Which Perceptions Do Primary School Children Have about Programming?

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ABSTRACT

It is generally accepted that children have their own understanding of how the world works. Teachers need to take their ideas and knowledge into account in the learning process. While there exists a lot of research on children's perceptions of science concepts, little is known about their perceptions of programming. Since the topic is now becoming more and more relevant in the primary school context, our study aims to provide insights into children's ideas and knowledge about programming. For this purpose, we conducted and filmed seven group discussions with a total of 61 third- and fourth-grade students (age 8-11). The videos were transcribed and analyzed using qualitative content analysis. The findings show that the students associate actions as well as programmable devices with the term *programming*. Furthermore, we have found out that boys and girls have very similar ideas about it.

CCS CONCEPTS

• **Social and professional topics → Computer science education**;

KEYWORDS

computer science education; primary school; programming; preconceptions; prior knowledge

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1 INTRODUCTION

In order to create a learning environment in which students can develop skills and conceptual knowledge, it is important that teachers have a good understanding of their students' current state of development: all students bring beliefs, experiences and information from school and their daily lives into the classroom that affect what and how they learn [3]. These conceptions and preexisting knowledge can support the process of knowledge construction or – if they are insufficient or inaccurate – they may actively interfere or hinder learning [16]. While there is already a lot of research on children's ideas of natural phenomena and science concepts (e.g. light, gravity, nutrition) [23], we do not have sufficient know-how about how they explain the digital world. This could be all the more interesting as several countries have already introduced computer science or programming in their primary school curricula (e.g. the UK [15], Australia [26] or Finland [36]). Getting an impression of children's ideas about this new topics could give teachers orientation and support the learners' knowledge construction.

In the following, we outline the importance of children's conceptions and prior knowledge and give an insight into the research that refers to children's ideas of the digital world. We then describe our study whose main purpose it is to investigate children's perceptions of programming. In addition, we investigate which stimuli seem to work better to elicit these perceptions and whether there are any differences between girls and boys.

2 THEORETICAL BACKGROUND

2.1 Children as Active Learners

Children's individual ideas determine how they perceive the world. Piaget was the first to introduce the idea that children build their own knowledge that differs from that of adults and evolves throughout childhood [9]. Ideas and concepts are developed through everyday experiences and activities and thus enable learning even before entering formal education [2]. This constructivist view of learning argues that learners not just absorb information, but instead are actively involved in the process of knowledge acquisition by interpreting information in the context of their experiences and prior knowledge [30].

The recognition of children's ideas and abilities as an integral part in every teaching-learning process led to an increase in research focusing on learner's understanding in the 1980s – especially within particular science domains [33]. Interviews and other interpretative techniques were used to investigate and describe how students make sense of natural phenomena and what they already know about certain topics [22].

2.2 Ideas and Preconceptions

By the time they enter school, children have already developed informal theories about how things in their environment work (e.g. *Where do clouds come from?*). These ideas arise from their own experiences and socialization, thus different children will have different ideas about certain topics [53]. For decades, these ideas are an ongoing research topic and are described as *conceptions*, *misconceptions*, *preconceptions* or *alternative frameworks* [9]. Whether correct

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or incorrect, they should be taken seriously. Accurate ideas can provide a foundation for building new knowledge, but if inaccurate ones are not engaged, children may fail to properly understand new concepts [16] or they may learn them for a test but return to their preconceptions outside the classroom [11]. Research has shown that school children can proceed through their school education and maintain erroneous conceptions about many science concepts [1]. In the context of this study, we will use the term *preconceptions* when we refer to children's ideas that have probably been developed autonomously without being discussed in an educational environment.

2.3 Prior Knowledge

Besides children's preconceptions, their prior knowledge is a major factor that influences the learning process [34]. In literature, the terms *prior knowledge* and *background knowledge* are usually used synonymously. While Stevens [49] defines prior knowledge simply as what a person already knows about a subject, the definition of others is more complex. Biemans & Simons [8] describe it as "all knowledge learners have when entering a learning environment that is potentially relevant for acquiring new knowledge" (p. 6). Dochy & Alexander [21] go even further, claiming that prior knowledge is a person's entire knowledge that can be explicit and tacit, containing both conceptual and metacognitive components. They all agree that learners construct new competences based on what is already understood and believed. Research even indicates that prior knowledge is one of the most influential prerequisites for learning (e.g.[4][20][51]). As with the preconceptions, learners' prior knowledge can facilitate or hinder the understanding of new information [11][47].

When we use the term *prior knowledge* in this paper, we refer to everything the students know about programming, whether or not it was developed in an educational context (incl. *preconceptions*).

