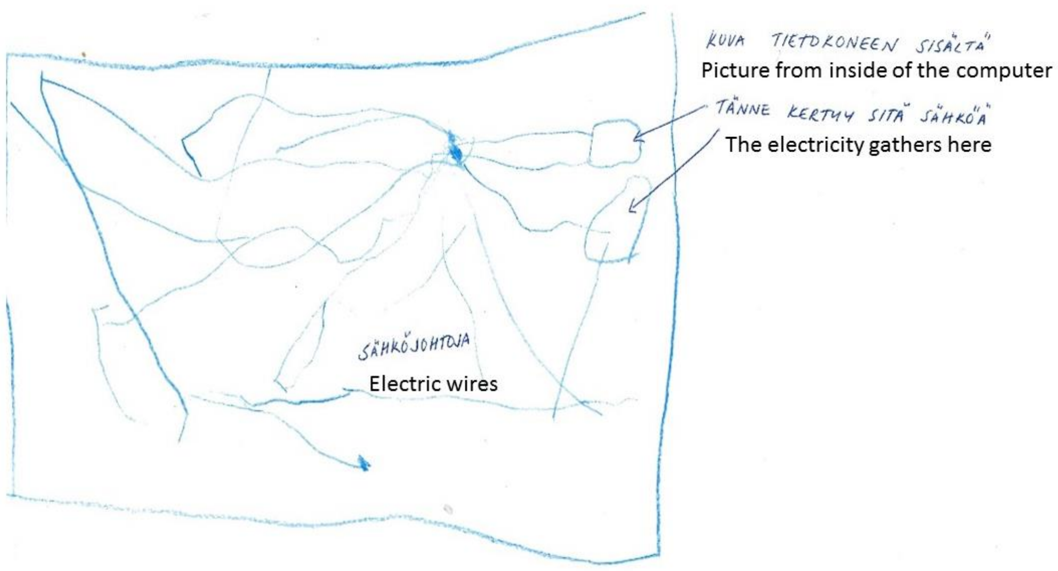

Fig. 1. Inside the computer (Boy#4 6y7m)

Two-thirds of the children included wires in their drawings [see also 9,31]. Other prominent features were monitors and keyboards, which were found in 88% and 75% of the drawings, respectively. In addition, more than half of the children conceptualized computers as electrical [see also 9,10,26]. Most of the children drew the computer from the user's perspective, which is a common feature in children's drawings of digital devices [10,48]. This explains—at least partially—why the drawings included elements that resembled monitors and controllers (keyboards and mice). One explanation for the prominence of electricity and wires in the drawings is that they are both vital for the computer to work properly: If the power cord is detached, then the computer will not start, and if the wire of the mouse or the keyboard is loose, then the user cannot execute desired functions. This explanation is piquantly captured in the following extracts:

> Computer works when you plug the chord into the wall. Writing transfers on the screen because there are wires between them. A wire goes from the mouse into the computer (Boy#26 7y0m).

> [computers] are like electrical, and they need to have something to write on. I mean, how else could those pictures come into it? It needs cords. Otherwise, they can turn off entirely. (Boy#30 6y7m)

Table 5 summarizes the distribution of parts and other mechanical features included in the children's drawings.

Table 5. Distribution of parts and other mechanical features

	Monitor	Keyboard	Wires	Electricity	Mouse	Fan	USB-stick	CPU	Speakers	Memory card	Optical drive
n (%)	57 (88%)	49 (75%)	43 (66%)	33 (51%)	20 (31%)	2 (3 %)	2 (3%)	2 (3%)	1 (2%)	1 (2%)	1 (2%)

While 40% of the children conceptualized a computer as a desktop computer and drew detailed pictures, only two of the children included a central processing unit (CPU)[2] in their drawings. Such a drawing is presented in Fig. 2, whereas Fig. 3 is a drawing of a desktop computer without a CPU.

