Which Computing-Related Conceptions Do Learners Have About the Design and Operation of Smartphones? Results of an Interview Study

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ABSTRACT

Smartphones have had a rapid rise. From the first affordable mobile phones to modern high-tech devices, they have become ever more complex and increasingly popular. In 2016, almost 100% of the 12 to 19 years-old youths in Germany owned a smartphone and used it regularly. Considering their large impact on adolescents' lives, smartphones are uniquely suited to be analyzed as examples of socio-technical computing systems in secondary computing education. Moreover, they play an increasing role in digital media education in all school subjects. There is however, among other things, a lack of scientific work covering learners' conceptions of smartphones needed for learner-centered computing education with and about smartphones. This article describes an explorative study that investigated secondary school learners' conceptions in the context of smartphones. A first overview of existing conceptions regarding selected aspects of smartphones was derived from eight semi-structured interviews.

CCS CONCEPTS

• **Social and professional topics → Computing literacy**; **K-12 education**; *Computational thinking*;

KEYWORDS

Learner conception, K12, computing education, smartphone, mobile phone, semi-structured interview, explorative study

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1 INTRODUCTION

Living in the modern world, we are in constant and increasing contact with different computing systems. Aside from traditional desktops and mobile computers, in the age of the "Internet of Things" we can find embedded computing systems also in many other objects like cars, household appliances, entertainment electronics, heating systems and many more. In accordance with curricular recommendations from both national (see [5], [6], [15]) and international sources [2], computing as a school subject should teach the basics of computing system design and uncover the complex processes affecting both individuals and society as a whole [20]. In this context, the instructional use and analysis of computing systems should not be restricted to traditional computers, but explicitly include systems that are prevalent in the learners' lives.

Concerning commonness, one such computing system stands out from other systems: the *smartphone*. According to the German annual JIM study 2016 on "youth, information and (multi-) media" [22], 95% of all teenagers own a smartphone with touch-screen and Internet access. The vast majority of adolescents use their devices on a daily basis as was also stated in one of the interviews conducted in the course of the study reported here: *"Well, I use it constantly. When I, for example, wake up in the morning, I check it immediately or when I come home from school or on my way back from school. I have got an internet flat-rate, so that I can use, for example, WhatsApp or Facebook. Most of the time, also in the afternoon in-between, when I get a message I check it, write back and in the evening, before I go to sleep. So, almost continuously, whenever something happens."* [3, p. 123]

There already are some approaches that focus on the use of smartphones for educational purposes in computing education (e. g. [4], [18], [24]) and with the *MIT AppInventor*[1] there also exists a contemporary and motivating teaching aid, with which even younger learners can design smartphone apps using a block-based programming language. However, aside from app development, smartphones offer further opportunities to work on the goals of computing education, for example, in the fields of computer networks or computer architecture. For the instructional design of computing lessons, which follow the principle of educational reconstruction (cf. [13], [10]), there currently is a lack of empirical results concerning learners' conceptions, which they form by their everyday smartphone uses and bring into computing classes. Uncovering

[1] cf. http://appinventor.mit.edu

invisible aspects of ubiquitous computing systems is considered a valuable educational goal (cf. [7], [14]). Therefore, the empirical exploration of learners' conceptions as a potential starting point for corresponding instructional processes following the principle of educational reconstruction [13] was the subject of an interview study that is reported in this paper.

The rest of this paper is structured as follows: related research will be presented in chapter 2. Chapter 3 serves to give a short overview of current smartphone technology. Chapter 4 motivates and details the chosen research method, while chapter 5 will present the results of the study. Finally, conclusion and outlook complete this paper in chapter 6.