2.4 Implications for Teaching

If new knowledge must be constructed from existing knowledge, teachers have to pay close attention to what their students know and believe to know about a topic. It is considered important to help students to activate their beliefs and knowledge so they can productively build on them [3]. Without teacher guidance, they may not relate their everyday know-how to the subjects taught at school [11]. A variety of techniques, e.g. concept maps or brainstorming, can be used to explore children's thinking on topics and phenomena [52] – even small instructional measures seem to activate students' relevant prior knowledge to positive effect [12][29]. In addition, once the teacher has identified the nature of the students' beliefs, it becomes easier to plan activities that support the intended learning process [23]. Despite these positive effects, research has shown that teachers rarely have or take the time to identify students' prior knowledge and often just assume a certain "base level" of knowledge and ideas [35].

2.5 Exploring Student's Prior Knowledge

There exists a wide range of formative *classroom assessment techniques* that serve the purpose of probing students' thinking and evoking information about their knowledge, understanding and attitudes. It should be noted that these forms of diagnostic assessment should not be threatening for the students and are considered an *assessment for learning* in contrast to an *assessment of learning* [54]. What sounds trivial seems to be difficult for many teachers – they usually listen for the "correct" answer rather than what they can learn about the students' thinking [18].

Driver and Erickson [24] distinguish two main methodologies to access different aspects of students' prior knowledge: phenomenological and conceptually based approaches. Phenomenological approaches consist of presenting events or systems to students and asking them to make predictions or give explanations for the way things are happening. Classical examples are the *Piagetian clinical interview* as well as *predict-observe-explain* [31] and *interview-about-instances/events* [42] techniques. In conceptually based approaches, students are usually presented with words or propositions to which they have to perform tasks. This can be word association tasks, brainstorming, creating concept maps or just asking the students to define a term [37]. In our research, we have adapted one technique from both approaches:

Reflection and Recording (Conceptually Based Approach). One of the easiest ways for activating prior knowledge is to prompt the students to tell or write down what they know about a topic (e.g. with questions like "What do you think of when you hear the word xy?" or "What do you already know about xy?") [50]. Different meta-analyses [39][44] show that this technique can increase students' learning outcomes.

Interpretation of Topic-related Pictures (Phenomenological Approach) A variation of the *interview-about-instances technique* is to show students different images related to the respective topic and ask corresponding questions (e.g. "Would you say that there is an electric current in these pictures?"). One advantage of this method is that students seem to be more comfortable and willing to speak if they are offered pictures as a stimulus for their thinking. [43]. Pictures can offer concrete anchor points to which students can refer and also enable them to answer more abstract questions [6].

3 RELATED WORK

Sheehan [48] asked 36 primary school students of two different age groups (age 6-7 and 9-10) to draw pictures of people programming computers. A week later, the children were asked to comment on their pictures as well as answer questions about computers and programming. Neither group showed a deep understanding of what computer programs are and how they are produced. They saw programming as the production of visual and audio effects. The older children recognized that programming had something to do with controlling the computer. There exist several other studies in which students are asked to draw computers or computer scientists to capture children's attitudes and understanding how computer work (e.g. [14][19][32]).

Balkan Kiyici [5] selected four different methods to collect data on the perceptions of 58 fourth-graders about technology. The study included drawing pictures, word association tests, finding metaphors and semi-structured interviews. The analysis of the pictures and association tests showed that children tend to associate the term technology with high-tech products. In the metaphors and interviews, they defined technology as things that make life easier, yet emphasized that it has positive and negative aspects. Children's view of technology was also investigated in the work of Levin & Barry [38] – they placed special focus on the role of the students' age and gender.

In her dissertation, Bergner examined the ideas that children and adolescents have of computer science and computer scientists [7]. For this purpose, she evaluated questionnaires from 116 primary school children and 879 students of lower and upper secondary school. Her work showed that primary school children do not yet have strong associations with computer science. From 5th grade onwards, students most frequently mention *computers* and *programming* when asked for associations with *computer science*. Borowski et al. [10] avoided the term *computer science* and asked over 600 primary school students what they would ask an expert that can answer all their "questions on computers, mobile phones, robots and so on". They used qualitative content analysis to create a two-dimensional category system. The first dimension consists of the artifacts *Internet*, *computers*, *robots*, *mobile phones*, *sound and pictures*, *game consoles*, and *games* – the second dimension describes the perspective of the question (e.g. *history/future, operation, potential*).

In an interdisciplinary literature review, Rücker & Pinkwart [45] examined children's ideas and beliefs about how computers work, what they are made of and what their abilities are. They were able to identify five conceptions: computers are intelligent, omniscient databases, mechanical, wired networks and/or can be programmed.