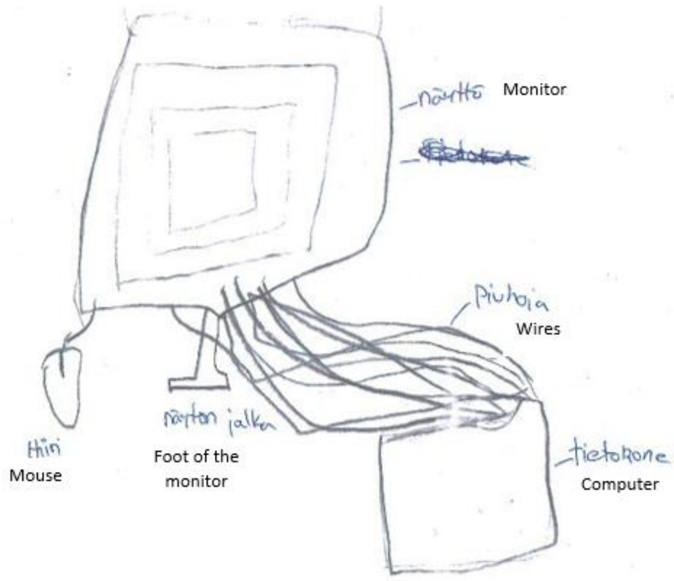

Fig. 2. Desktop computer with a CPU (Boy#22 6y4m).

[2] A CPU can refer to either the CPU chip or the computer tower inside of which the CPU chip is located. In this paper, a CPU refers to the latter.

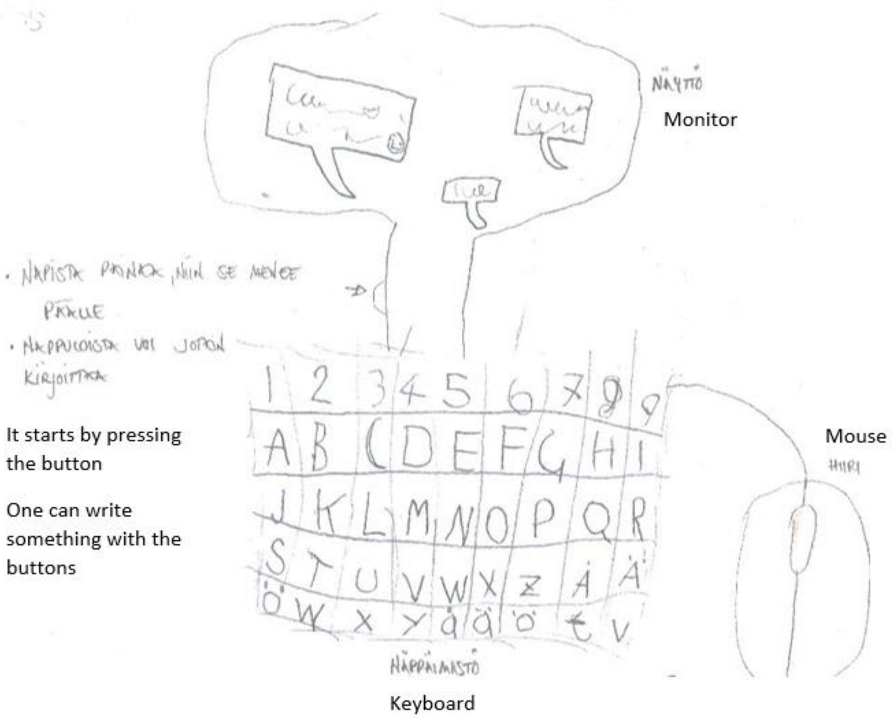

Fig. 3. Desktop computer without a CPU (Girl#51 6y6m).

There is no single, unambiguous explanation for the missing CPUs. However, Hammond and Rogers [13] found that children sometimes consider the monitor as the computer. This notion is supported by the present study. One child, for example, called the foot of the display as the “thing that holds the computer up” (Girl#20 7y0m), whereas another child referred to the foot of the display as the “bottom of the computer” and explained: “Computers are like that there is a black block and another one in it. In between them is the screen. And then there is the holder under it so that it stays up*”* (Boy#10 7v0m). When these narratives are compared with the drawings produced by the other children (see Fig. 4), it appears that the “black blocks” are the frames of the monitor and that the holder is the foot of the monitor.

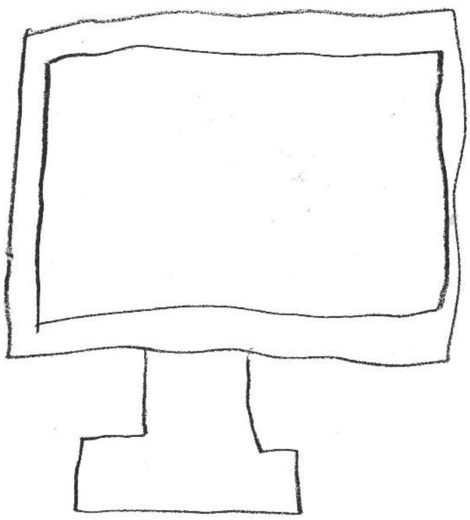

Fig. 5. Monitor (Girl#25 6y2kk).