2 RELATED WORK

2.1 Smartphone Use in Computing Education

There have been attempts to utilize the attractiveness of smartphones for computing education for some time. By implementing apps instead of traditional applications in the classroom [4] it is implicitly hoped to increase the learners' motivation and interest by "transferring" a part of the devices' attractiveness to the computing class. Aside from such starting points, there are also more comprehensive approaches and first experiences in using smartphones as the only computing systems in computing education (e. g. [18], [24]). These experiences show that it is possible to carry out computing education only with smartphones and that this approach contains some pedagogical advantages, such as an earlier understanding that computer science does not solely consist of working with computers, a more effective use of classroom time and a more gender-neutral approach to the computing system used in class. The so far rather little distribution of corresponding teaching examples, the screen sizes of smartphones and the availability of software development apps, which are comparable to desktop applications concerning functionality and usability for the implementation of smartphone apps and other programming purposes, as well as existing school regulations restricting the use of personal smartphones in school may explain, why such approaches so far have not been implemented more widely in computing education. For introductory computing education however, an increasing number of apps for mobile operating systems has been developed to introduce learners to programming concepts, such as *BugsButtons*, *ScratchJr*, *LightBot* and *Hopscotch*, and environments like the *AppInventor* or *Snap* are both available via web browsers. These tools have potential for including smartphones and tablets into computing education in a motivating and fun way.

2.2 Computing-Related Learners' Conceptions

The analysis of learners' conceptions and their alignment with the associated scientific concepts is a major concern of the model of educational reconstruction, which was originally developed for science education [13], but meanwhile has been transferred to computing education and been extended for this purpose by Diethelm et al. [10]. They expanded the original model to include societal requirements for a computing subject, computing phenomena as a starting point for planning instruction, and the teachers' points of view. Concerning computing education research, further work is needed in the above-mentioned extension areas as well as concerning learners' conceptions, because especially in this field only a very small number of studies have been published so far.

During the literature analysis for this research, no computing-related work was found, which focused explicitly on learners' conceptions concerning smartphones. However, a number of conception studies of different associated aspects of the networked computing system smartphone do exist. For example, learner conceptions of the structure and functioning of the Internet have been investigated in a number of works. In 2005, Papastergiou published results of a study containing general conceptions, which Greek learners had concerning the Internet [26]. Diethelm et al. found various learner conceptions about the structure of the Internet and the working principles of specific services like video streaming [11]. Conceptions about how search engines work were the subject of a study conducted by Seifert et al. [27]. Furthermore, a number of studies can be found concerning the computing system "computer". The works of Mumtaz [25], Hammond and Rogers [17] as well as Grover, Rutstein and Snow [16] can be mentioned here.

3 CURRENT SMARTPHONE TECHNOLOGY

Like any other computing system, smartphones consist of a specific combination of hardware, software and network connections employed to manage the multitude of tasks expected of smartphones. The central part of each smartphone's hardware is a system-on-a-chip, which is a combination of a processor and a memory running an operating system contained on a single chip. Peripheral components include such things as a display, touchscreen, an additional memory card and the components necessary for radio transmission. Using radio transmission, smartphones connect to the Internet either through wireless local area networks or through dedicated mobile phone base stations. Both serve as wireless access points to different networks that are connected to the Internet. The nature of radio transmission implies a limited range of each access point. Obstacles such as concrete and metals common in buildings tend to disturb the signal. Following the principle of "always best connected", smartphones frequently change access points in handover (also: handoff) strategies [19]. Not every access point offers the same quality of service. As technology evolved, a number of successive standards for mobile phone networks were developed that steadily increased the volume of data that could be transmitted. Tele-communication standards include, among others and various expansions, GPRS, EDGE, UMTS, LTE and LTE Advanced. LTE constitutes the first internationally valid standard and uses the Internet protocol exclusively for all data transmissions. LTE no longer employs different transmission strategies for phone connections and other data transfer [8].

As it is time-consuming and expensive to upgrade the mobile phone networks, numerous basis stations constructed for different standards exist and are utilized simultaneously. It is relevant to the study reported in this paper that the region, within the interviewed learners lived, was well-covered by LTE and LTE Advanced. There are some areas, especially more rural ones, within which the network connections work with older standards [9]. Especially, when they have been on vacation in rural zones the interviewed learners can be expected to have encountered different generations of mobile phone networks. The main input device of a smartphone is the touchscreen, which consists of two main components: a transparent plate, that registers touch, and a display mounted directly behind the plate. The most commonly used touchscreens for smartphones are capacitive touchscreens, though a combination of capacitive and inductive touchscreens is also used for high-end models. Both systems register touch through an electric grid mounted on the transparent glass plate. In their use, they differ insofar that inductive touchscreens require special pens to be used while capacitive touchscreens register human fingers. The inductive touchscreens' requirement of special pens prevents confusing signals caused by inadvertent contact between the user and the screen. Smartphones are also increasingly able to be operated through voice commands.