The work of Müller & Schulte [41] investigates the preconceptions children have about robots. In a questionnaire they asked 79 students (age 7-10) about the purpose of robots and whether they can be controlled and trained. The students were also asked to draw a picture of what a robot looks like. The most frequently mentioned robots were robotic lawnmowers and vacuum cleaners, Alexa as well as robots from Star Wars and television.

4 METHODOLOGY

To gain information about the preconceptions and knowledge of children about *programming*, we conducted, filmed and analyzed a total of seven teacher-student discussions with children in third and fourth grade. These discussions were the beginning of several three-day programming courses held in 2016 and 2017 at the facilities of our university (for further information see [27][28]).

We chose this form because we wanted to collect data on the one hand, but on the other hand, we also wanted to allow the students to exchange information and thus support the process of knowledge construction. This way, we hoped to provide a setting in which previously implicit ideas could be made explicit and accessible for reflection, review and association.

4.1 Participants

A total of 33 boys and 28 girls took part in our study (n=61). The ten children of the first discussion (one girl, nine boys) were between eight and ten years old and attended the programming course as part of a voluntary holiday program in rural Bavaria. Three children already had experience in programming Lego WeDo, two children in Scratch.

Table 1: Students' Self-Assessment of Prior Knowledge

	← *I didn't know anything about programming*				*I knew exactly what programming was* →
	1	2	3	4	5
girls	8	3	8	7	1
boys	3	6	3	6	6
total	11	9	11	13	7

A total of 27 girls and 24 boys at the age of eight to eleven took part in the six other teacher-pupil discussions. The children came from one 3rd and five 4th classes of two primary schools in urban areas of Southern Germany. Each group consisted of 7-10 children from the same class – the composition of the individual groups was based on which parents agreed to record the children on video. The participating students completed a short questionnaire at the end of the course day on which the discussion took place. They were asked to judge their previous knowledge of programming on a five-level Likert scale from 1 "I didn't know anything about programming" to 5 "I knew exactly what programming was'. The overall responses were quite balanced (see Table 1). If we look at the gender difference, we can see that the girls say they have less prior knowledge than the boys. More boys claim "they know exactly what programming is".

4.2 Data Collection

In the three sessions in 2016, we only used the conceptually based approach of asking the group "What do you think of when you hear the word *programming*?". In the four courses in 2017, we expanded this approach with elements of the phenomenological approach. As soon as there were no more answers to our question, we presented various picture cards and asked the question again. The visual impulses showed graphic depictions of a smartphone, a road intersection, the scene of a non-existent computer game, a Mars rover and an assembly line with an industrial robot in a factory. In both years, we collected the students' answers to the question for all to see on a poster in the course room. To analyze them in-depth later on, we recorded the entire situation with at least two cameras. There were no computers in the room. In total, we got 67 minutes of video footage (conceptually based approach: ∅ 5 minutes per discussion, phenomenological approach: ∅ 8 minutes per discussion).

4.3 Data Analysis

The video recordings were transcribed and analyzed using Mayring's qualitative content analysis [40]. The answers of the children without and with the use of visual impulses were evaluated separately.

The analysis of the student answers without visual impulses resulted in an inductively developed category system, which we describe in the following section. To ensure the quality of the code system, the categories were discussed within our team and we measured the inter-coder agreement. All transcripts were given to a second coder together with all content-analytical rules and the category system. This resulted in an intercoder coefficient Kappa [13] of 0.75 which is regarded as a substantial inter-coder agreement.

Table 2: Category System with Number of Codings

Category	Subcategory	Codings
Objects (58) ↓ *What is programmed?*	consumer electronics (11)	TV, Xbox, Wii, Nintendo, Playstation, iPad, mobile phone
	computer (9)	computer
	games (8)	games, computer games
	mobile apps (6)	apps, music apps, security apps
	motion picture (6)	movies, cameras
	computer software (6)	programms, virus, scripts, Scratch, objects
	robots (5)	robots
	home (4)	houses, fire extinguishers, elevator, lights
	people (2)	people
	industry (1)	assembly lines
Actions (34) ↓ *What do you do?*	creating (12)	inventing, producing, making something, bringing to life, trying out
	handling (10)	typing, writing, loging in, adjusting, choosing, assembling blocks, combining
	transmitting data (6)	transferring, downloading, installing
	running a process (4)	controlling, steering
	working (2)	working something trough, working with scripts

To describe the students' associations with the five visual impulses, we coded the students' statements starting from the moment the first image was shown. The coding unit, in this case, was a complete statement of a student – this could be single sentences or several cohesive sentences. We coded which statement was given to which of the five pictures.

5 RESULTS

In the following section, we describe the results of the seven teacher-student discussions, grouped according to the method of data collection. Since the discussions were conducted in German, we translated the codes, categories and statements which were derived.