Again, there is no unequivocal explanation for what makes children believe that the monitor is the computer. One possible explanation is that children often cannot see a computer's CPU. In laptops, the CPU is hidden under the keyboard and there are also "all-in-one" desktop computer models in which the monitor and the CPU are integrated. Examples of such computers are Apple's iMacs and Envy 27-b110no by Hewlett and Packard. In traditional desktops, the CPU is located under the table or behind the monitor. Another possible explanation is that children seldom operate the CPU. Some of the children commented that the power button of the display is the one that turns on the computer (see Fig. 3), and some of the children said that the computer turns on when the password is entered. Both examples suggest that when these children use computers, the CPU is already running, and all the children have to do is to turn on the monitor and/or enter the password.

4.1.2. Code

The meaning of the terms "coding" and "programming" were unfamiliar to the children, and 46% (n=30) of the participating children could not provide an answer to questions of what programming and/or coding were [see also 10,29]. In addition, most of the provided answers did not have much to do with computing. The terms "code" and "coding" were most often connected to pin codes and passwords needed to log into a computer or un-lock touchscreen devices. In the following extract, the child understands a code as a pattern lock, which is a typical safety feature in tablet computers and mobile phones (see Appendix 1 for a reference picture): "You need a code for opening the pad. I can't open it because I don't know the code. The code can have, like, spots from which you have to draw the figure." (Girl#47 6y7m.).

The words "program" and "programming", in turn, were connected to watching programs, as one child stated that "programming means that one watches some program" (Boy#5 6y7m). Moreover, the terms were connected to reading manuals, as one child state that "programming can be also that somebody reads a manual" (Girl#53 6y2m). In these cases, the children appeared to use conceptual similarities as the basis of their reasoning, as in Finnish the terms programming (*ohjelmointi*), program (*ohjelma*), and manual (*ohje*) are similar. Only 5% (n=3) of the children appeared to have some understanding that programming was about giving commands.

> I have played a game in which one has to program a wasp to find a flower. You have to move it, for example, forward and to side. When you push the buttons is starts moving. (Boy#12 6y5m)
>
> Programming means that you program something in the way you want. Like a robot. (Girl#6 6y2m)
>
> When you push the buttons, the thing you program is programmed. Coding is perhaps someone's job. (Girl#17 6y1m)

All these examples, most prominently the first one, suggest that these children had played coding games[3] or had played with programmable toys. In the first example, the game involving a programmable wasp is likely either the web-based emulator[4] or mobile application[5] of a programmable floor robot called "BeeBot" (see Appendix 2 for a reference picture). This notion is line with previous research that suggests that having some scientific understanding of programming requires that children have had first or second-hand experience with programming activities [10,26,28,30,32,33,35].

4.1.3. The Internet

When the children were asked about what the Internet was and how it worked, most of them provided examples of what could be done using the Internet, which in this paper was categorized as everyday concepts and discussed in Section 4.2. Nevertheless, the data included some conceptualizations of the functional principles of the Internet. Some of the children used tool-based concepts [see also 8] and conceptualized the Internet as something that is located inside the computer [see also 4,37,38]. As put by one child, the Internet "is inside the computer --- and you can get in there by pressing the icon" (Boy#10 7y0m).

The question of "how the Internet works" inspired some of the children to describe occasions when their home Internet connection had not worked properly or what was required to connect to the Internet. These descriptions revealed information about the children's understandings of the Internet. The following extract is an example of the first rationale: "Sometimes it says that 'no Internet connection.' Then you can't go to the Internet and you can't play games or watch videos" (Girl#7 6y9mm). While the word "connection" was frequently used in such descriptions, it did not refer to an understanding of the Internet as connected networks [see also 4] but—as illustrated in the previous quote—to an understanding that one has to be

[3] Such games include Lightbolt, Kodable, and the Foos.
[4] https://www.bee-bot.us/emu/beebot.html
[5] https://itunes.apple.com/fi/app/bee-bot/id500131639?l=fi&mt=8

connected to the Internet to be able to conduct online activities [see also 23]. Experiences with a broken network allowed the children to observe their parents attempts to recover the connection, which provided the children with subtle information regarding how the Internet worked. One child explained that “sometimes it [Internet connection] breaks. Mommy and daddy then shut it down, but it doesn’t always help” (Boy#32 6y3m). Another child, in turn, said that when facing broken connection “one has to go to the settings. Then it [Internet connection] works” (Girl#47 6y7m).