Smartphone apps are regular applications. In the German language, the term "app" was first exclusively used for smartphone and tablet applications. In recent times, it is also used for applications on desktop operating systems. The German term "app" however still carries the notion that an "app" has a smaller range of functions than an application for a desktop computer. While the application MS Word allows for a large number of different functions to be used for composing text, an "app" for composing texts would have a limited number of simple tools and other constraints such as a character limit for the text.

4 OBJECTIVES AND RESEARCH METHOD

The objective of the study was to identify learner conceptions of constituting aspects of smartphones. Within this study, a *wireless network connection*, *apps*, the *operation by means of a touch-screen* and the *compact design* were identified as relevant aspects of smartphones, because they serve do differentiate them (but also phablets and tablets) from desktop computers. Therefore, the broad initial research question *"Which computing-related conceptions do learners have about smartphones?"* was divided into:

Which computing-related conceptions do learners have about

1. *the wireless connections of smartphones?*
2. *apps on smartphones?*
3. *operating smartphones by means of touchscreens?*
4. *the compact design of smartphones?*

Learner conceptions to be identified in this work were not directly measurable, as they are latent, i.e. not visible. Therefore, a research method was needed with which the learner conceptions could be discovered. Since no computing-related conception research on smartphones was found by the authors within their literature research (see section 2.2), the decision was made for an explorative qualitative research design. For the above-mentioned conditions, especially the questionnaire and the interview method are suitable candidates for data collection.

The advantage of the *questionnaire method* is that many statements can be collected in short time. In contrast to interviews, questionnaires can be completed quickly and at any time: for an interview, an appointment must be made by the interviewer and the interviewed person. Moreover, questionnaires are more discrete and more anonymous. Unlike in an interview, the person interviewed does not sit face to face. If a person exchanges only reluctantly about a subject of research, for example, because of the fact that he or she is ashamed of his or her own situation or low level of knowledge, this person would rather fill out a questionnaire than prepare for an interview (cf. [12, p. 398]). Because many statements can be collected quickly, the questionnaire method is particularly suitable for quantitative research, however, also qualitative research approaches can be implemented using it. A qualitative questionnaire consists only of open requests to the respective person to express him- or herself in written form on a topic [12, p. 401]. An invitation to write longer texts was considered not ideal in the study reported here, since the participants are pupils. The best way to organize the survey was through schools and to carry it out there as well. Writing longer texts takes time. If the survey was to take place during school lessons, teaching time would be lost there. If the texts were to be written outside the classroom, the learners would probably consider it too awkward, too much work.

The *interview method* is more suitable for qualitative research approaches in that a lot can be said in relatively short time. The participants can simply be asked to tell something about a topic and the data collection can begin. In the course of the interview, the interviewing researcher will be able to respond to the learners' replies and thus receive further statements on a topic. As the interviewee should also tell the interviewer as much as possible in the qualitative interview method, the interviews should be open. A qualitative interview can be carried out either in an unstructured or semi-structured way. Within unstructured interviews, the interviewee should speak freely, the interviewing researcher asks questions that arise spontaneously. The course of conversations between several unstructured interviews can be very different [12, p. 358]. For the work reported here, it was decided not to carry out unstructured interviews, because they are difficult to compare. Instead, semi-structured interviews were conducted [1]. Therefore, an interview guide was developed (see Appendix A), which was structured following the suggestions of Misoch [23, pp. 68-71] into an information phase, an introduction phase, a main phase and a concluding phase, which were carried out consecutively. The guide includes the above-mentioned interview phases, pre-formulated questions, and possible responses to various responses from learners.

In autumn of 2016, twelve interviews were conducted using the prepared guide (see Appendix A). The participants were both male and female learners of the grade levels 9 and 11 of a secondary school in the Ruhr area in West Germany. Half of the participants attended a computing class, while the other half did not. The interviews lasted between 20 and 30 minutes and were audio-recorded.

The main phase according to the interview guide took the most time as it contained four separate sections of questions. Each section covered one of the above-mentioned distinguishing aspects of smartphones and could be conducted in variable order. During the interviews, the participants were invited to produce sketches to illustrate their conceptions. Furthermore, their age, gender, grade, and choice of computing courses at school were documented as well as the extent to which they were concerned with computer science in their free time and how they used their own smartphones.