5.1 "What do you think of when you hear the word *programming*?"

From all student responses, we gained 92 codings that led to a category system with two main categories (see Table 2). The category *Objects* summarizes everything that refers to something that is programmed, the category *Actions* refers to all actions the children thought of in the context of programming.

In Table 3 we see that no coding category could be found in all seven group discussions – the ones that are mentioned in the most are computers, robots and games. The gender distribution of all codings in the individual categories is shown in Figure 1. It can be seen that boys and girls made overall the same number of statements that fall under the main category *actions*. If we look at the individual subcategories, we see that only the subcategory *working* consists exclusively of coded statements of boys. If we look at the second main category *objects*, we can see that boys have made more statements than girls that refer to something being programmed. It is noticeable that only statements by boys were coded under the subcategories *computer software* and *people*. There were also more boys who mentioned programmable things around the house that were subsumed under the subcategory *home*.

Table 3: Codings Mentioned in the Most Discussions

Coding	Number of Discussions in which the Coding occurred
computer	6
robots	5
games	5
mobile apps	4
films	3
making	3
producing	3
transferring	3

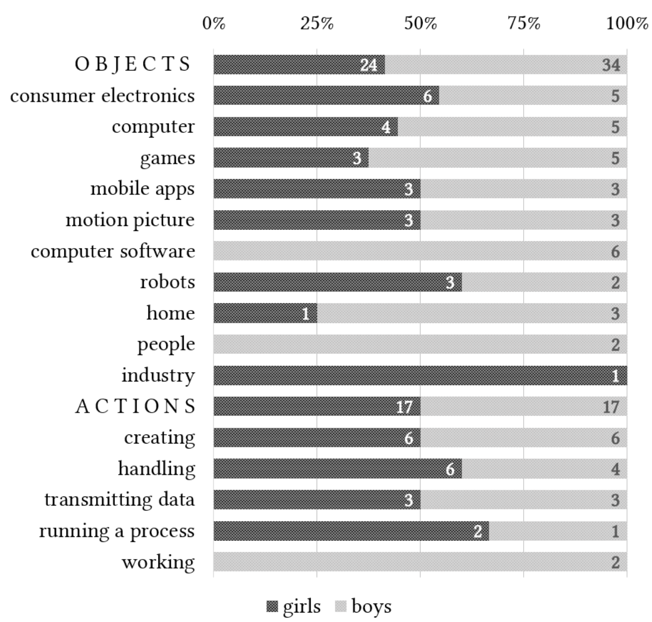

Figure 1: Gender Distribution of Coded Statements

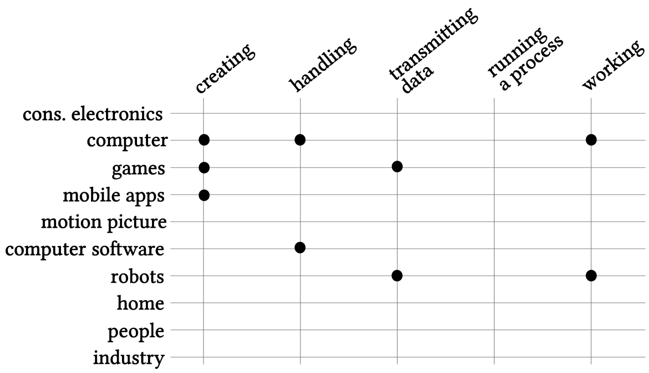

Figure 2: Intersections Between the Two Main Categories

Figure 2 shows where the main categories cross (e.g. "inventing a game" is encoded in the category *games* as well in *creating*). *Creating* is linked by the students to the categories *computers*, *games* and *apps* in five statements. The subcategories *handling* and *working* are both mentioned together with *computers* and *computer software*. *Transmitting data* is named twice with *games* and twice with *robots*.

In Figure 3 we can see the individual codings that were found in each teacher-student discussion. It can be seen that in some discussions several student statements were assigned to the same subcategory (see grey marking). This may indicate that the students have influenced or inspired each other in their expressions. Particularly striking is discussion 6, in which the students mention seven devices that were subsumed under *consumer electronics*. When looking at the video transcript, we can see that one boy mentions a *Playstation* and relatively shortly afterwards other children mention *Nintendo*, *Wii* and *Xbox* in their statements.

5.2 Visual Impulses

In the following, we summarize the student statements to each picture. Table 4 further shows how many statements were made on the individual images and how many were given by girls and boys.

Picture *Smartphone*. The children named individual mobile phone models, such as the iPhone, and suspected that apps, such as WhatsApp, needed to be programmed. They also said that "the mobile phone itself has to be programmed so that one can put other things on it" and "one has to program that it can take pictures and that it can write SMS or make phone calls".