Further, it appears that children’s conceptions of the Internet were mainly conceptions about wireless connection, which is the most common type of broadband connection in Finnish households [57]. One child, for example, described a mobile router by saying that “we have an Internet device at home. It is for the iPads—we can take it with us at the cottage as well” (Boy#30 7y1m). Another child included a detailed picture of a router in his drawing and explained that “when this [router] is shut down nothing works except phone and televisions” (Boy#9 7y0m) (Fig. 6) Some children also commented that Internet connection can be shared via smart phones: “We can share the Internet from mommy’s phone” (Boy#12 6y5m). Only two children expressed that an Internet connection could be a wired broadband connection. According to the first one “one has to put the cord in the wall and then click the picture of the Internet” (Girl#18 6y6m) while the second one commented that “there is this internet and the cord” (Girl#52 6y2m) [see also 8].

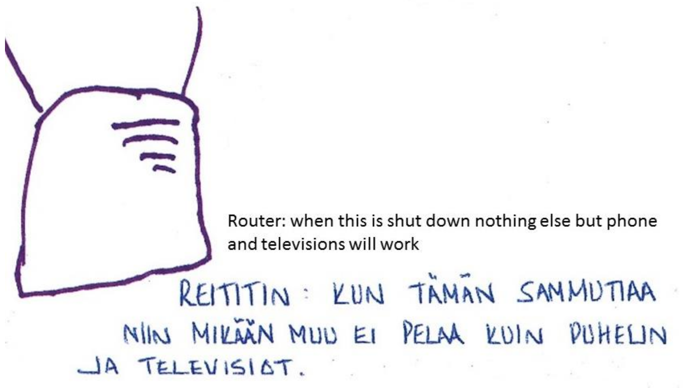

Fig. 6. Router (Boy#9 7y0m)

Experiences with the Internet as a wireless home network made some of the children believe that the Internet was located in a specific area, such as home, as the connection did not work when one moved too far away from the access point. According to one child, “the Internet woks if you are not too far away from the Internet” (Girl#49 6y8m), whereas another child commented that *“*I can put the Internet on from my phone --- It [the Internet] doesn’t work far away from home” (Girl#56 5y6m).

4.2 Children’s conceptions of what can be done using computers and the Internet

As discussed in the beginning of this paper, one deficiency in previous research is that identical forms of computer use—for instance, playing digital games—have been categorized either as children’s concepts of computers [9] or children’s concepts of the Internet [8] depending on the research objective. Thus, one of the objectives of the present study was to improve and clarify the state of knowledge by exploring children's everyday concepts of computers and the Internet side by side. This was done by categorizing children's descriptions of computer use based on whether the children thought that an Internet connection was required. The categorization and distribution of the answers are presented in Table 6, which also contains examples from the data.

Table 6. Children's conceptions of what can be done using computers and the Internet

	Computer		**Internet**		**Data examples**
	n	%	n	%	
Play games	58	89	24	37	You can play a tank game (computer) (Boy#36 6y9m)
Consume content (i.e. watch videos, listen to music)	40	61	20	31	Go to YouTube (Internet) (Girl#38 6y9m)
Bills, shopping etc.	20	31	12	18	Daddy has ordered ski boots for me (Internet) (Boy#64 6y0m).
Work	18	28	5	8	One can do important stuff, like work stuff (computer) (Boy#32 6y3m)
Write	18	28	3	5	Write my own name (computer) (Boy#50 6y4m).
Information retrieval	13	20	8	12	You can check the weather forecast (computer) (Boy#8 6y8m)
Communication (email, video calls etc.)	13	20	5	8	Read e-mail (computer) (Girl#47 6y7m)
Use Internet	8	12			Go to the Internet (computer) (Girl#55 6y10m)
Studying	5	8	1	2	Do homework (computer) (Boy#26 7y0m)