As the interview study was conducted as part of the master thesis of the second author [3], eight recordings were selected (because of time constraints as well as because of disturbances in other interviews) for the analysis with regard to their content as follows. Four persons of grade 9 and four of grade 11 were chosen. Each of these groups of four were half male and half female with one male and one female attending a computing class and the others not. The female learner in grade 9 had previously attended a composite subject containing aspects of mathematics, computer science, natural sciences and technology education. This class had covered a number of computing concepts, so for the purpose of the analysis in this study she was classified as having had some computing education. The selected interviews were fully transcribed and evaluated with a deductive qualitative content analysis according to Mayring [21] using the analysis tool *MaxQDA V.12.2* (www.maxqda.de). Grounded theory was also considered for the evaluation, but discarded for research-pragmatic considerations.

As a first step, four top-level categories and 14 sub-categories were deduced from the main phase of the interview guide:

K1: Learner conceptions of wireless connections used by smartphones
- K1.1: *Architecture of cellular networks*
- K1.2: *Addressing in cellular networks*
- K1.3: *Transmission medium used by smart-phones*
- K1.4: *Handover strategies used by smartphones*
- K1.5: *Internet protocol as a basis of web-based services*

K2: Learner conceptions of apps on smartphones
- K2.1: *Definition of an app*
- K2.2: *Program invocation on a smartphone*
- K2.3: *Origin of apps*
- K2.4: *Installation of apps*

K3: Learner conceptions of operating smartphones by means of touchscreens
- K3.1: *User interface elements of smartphones*
- K3.2: *Touchscreens of smartphones*
- K3.3: *Program architecture of smartphones*

K4: Learner conceptions about the compact design of smartphones
- K4.1: *Compact hardware in smartphones*
- K4.2: *Technical limits of smartphones*

The learner conceptions assigned to each of these categories were analyzed afterwards and further structured in the case that they described similar conceptions.

5 RESULTS

Following the procedure described in section 4, a number of learner conceptions were identified in the study, which will be summarized in section 5.1. After that, the conceptions are analyzed for their concordance with reality in 5.2 and for a potential impact of previous computing education in 5.3.

5.1 Learner Conceptions

5.1.1 Learner conceptions of wireless connections used by smartphones (K1). All students were aware that their smartphones are connected to a widespread network *(K1.1)*. Six of them specifically named the Internet. None of the interviewed learners gave a complete overview of the Internet's infrastructure. Four participants imagined that the connection happens via "transmission poles", three named servers and other three mentioned satellites (see also Figure 1). Further differences can be found in particular details of

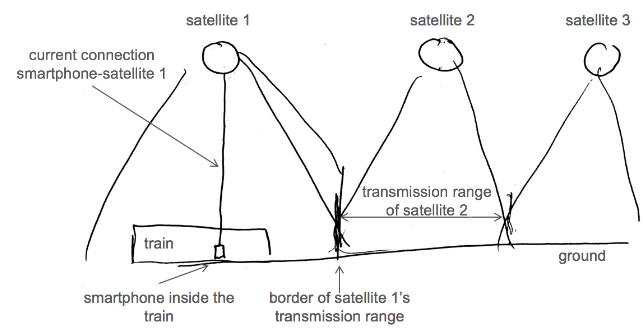

Figure 1: An internet connection in a travelling train as sketched by a participant (annotation by the authors)

the given conceptions. The conceptions that, for example, data is transmitted in an encrypted way or that it is stored temporarily during the transmission were each supported by two learners. Concerning the transmission via poles, learners named different types of poles like "power poles", "telephone poles" and "Internet poles".

The learner conceptions within category *K1.2* covered addressing of data during transmission to a smartphone. The most prominent conception – that addressing is implemented through a number – was mentioned by five of the eight learners. Only one of the five explicitly stated that this number would be distinct. However, it can be assumed that the other conceptions implicitly include a distinct number, as the examples suggested by them were generally understood to be distinct. Three of the participants named the phone number of the target smartphone, others mentioned a serial number and an intern account number of individual services assigned to the target phone. Therefore, the learner conceptions are close to the technical reality of distinct MAC addresses.