Picture *Road Intersection*. It was said that it has to be programmed when a traffic light has to switch from green to red and what happens when the button of the traffic light is pressed. In addition, the students had many ideas and associations about what to program in a car. Some children were familiar with electronic parking assistants, which are programmed to stop the car when something stands in the way. Others mentioned adaptive cruise control and said that it must be programmed to maintain/control speed or to maintain a certain distance. The children also discussed self-driving cars and explained that they must be programmed to stop in front of an obstacle and drive to a particular destination. One boy thought of a navigation system and said that it had to be programmed "because all roads had to be programmed in".

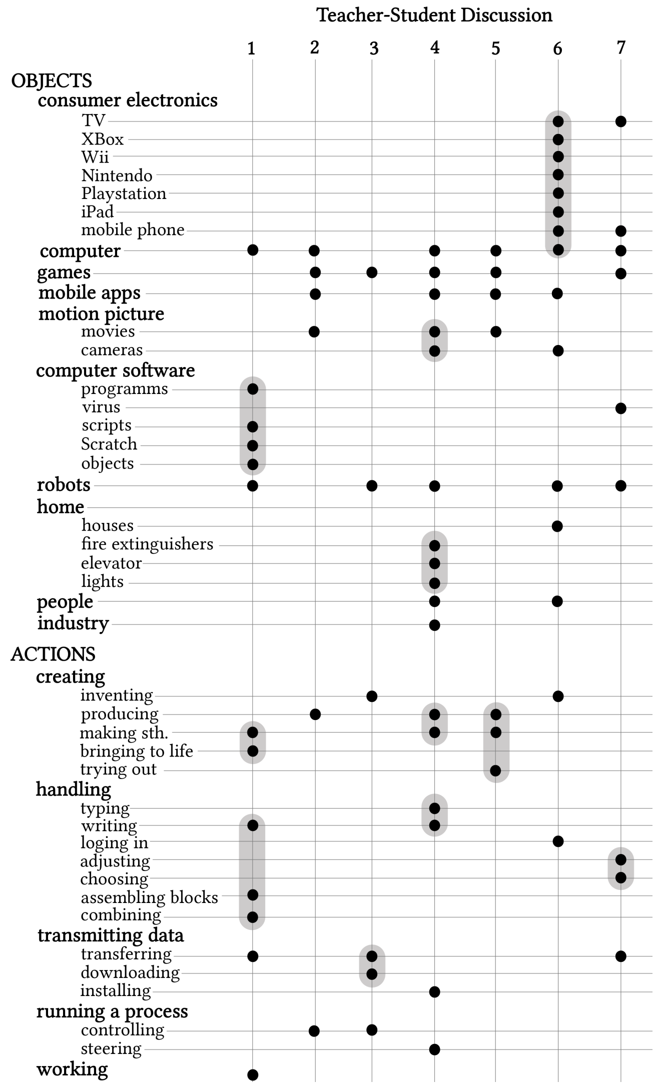

Figure 3: Distribution of Codings by Discussions

Picture *Computer Game*. The students stated that video and mobile games also have to be programmed. Apart from that, they only listed individual games, e.g. Minecraft, Super Mario.

Picture *Mars Rover*. With the image of the Mars Rover, the children associated robots in general, space robots, solar-powered robots and the animated film character Wall-E. They said that the rover could be programmed to drive, do something specific, take pictures, measure the temperature and pick something up. One child specified that the computer inside would be programmed. They also talked about how you have to be able to see what the robot sees from Earth and that there is a remote control for it.

Picture *Assembly Line with Industrial Robot*. Looking at the picture, the students stated the robot is located in a factory or workshop and is programmed to repair something, to weld something together and to manufactures cars/toys/something big out of metal. When the teacher pointed to the industrial robot and asked what

Table 4: Number of Statements to the Visual Impulses

	Statements		
Visual Impulse	Girls	Boys	Total
Smartphone	3	3	6
Road intersection	12	16	28
Computer game	1	6	7
Mars rover	6	15	21
Assembly line	6	11	17
Total	28	51	79

it was, one boy said “a computer”. Another one shared with the group that his brother had told him “that at *Mercedes* the shapes of the cars are initially made on the computer”. Another boy told the group about an attraction in Legoland, where you can control the course of a flight by programming the movements of huge grippers.

6 DISCUSSION

The main purpose of our study was to investigate children's perceptions of programming. It can be derived from our category system that they associate both actions and objects with the term *programming*. It was very surprising for us that the subcategory *creating* had the most codings over all seven discussions. One possible explanation could be the emerging role of *making* in education which comes with the *maker movement* and has experienced a remarkable upswing in recent years [46]. However, we do not know whether the children participated in such courses or offers before our study.