A comparison of the relative number of examples of computer and Internet-based activities suggested that it was difficult for some of the children to distinguish whether they were online or not when they use a computer (or observe others' computer use). For instance, 20% (n=13) of the children commented that computers could be used for communication purposes (i.e., writing e-mail), whereas only 8% (n=5) expressed that an Internet connection was required for such activities. Similarly, 31% of the children (n=20) said that computers can be used to pay bills or buy and sell stuff, but only 18% (n=12) connected these activities with Internet use, although an Internet connection is a prerequisite for online shopping. Data from one child (Boy#32 6y3m) provides a piquant example of this phenomenon. When asked what can be done with computers, he stated, "Daddy has bought flights to America and to Disney on Ice." However, when he was asked about what can be done on the Internet, he said, "I don't know much about it because we have not talked about it at home," but he was able to reply that the Internet can be found from the "TV, [desktop] computers, and laptops." In other words, the child was aware that his family had an Internet connection at home, and that they had various devices that were connected to the Internet. He had also observed his father's online activities. This information, however, was not enough for the boy to create an understanding of which activities require an Internet connection. The data suggests that two main factors influence children's online–offline concepts—and technological concepts in general: 1) the fluidity of the user experience, which refers to the user-friendly and intuitive nature of modern technologies, and 2) learning from others, which refers to the social foundations of children's conceptual development [11,12]. Both themes are discussed in more detail in separate subsections.

4.2.1. Fluidity of the user experience

Fluidity, in the context of digital technologies, refers to a smooth and effortless user experience [58]. This is something that modern high-speed wireless connections and intuitive mobile devices can provide. Sometimes, the experience can be so smooth that the user does not even realize that he or she is online. For example, a study by Chaudron et al. [1] showed that it is typical for the devices children use at home—tablets, smartphones, and laptops—to automatically connect to the wireless home network, and children, as well as their parents, are not aware if and when children are online and offline at home. This notion is supported by the present study. Whereas 97% (n=63) of the children reported having first-hand experiences of using computers, only 48% (n=31) said they had first-hand experiences of being online. The latter number is likely much smaller than reality, as, according to the most recent Finnish Children's Media Barometer [46], all five to six-year-olds have been online, and 66% are online on a weekly basis. Some of the children said that they did not know whether they were online when they used a computer. A child stated, "I have written something, but I don't know if it was on the Internet" (Girl#3 6y4m). Others commented that they did not know what the term "the Internet" meant. A child stated, "I have heard that word, but I don't have that much experience" (Girl#55 6y10m).

To conclude, it is a logical outcome that the fluidity of the (wireless) Internet connection makes being online or offline an opaque phenomenon for children. Put differently, how can children become aware of whether they are online or not if nothing is required from them to go online? As discussed in Section 4.1.3, it seems that understanding the differences between being online or offline requires that the fluidity of the Internet must be disturbed. Take, for example, the child (Girl#56 5y6m) who reported that she first needs to connect her phone to the wireless home network and not move too far away from the hotspot to remain connected. This brief example includes illustrations of two disturbances to the flow. First, being connected to the home network is not the default setting but something she needs to do manually. Second, fluidity can be achieved only within specific geographic limits.

4.2.2. Learning from others as the source of conceptual development

Concepts are not formed and learned independently from the social context in which children live [11,12]. This was something the participating children were aware of; 75% (n=49) explicitly commented that their knowledge of computers and the Internet was the result of intentional or unintentional tutoring from their parents, siblings, grandparents, or other close relatives. Children, for example, explained that they had learned things by observing their parents' computer and online practices. A child said, "I know this because I have watched Mommy working" (Boy#36 6y9m). In addition, explicit statements that parents had told them about computers and the Internet and what could be done using computers and the Internet were found in the data. Quotes such as, "Daddy has shown me" (Boy#4 6y2m) and "my parents have taught me" (Girl#17 6y1m), are typical examples.

Parents are also the ones who determine how and how often children can use computers and/or be online. Previous research suggests that younger children's computer and Internet use is more filtered and regulated than older children's [14,41], and the nature of these experiences influences the kinds of concepts children are able to develop [14]. This argument is supported by the present study as children reported their first-hand experiences of computer use and online activities being mainly playing digital games and watching movies and children's programs. The data also suggests that children understand that their computer and Internet use is controlled and filtered and that the children are aware that some practices are for adults only [see also 23]. A child said, "I can play children's games, and Daddy plays adults' games. Adults can also use Facebook" (Girl#56 5y6m). Eighteen (28%) of the children explained that a password is needed to either open the computer or connect to the Internet. Several children also commented that only adults knew what the password was. All these themes are comprised illustratively in the following extract:

> I have only played games and watched children's programs. I can't use the computer by myself anymore because Mommy has to do school stuff. I might accidently push some button and delete Mommy's school stuff. (Girl#48 6y6m)

It appears that parental concern and rules for keeping the computer and its files safe had steered some children to conceptualize computers as delicate and unreliable machines. One child, for example, said that computers "can go crazy sometimes" (Girl# 6y4m) while another commented that computers are "really fragile. If You throw it on the floor it won't work anymore" (Boy# 6y2m).