No overarching conception regarding which transmission medium is used by smartphones could be discovered *(K1.3)*. Radio transmission was not considered, even if directly asked for. Only one participant casually mentioned radio transmission in a subsequent segment of the interview in the context of a dead zone. Statements about a possible transmission medium were generally only given very haltingly. It can be assumed that the learners had not yet thought about a specific medium. Due to that they presented conceptions that were very diverse and two students even contradicted themselves. Four of the eight participants could not name a concrete transmission medium even after they were prompted. They answered only that signals would be used. Only the conception that data is transmitted in binary code through electrical signals was mentioned by more than one student. According to them, in this kind of transmission applied current would be interpreted as a "1" and a lack of current as a "0". One participant, who did not name a transmission medium, differentiated modes of transmission depending on what kind of network access point would be available at a smartphone's position. A WLAN would be used at home and a SIM card away from home.

All students were aware that the quality of transmissions fluctuates *(K1.4)*. They could infer reasons for fluctuation, e. g. the distance from an access point, from their own experiences. Half of the participants concluded that smartphones eventually search for a new access point and execute a handover (see also Figure 1).

Half of the learners believed that different services – like phone calls, which require a continuous data transmission, and text messages, which only need short burst transmissions – place different requirements on a network connection *(K1.5)*. Three participants stated that these different services use the same network. One female student concluded explicitly that "everything works through the Internet" [3, p. 134], because her messenger app is only usable while her smartphone has an active Internet connection.

5.1.2 Learner conceptions of apps on smartphones (K2).

Within the learner conceptions of apps, it stands out that six of the participants named all applications on their smartphones that accomplish specific tasks as apps *(K2.1)*. This conception is in line with the formal definition of applications, even if the terms "application" and its German equivalent "Anwendung" were used by only three learners. Five learners named everything that can be downloaded from a store (for example the Apple AppStore) as an app. One of them even went as far as stating that everything downloaded from the Internet – and not just a store – is an app. Of these five only one did not supplement their statement with its negative counterpart: that everything that is already present on a smartphone, when it is bought, is not to be considered an app.

The conceptions included in category *K2.2* (program invocation on a smartphone) are altogether limited. Five of the eight participants imagined that the smartphone or something within it works to execute a program. Two of them added that signals are transmitted within the smartphone, when an app is executed. These statements show a limited, but correct conception of the technical aspects of program invocation and the underlying notional machine (cf. [28]). Two other participants could not name any processes of any kind. Their conceptions were so limited that they simply stated the app opens, when it is invoked. Two further learners had more detailed conceptions, which address the data contained in an app. One thought that a program invocation calls up a layout of an app, which is filled afterwards with data obtained from the Internet. He related this "app basis" to the concept of a Java standard constructor for classes. Another female student described that some information is loaded, when an app is invoked. The information could be either programmed in the app by its creator or it could have been saved in a file, when the app was opened previously.

All students had previously downloaded an app from an app store *(K2.3)*. Except for one female learner all participants regarded themselves as mere consumers of apps. Solely she mentioned the possibility that she could create her own app.

Category *K2.4* about the installation of apps contains only two conceptions. Half of the participants mentioned no other installation steps besides the download itself. They considered apps as immediately usable. Of these four, one learner added that the download could take some time and use up the smartphone's energy. Three other learners mentioned further installation steps that need to be performed before an app can be used. One learner stated that the app is permanently written into the smartphone's internal memory. Another one mentioned that the app's access authorizations for, for example, the contacts have to be configured.

5.1.3 Learner conceptions of operating smartphones by means of touchscreens (K3).

In this category, only a small number of conceptions could be obtained. Not a single true conception could be found for category *K3.1* (user interface elements of smartphones). The answers were nearly completely limited to simple observations about which operating elements can be found in a smartphone. Five learners described the touchscreen as a peripheral of the smartphone that detects touch and sends equivalent signals to a central processing unit *(K3.2)*. Six of the participants further stated that the smartphone reacts to these inputs according to pre-programmed patterns. Without those patterns, a smartphone would be unable to react to input *(K3.3)*.