Among the objects being programmed, *consumer electronics*, *computers* and *games* were the most frequently mentioned categories. This is not surprising, because the children probably have many points of contact with them in everyday life. Comparable categories were also found in the study of Borowski et al. [10] in the dimension *artifacts*. In Balkan Kiyici's study on children's perceptions of technology [5], high-tech products were also mentioned most frequently.

We were initially surprised that the children mentioned *movies* and *cameras* in their statements. While some children explicitly mentioned animated films, others may have simply been inspired by the film cameras that were present in the classroom for filming the discussions. The two main categories *actions* and *objects* were also found in the students' statements on the visual impulses. For example, when the picture of the road intersection was shown, the students named cars and traffic lights as objects that are programmed and also described what is being programmed (e.g. the car is programmed to keep a certain distance).

The primary school curricula of the individual German states differ considerably not only in general but also in the thematic areas of *media* and *technology* [25]. Since our sample of students is relatively small and we only collected data in Bavaria, we cannot assume that our results are representative for all German primary students. In addition, we only interviewed students of third and fourth grade of primary school. Furthermore, most students knew in advance that they were going to attend a programming course. Therefore, it cannot be excluded that they informed themselves beforehand, asked their parents, etc. Nevertheless, we believe that our results can provide important insights into children's perceptions and thus provide starting points for programming lessons in primary school.

In the present study, we have also used different approaches to investigate students' perceptions. The conceptually based approach of asking “*What do you think of when you hear the word programming?*” worked well for us. Although the students did not know the course instructor until then, they felt comfortable enough to express their ideas. The open question and the fact that there can be no wrong answers to it could have helped significantly. As an example of a phenomenological approach, we showed the students different programming-related pictures and asked the question again. We can confirm that offering pictures as reference points work well to invite students to speak. At the same time, there is a risk that they only describe what they see in the pictures. We could imagine that the pictures would be especially helpful for even younger children, who would be overwhelmed by the rather abstract question. We recommend selecting the visual impulses very carefully. As one can see in Table 4, very few statements were given to the pictures of the smartphone and the computer game. We suggest to choose pictures that give room for various associations and ideas. Besides, it might be very interesting to show the students pictures of “un-programmed” things (e.g. a plant or a mechanical machine). Further recommendations for the selection or the design of pictures for the *interview-about-instance technique* can be found in [17][42].

Regarding the setting of the data collection, it would be interesting to conduct interviews with individual pupils. One would have the possibility to ask the students for further descriptions and explanations – something that was only possible to a limited extent in our group setting. Another advantage would be that the students would not be able to influence each other in their statements. A disadvantage, however, could be that the interview situation could be intimidating, especially for younger children.

The final aim of our study was to investigate whether there are any noticeable differences between boys and girls. Although there have been some small signs of gender differences in the results, we do not have enough data to draw further conclusions. However, it was noticeable that more boys gave their views on the visual impulses (see Table 4). Special care should be taken to select or design the images in a way that they appeal to girls as well as boys.

7 CONCLUSION AND FUTURE WORK

It is a well-known, popular and frequently formulated demand for teachers that lessons should be based on students' ideas and prior knowledge. However, it is often unclear what should be used as an orientation – especially in a quite new topic such as programming. Therefore, this study examined what primary school students think of this aspect of computer science. In the future, it should be examined whether our results can also be reproduced in a larger sample and whether adjustments to the method of data collection are necessary. Adjustments can also be made concerning the question of whether the perceptions of boys and girls are different (e.g. one could ask groups of boys and girls separately).

Also, there is the task of how we can take the students' prior knowledge into account when selecting teaching content and methods in a way that misconceptions can be avoided and sustainable knowledge can be acquired. We will pursue these questions in our future research.

REFERENCES

[1] Valarie L. Akerson, Lawrence B. Flick, and Norman G. Lederman. 2000. The Influence of Primary Children's Ideas in Science on Teaching Practice. *Journal of Research in Science Teaching* 37, 4 (2000), 363–385.

[2] Michael Allen. 2010. *Misconceptions in primary science.* McGraw-Hill, Berkshire and New York. http://site.ebrary.com/lib/academiccompletetitles/home.action

[3] Susan A. Ambrose. 2010. *How learning works: Seven research-based principles for smart teaching.* Jossey-Bass, San Francisco, CA.

[4] David P. Ausubel, Joseph D. Novak, and Helen Hanesian. 1968. *Educational psychology: A cognitive view.* Holt Rinehart & Winston, New York.

[5] Fatime Balkan Kiyici. 2018. Primary School Students' Perceptions Of Technology. *Malaysian Online Journal of Educational Technology* 6, 4 (2018), 53–66.