These findings are in line with previous research, which suggests that much of children's learning about digital technologies takes place at home [1,8,19]. Nevertheless, data from five children (8%) suggests that preschool is also a place where children learn about what can be done with digital technologies. One child commented that she had used a computer to print papers in preschool, and another child said that she had learned in preschool that computers can be used for writing. Moreover, three children explained that they had played learning games in preschool. These three examples constitute half of all the references (n=6) to computers and the Internet as tools for studying things.

5. Conclusions

This paper explored five to seven-year-old children's conceptions of computers, code, and the Internet. Unlike in previous research, this study examined all three topics simultaneously. The findings suggest that most of the children had no idea how code and programming related to computers. Accordingly, many children found it difficult to distinguish between online and offline practices. I conclude this paper by summarizing the key findings of the study, discussing what these findings mean in terms of pedagogical implications and suggestions for future research, and addressing the limitations of the present study.

5.1 Traditional conceptions of computers

Interestingly, the computers the children drew did not reflect the contemporary digital landscape of children's life-worlds, in which mobile touchscreen devices are the most commonly used computers [1,8]. Forty-six percent of the children conceptualized computers as laptop computers, and 40% of the children conceptualized computers as desktops. Only one child conceptualized a computer as a tablet computer, whereas several of the children considered computers a distinguished form of technology when expressing their views about the Internet. Accordingly, none of the children expressed that computers could be located inside other technologies (i.e. cars, washing machines, or toys).

Although the data provided no unequivocal explanation for why tablets were not considered computers, one possible reason is related to children's conceptualization of computers as the "whole package" consisting of a monitor, a keyboard, and wires (mentioned by 88%, 75%, and 66% of the children, respectively). The children participating in this study thought computers were required to have all these components [see also 9,10,13, 25,26]. To teach children about contemporary ubiquitous computing, children's initial scientific concepts must be challenged. Previous research suggests that if children are taught that computers are programmable chips (and shown what the chip looks like), the children are able to identify a range of devices, including tablets, phones, video cameras, traffic lights, clocks, and watches, that might contain such chips [9]. It is possible that the non-descriptive questions used in the data collection (see section 3.1) may have not provided the children enough concreteness for them to be able to distinguish between the meanings given for computers in colloquial language and in scientific language. This notion needs to be considered a potential limitation of the present study.

5.2. The role of linguistic cues in children's concepts of coding and programming

There is an ongoing discussion whether elementary programming should be introduced as "coding" or as "programming" to young children [7]. Some have opted for coding because it contains existing connotations of mysteries (secret codes) and achievements (cracking the code) that are believed to capture children's interest [7]. According to the present study, linguistic cues appear to play an important role in children's concepts of code and programming as several of the children related code and coding to PIN codes and programming to watching (television) programs. This means that investigating children's preconceptions of the terms "coding" and "programming" is a prerequisite for effective teaching.

Moreover, the three children who connected programming and coding giving commands had played with coding games or programmable toys. This notion supports previous research that argues that children rarely come up with the idea of programming by themselves but that having this idea requires involvement in programming activities [10,26,28,30,32,33,35]. However, in the present study, the children were not able to transform these experiences into scientific concepts of computers as programmable machines. While the pedagogically well-designed use of such games and toys may support children's algorithmic thinking and memory [59,60], it is not likely that children would recognize the connection between programming a BeeBot and the principles of computer programs and programming without adult mediation and guidance.

5.2 Dysfunctional technology as a source of accurate scientific concepts

This paper supports previous research suggesting that young children seldom possess an accurate scientific understanding of the Internet [1,38]. However, the present study provides new—albeit indicative—information about how children's accurate scientific concepts of the Internet begin to emerge. It appears that children become aware of the Internet as a network and the difference between online and offline activities in situations in which the Internet connection does not function properly. In some cases, the children had made such conclusions by themselves. For example, two children reported that the Internet connection did not work well if they were too far away from the access point, which indicated that these children had developed an accurate scientific concept about the limits of the coverage of a wireless network. In addition, there was subtle evidence in the data that suggested that in such occasions parents explained to the children why the connection was not working and began to fix the problem by providing the children the opportunity to observe what was required for the Internet connection to work properly (i.e. circuitry, computer settings). Such experiences appear to be meaningful for the development of a mature concept, in which the everyday concept and (accurate) scientific concept merge [11].