5.1.4 Learner conceptions about the compact design of smartphones (K4).

In this category, questions about two different concepts were asked: reasons as to why the hardware of smartphones could be that small and the technical limits of smartphones. Half of the students believed that smartphones are designed to be compact, because the data stored on them does not need much or any space *(K4.1)*. Their conceptions differed as to why they imagine that. Two students said that smartphones were compact, because they did not actually have to save any data. They imagined that the data is saved externally, for example on an external server or a cloud up in the sky. This shows, how everyday visualizations can be reflected in learners' conceptions. Another two learners mentioned the conception that the physically small internal memory of a smartphone is capable of saving a lot of data. One other learner had the conception that data needs no space, since it consists only of bits and bytes and as such has no physical presence.

Five of the eight learners mentioned that smartphones have an inferior performance than more extensive computing systems like desktop computers *(K4.2)*. They named a smaller memory, slower processing units and weaker video cards. Additionally, half of the participants considered smartphones to be generally inferior to other computing systems, since smartphones cannot connect to as many external devices: a smartphone lacks a mouse, a keyboard and a USB port. Since all rating processes in this research were conducted by the second author as part of her master thesis research project (cf. [3]), no second rater was available. Though the categorizations were done thoroughly and with care, they should be checked for consistency by a second rater in future work (see also sect. 6).

5.2 Comparison with the Technical Concepts

Next, the degree of concordance of the identified learner conceptions with current technology was analyzed. To accomplish this, the conceptions were rated to which degree they reflect the underlying technical concepts. Table 1 shows the results of this process.

Four conceptions could not be adequately evaluated. For example, two students said that the connection during a phone call differs from the connection when they use an app. They did not elaborate, how the connections differ and as such it could not be determined, whether they eventually picture a real event, for example that the

Table 1: Learners' conceptions concordance with current smartphone technology

Category	Conceptions that reflect reality	Incomplete conceptions that reflect reality	Conceptions that partially reflect reality	Conceptions that do not eflect reality
K1.1	1	4	1	1
K1.2	-	2	2	-
K1.3	2	2	-	4
K1.4	1	3	2	-
K1.5	2	-	1	1
K2.1	2	1	2	4
K2.2	-	3	-	1
K2.3	2	2	-	-
K2.4	-	1	1	-
K3.1	1	3	-	-
K3.2	2	2	2	2
K3.3	2	1	1	-
K4.1	1	1	-	3
K4.2	2	2	2	-
Sum	18 (24.0%)	27 (36.0%)	14 (18.7%)	16 (21.3%)

rate of data transmissions differ, or have a misconception, for example that phone calls and data transmission use entirely different networks. As this conception and alike ones could not be rated as to their concordance with current technology, they were not included in this analysis. *Correct conceptions* reflecting a complete aspect of real smartphone technology were often composites of several conceptions stated by a single interviewed learner. If a learner, for example, said separately that the quality of a transmission depended on the distance between the smartphone *and* a network access point and that obstacles such as concrete hindered the transmission, then these statements were rated to jointly belong to an existing wider conception.

Conceptions were rated as *incomplete*, when they were concordant with reality, but either missed a key concept or were too widely formulated to be considered complete reflections of current technology. Amongst them were conceptions such as "Something inside the smartphone works to execute an app" and "Data is transmitted through signals". While such statements show that the interviewed learners have conceptions, which are based in reality, they also do not contain any details, which would fill these conceptions with concrete notions.

Partially correct conceptions contained at least one aspect, for which there is no concordance with reality.

Conceptions not reflecting reality are to be considered misconceptions. Those conceptions were contrastingly concrete (see Table 2). The learners named conceptions that are simply not based, in some cases like "touchscreens registering input through pressure" not based any longer, on smartphone technology. It could be considered that they wished to give concrete and detailed answers to the interview questions and as such named very specific technologies and concepts.