[6] Keith C. Barton and Linda S. Levstik. 2004. *Teaching history for the common good.*

[7] Nadine Bergner. 2015. *Konzeption eines Informatik-Schuelerlabors und Erforschung dessen Effekte auf das Bild der Informatik bei Kindern und Jugendlichen: Dissertation.* Rheinisch-Westfälische Technische Hochschule, Aachen.

[8] Harm J. A. Biemans and P. Robert-Jan Simons. 1996. Contact-2: A computer-assisted instructional strategy for promoting conceptual change. *Instructional Science* 24, 2 (1996), 157–176. https://doi.org/10.1007/BF00120487

[9] Joan Bliss. 1993. The relevance of Piaget to research into children's conceptions. In *Children's informal ideas in science*, Paul Joseph Black and Arthur Maurice Lucas (Eds.). Routledge, London, 20–45.

[10] Christian Borowski, Ira Diethelm, and Henning Wilken. 2016. What children ask about computers, the Internet, robots, mobiles, games etc. In *Proceedings of the 11th Workshop in Primary and Secondary Computing Education*, Jan Vahrenhold and Erik Barendsen (Eds.). ACM, New York, NY, USA, 72–75.

[11] John D. Bransford. 2000. *How people learn: Brain, mind, experience, and school* (expanded ed., 7. print ed.). National Academy Press, Washington, DC.

[12] John D. Bransford and Marcia K. Johnson. 1972. Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior* 11, 6 (1972), 717–726.

[13] R. L. Brennan and D. J. Prediger. 1981. Coefficient Kappa: Some Uses, Misuses, and Alternatives. *Educational and Psychological Measurement* 41, 3 (1981), 687–699.

[14] Mark Jeremy Brosnan. 1999. A new methodology, an old story? Gender differences in the "draw-a-computer-user" test. *European Journal of Psychology of Education* 14, 3 (1999), 375–385. https://doi.org/10.1007/BF03173121

[15] Neil C. C. Brown, Sue Sentance, Tom Crick, and Simon Humphreys. 2014. Restart: the resurgence of computer science in UK schools. *ACM Transactions on Computing Education* 14, 2 (2014), 1–22. https://doi.org/10.1145/2602484

[16] Linda M. Campbell and Bruce Campbell. 2008. *Mindful Learning: 101 Proven Strategies for Student and Teacher Success.* SAGE Publications, Thousand Oaks.

[17] Christine Chin. 2001. Eliciting Students' Ideas and Understanding In Science: Diagnostic Assessment Strategies for Teachers. *Teaching and Learning* 21, 2 (2001), 72–85.

[18] Brent Davis. 1997. Listening for Differences: An Evolving Conception of Mathematics Teaching. *Journal for Research in Mathematics Education* 28, 3 (1997).

[19] Pearl Denham. 1993. Nine- to fourteen-year-old children's conception of computers using drawings. *Behaviour & Information Technology* 12, 6 (1993), 346–358.

[20] Filip Jozef Reginald Cornelius Dochy. 1992. *Assessment of prior knowledge as a determinant for future learning: The use of prior knowledge state tests and knowledge profiles.* Centre for Educational Technology and Innovation, Open University.

[21] Filip J. R. C. Dochy and Patricia A. Alexander. 1995. Mapping prior knowledge: A framework for discussion among researchers. *European Journal of Psychology of Education* 10, 3 (1995), 225–242. https://doi.org/10.1007/BF03172918

[22] Rosalind Driver. 1989. Students' conceptions and the learning of science. *International Journal of Science Education* 11, 5 (1989), 481–490.

[23] Rosalind Driver. 2014. *Making Sense of Secondary Science.* Routledge, London.

[24] Rosalind Driver and Gaalen Erickson. 1983. Theories-in-Action: Some Theoretical and Empirical Issues in the Study of Students' Conceptual Frameworks in Science. *Studies in Science Education* 10, 1 (1983), 37–60.

[25] Daniela Efler-Mikat. 2009. *Synopse der Lehrpläne der deutschen Bundesländer für das Fach Sachunterricht in der Grundschule.* Leibniz-Institut für die Pädagogik der Naturwissenschaften, Kiel.

[26] Katrina Falkner, Rebecca Vivian, and Nickolas Falkner. 2014. The Australian Digital Technologies Curriculum: Challenge and Opportunity. In *Proceedings of the Sixteenth Australasian Computing Education Conference - Volume 148 (ACE '14).* Australian Computer Society, Darlinghurst, Australia, 3–12.

[27] Katharina Geldreich, Alexandra Funke, and Peter Hubwieser. 2016. A Programming Circus for Primary Schools. In *Proceedings of the 9th International Conference on Informatics in Schools: Situation, Evolution, and Perspectives.* 46–47.