This notion provides interesting pedagogical possibilities that support the development of mature concepts of computers, code, and the Internet. In other words, the learning affordances of dysfunctional technology can be operationalized into intentional pedagogical approaches to teach children about the functional properties of computers and the Internet. This, however, requires that instead of mere observation children should engage in problem solving. Working with real-life technological problems overlaps with the trending makerspace ideology, which prescribes "a model of learning-by-doing in which individuals can work on creative design projects that are personally and/or collectively meaningful" [61, p. 14].

5.3 Children's awareness of the role of adults in their learning

The present study suggested that much of the children's learning about technology was based on observations of their parents' computer routines and that the children were fully aware that they learned from their parents. This finding locates this study within the growing body of research debunking the myth of children as "digital natives" [18] who learn the language of computers only by being born around digital technologies [62,63]. Challenging this myth is vital for at least two reasons. First, parents often underestimate their direct or indirect role in children's learning. Parents tend to consider children to be "just picking it up" when it comes to learning about technology [19]. Future studies can introduce children's conceptions to parents to determine whether and how this knowledge shapes parents' views about children and technology, as well as parents' technology practices at home. Second, preservice [64] and in-service [65] teachers often consider children born-savvy technology users, and these unfounded views have been found to lead to pedagogically inappropriate practices [66]. In other words, these notions are also vital in considering the question of how children's learning about technology should be supported in early years education in preschool and in primary school. Today, notable amounts of daily administrative tasks are performed with computers and via the Internet. Newsletters for families are sent via e-mail or by using another digital platform (i.e., a blog), and children's attendance is recorded using near-field communication tags and smartphones [48,67]. These daily routines should be recognized as pedagogically valuable moments for teaching children about computers, code, and the Internet.

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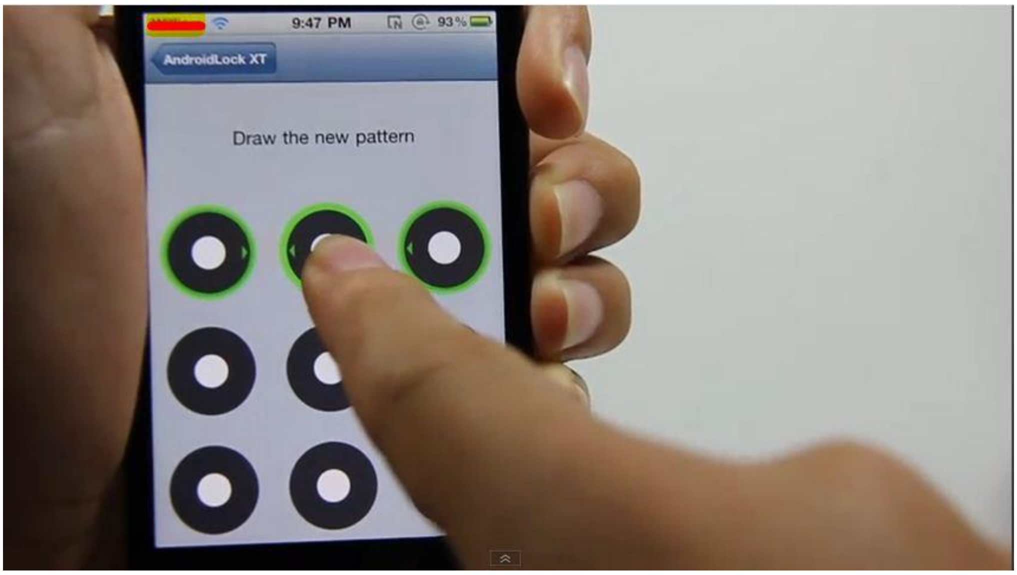
Appendix 1

Patter recognition lock screen[6]



Appendix 2

[6] Retrieved from: https://c2.staticflickr.com/8/7181/6917000655_ac16a092e0_b.jpg

A screenshot from Bee bot app[7]

[7] retrieved from: https://c2.staticflickr.com/8/7203/6890249097_4c3b933ea3_b.jpg)