Table 2: Misconceptions stated by learners (ordered by the category system in section 4

Misconception	#Learners	Category
Smartphones transmit data through satellites.	3	K1.1
Transmissions are carried out via infrared rays.	1	K1.3
Transmissions are carried out via higher waves on different frequencies. So-called "telephone tones".	1	K1.3
Transmissions are carried out via different radiation.	1	K1.3
Transmission of text messages is carried out as a virtual picture.	1	K1.3
The Internet – as used by WhatsApp and Skype – and the cellular network – as used during phone calls – are separate networks.	1	K1.5
Functions, which are pre-installed on smartphones, are not apps.	4	K2.1
Functions, like text messaging, which already existed on traditional mobile phones without touchscreens, are not apps.	2	K2.1
Apps have a certain size. Small files of only a few kilobytes size and little programs without a lot of functionalities are not apps.	1	K2.1
Everything that is downloaded from the Internet – even music – is an app.	1	K2.1
When an app is invoked, a layout is loaded, which is afterwards filled with data obtained from the Internet. The layout is an "app basis" similar to the concept of a Java standard constructor for classes.	1	K2.2
Touchscreens register touch through heat.	1	K3.2
Touchscreens register touch through pressure.	3	K3.2
Data is not stored on a smartphone, but instead on external storage like servers and clouds. (These clouds fly in the sky.)	2	K4.1
Data consist only of bits and bytes and as such have no weight and do not consume any space inside a smartphone.	1	K4.1
A smartphone does not need any conduits. This saves space inside it.	1	K4.1

5.3 Impact of Previous Computing Education

For determining, whether previous computing education had an effect on the conceptions stated by the participants, another step of analysis was necessary. Therefore, the numbers of statements showing a conception made by both learners with and without previous computing education were compared (see Table 3). In this first step the statements that could not be rated as to their degree of concordance with reality shown were included.

Learners with and without previous computing education each provided almost exactly half of the statements. Whether a learner attended computing education or not had no noticeable effect as to the number of conceptions developed.

Table 3: Number of statements showing a conception from learners with and without previous computing education (CE)

Total number of statements given	Statements given by learners with previous CE	Statements given by students without previous CE
187	96 (51.3%)	91 (48.7%)

In a second step, a possible impact of previous computing education on the correct- and completeness of the stated conceptions was analyzed. For this purpose, the numbers of statements for each of these groups was structured and compared in analogy to Table 1 . Both groups of learners contributed statements for all of the four degrees of concordance with reality. Learners without previous computing education had complete conceptions of smartphones congruent to current technology and learners, who attended computing education, also stated conceptions that do not conform to reality (see Table 4).

Table 4: Numbers of statements of learners with and without previous computing education (CE) by rated degree of concordance with reality. Statements containing ...

Learners	... conceptions reflecting reality	... incomplete conceptions reflecting reality	... conceptions partially reflecting reality	... conceptions not reflecting reality
With previous CE	26 (55.3%)	42 (49.4%)	10 (41.7%)	14 (56%)
Without previous CE	21 (44.7%)	43 (50.6%)	14 (58.3%)	11 (44%)
All	47	85	24	25

Given the small number of participants in this study and the unclear picture presented in Table 3, no seriously generalizable statements about the impact of computing education on learners' conceptions can be derived.

6 CONCLUSIONS AND OUTLOOK

With the results of the interview study described in this paper, a first qualitative insight into existing conceptions of learners of grades 9 and 11 concerning the design and operation of smartphones is given. The design and operation of smartphones were operationalized by questions concerning aspects, which distinguish smartphones from traditional computers, namely, wireless networks, apps, touch screen and compact design. The interviews of eight learners were fully transcribed and evaluated using a deductive qualitative content analysis according to Mayring [21], which led to the category system presented in section 4. In the results, the authors found a wide range from correct and elaborated conceptions to misconceptions. However, since this explorative research was conducted with only a small number of probands, the results mostly indicate the existence of the conceptions reported here and may at this stage not be generalized to a broader population.

As far as future work is concerned, further groups of learners should be investigated for their conceptions in order to analyze, whether the conceptions found in the study reported here can also be found among other learners and whether other learners also contribute additional conceptions.

Furthermore, in subsequent studies a more precise measurement and control of computing-related prior knowledge (derived both from computing education and personal activities) would be required to investigate the impact of computing education. Since the participants in the study reported here were from grades 9 and 11 of a secondary school in North Rhine-Westphalia, it can be deduced from the associated computing curricula that wireless networks and touchscreens are not typical topics of computing classes up to grade 11. In lower secondary education (until grade 9), there is the option of dealing with hardware aspects of computing systems or introducing programming using a block-based programming environment, such as the *AppInventor* or *Scratch*. Whether and to what extent this was carried out, however, was not investigated in the study. This background information may explain the figures presented in section 5. As suggested by Diethelm et al. [10], teacher conceptions should also be investigated to complete the picture in future.

The construction of multiple-choice questionnaires to investigate, how widespread the identified conceptions among learners or teachers are, might also be interesting future research, however, the question remains then, whether the probands indeed have the conceptions they select in the questionnaire among the presented alternatives or whether they just select entries, which appear plausible to them.

Finally, recommendations for computing education need to be derived.

A INTERVIEW GUIDE

In this interview guide actions on part of the interviewing author (the interviews very carried out by the second author) are denoted through brackets ( ).

A.1 Information Phase

(1) (Welcome the participating student)
(2) (Let the participant fill out the data survey)
(3) (Introduce the study)
(4) (Explain the procedure during the interview)
(5) (Remind learner that they cannot answer in a “wrong” way, that all their answers are of use to the study)
(6) (Point out the materials for sketching)
(7) (Start the recording)

A.2 Introduction Phase

(1) How often do you use your smartphone?
(2) What do you do with your smartphone?
(3) What kind of apps/functions do you use?

A.3 Main Phase

A.3.1 Wireless connections used by smartphones.

(1) You said that you had XXX (name a messenger app like WhatsApp that the interviewed participant already referenced) on your phone. What does it do? I don't know it myself, please describe it for me.
(2) How does a message, that you write, get to your friend? Please describe it.
  - How are your smartphone and the smartphone of your friend connected?
  - The message has to be transmitted somehow. (Joke) Maybe through smoke signals?
  - Please describe the way that the message takes. It starts on your smartphone and then ...?
(3) Is the connection different when you call someone instead of using your messenger app?
  - If yes: How is the transmission different?
(4) What happens to the connection, if you are using your smartphone while travelling fast? For example, if you are on a bus or a train.
  - Did you notice anything?
  - Is the connection the same as ever?
  - You told me that your smartphone connects to XXX (reference the learners' own statements). Would there be any problems, if you moved away from it?

A.3.2 Apps on smartphones.

(1) You told me that you had the apps XXX and YYY (reference the participants' own statements). Can your smartphone do even more things? Please tell me about it.
(2) Of all those things on your smartphone, which ones would you call "apps"?
(3) Why would you say XXX is an app and XYZ is not an app?
  - Alternative: Do you also have pictures on your smartphone? Are they also apps? Why/Why not?
(4) What happens in your smartphone, when you start an app?
  - Absolutely nothing happens?
  - Is it always the same? Do you start an app and it always plays the same song? That would be always the same.
(5) How do you get new apps?
  - How does a new app get onto your smartphone?
  - After you download an app, can you use it immediately? Or does something have to happen before you can use it?

A.3.3 Operating smartphones by means of touchscreens.

(1) How exactly do you operate your smartphone?
  - How important is the touchscreen?
  - Which gestures do you use?
(2) What happens inside of your smartphone, when you touch the touchscreen?
(3) You use many different gestures on the touchscreen to do different things on your smartphone. How does it know, what every gesture on the touchscreen means?
  - Let me give you an example. When you start your smartphone, you get to the lock screen. There you can do different things, like unlocking your smartphone or placing an emergency call. What do you have to do to unlock your smartphone? And how is your smartphone able to distinguish this from placing an emergency call?

A.3.4 Compact design of smartphones.

(1) What do you have "on" your smartphone? You already told me about different apps, but do you have other things as well?
  - You told me you send pictures to your friends? Do they count?
  - Did you ever take a picture?
(2) Do you have enough "space" on your smartphone?
(3) How is a smartphone so small and so light?
  - If such small components exist, why aren't they used in desktops as well?
(4) Does anything come to your mind that your smartphone can't do but a large computer can? If yes: What?
  - Can you describe, how XXX (reference the learners' own statements) is different on a smartphone and on a large computer?
(5) Why can a large computer do these things and your smartphone can't? Alternative: If your smartphone can do anything that a large computer can do, why do we even have large computers?

A.4 Concluding Phase

(1) Are there any other things that you think about your smartphone?
(2) Did you take computing classes in school?
  - If yes: How long have you taken computer science? What did you cover in your lessons?
  - If no: Did you ever do anything to related to computer science in your free time? How often and how long did you do this?
(3) Do want to ask me anything?
(4) (Thank the participant for their time, end the interview and the recording)

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