[28] Katharina Geldreich, Alexandra Simon, and Peter Hubwieser. 2019. A Design-Based Research Approach for introducing Algorithmics and Programming to Bavarian Primary Schools. *MedienPädagogik: Zeitschrift für Theorie und Praxis der Medienbildung* 33, Medienpädagogik und Didaktik der Informatik (2019), 53–75.

[29] Mary L. Gick and Keith J. Holyoak. 1980. Analogical problem solving. *Cognitive Psychology* 12, 3 (1980), 306–355. https://doi.org/10.1016/0010-0285(80)90013-4

[30] Aytac Gogus. 2012. Constructivist Learning. In *Encyclopedia of the sciences of learning*, Norbert M. Seel (Ed.). Springer, New York, 783–786.

[31] Richard F. Gunstone and Richard T. White. 1981. Understanding of gravity. *Science Education* 65, 3 (1981), 291–299. https://doi.org/10.1002/sce.3730650308

[32] Alexandria K. Hansen, Hilary A. Dwyer, Ashley Iveland, Mia Talesfore, Lacy Wright, Danielle B. Harlow, and Diana Franklin. 2017. Assessing Children's Understanding of the Work of Computer Scientists. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, Michael E. Caspersen (Ed.). ACM, 279–284.

[33] Philip Johnson and Richard Gott. 1996. Constructivism and evidence from children's ideas. *Science Education* 80, 5 (1996), 561–577.

[34] Slava Kalyuga. 2012. *Role of Prior Knowledge in Learning Processes.* Springer US, Boston, MA, 2886–2888. https://doi.org/10.1007/978-1-4419-1428-6_214

[35] Maria Kambouri. 2016. Investigating early years teachers' understanding and response to children's preconceptions. *European Early Childhood Education Research Journal* 24, 6 (2016), 907–927.

[36] Sei Kwon and Katri Schroderus. 2017. *Coding in Schools: Comparing Integration of Programming into Basic Education Curricula of Finland and South Korea.* Finnish Society on Media Education, Helsinki, Finland.

[37] John Leach, Rosalind Driver, Philip Scott, and Colin Wood-Robinson. 1995. Children's ideas about ecology 1: Theoretical background, design and methodology. *International Journal of Science Education* 17, 6 (1995), 721–732.

[38] Barbara B. Levin and Sean M. Barry. 1997. Children's views of technology: The role of age, gender, and school setting. *Journal of Computing in Childhood Education* 8, 4 (1997), 267–290.

[39] Robert J. Marzano. 1998. *A theory-based meta-analysis of research on instruction.* Mid-Continental Regional Educational Laboratory, Aurora, CO.

[40] Philipp Mayring. 2014. Qualitative content analysis: theoretical foundation, basic procedures and software solution. http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173

[41] Kathrin Müller and Carsten Schulte. 2018. Are children perceiving robots as supporting or replacing humans?. In *Proceedings of the 13th Workshop in Primary and Secondary Computing Education on - WiPSCE '18*, Andreas Mühling and Quintin Cutts (Eds.). ACM Press, New York, New York, USA, 1–4.

[42] R. J. Osborne and J. K. Gilbert. 1980. A Method for Investigating Concept Understanding in Science. *European Journal of Science Education* 2, 3 (1980), 311–321.

[43] David N. Perkins. 1994. *The intelligent eye: Learning to think by looking at art.* Getty Education Inst. for the Arts, Los Angeles, Calif. http://www.loc.gov/catdir/enhancements/fy0635/94000030-d.html

[44] Michael Pressley, Eileen Wood, Vera E. Woloshyn, Vicki Martin, Alison King, and Deborah Menke. 1992. Encouraging Mindful Use of Prior Knowledge: Attempting to Construct Explanatory Answers Facilitates Learning. *Educational Psychologist* 27, 1 (1992), 91–109. https://doi.org/10.1207/s15326985ep2701{_}7

[45] Michael T. Rücker and Niels Pinkwart. 2016. Review and Discussion of Children's Conceptions of Computers. *Journal of Science Education and Technology* 25, 2 (2016), 274–283. https://doi.org/10.1007/s10956-015-9592-2

[46] Sandra Schön, Martin Ebner, and Swapna Kumar. 2014. The Maker Movement. Implications of new digital gadgets, fabrication tools and spaces for creative learning and teaching. *Educational Technology* 39 (2014), 14–25.

[47] Amy M. Shapiro. 2016. How Including Prior Knowledge As a Subject Variable May Change Outcomes of Learning Research. *American Educational Research Journal* 41, 1 (2016), 159–189. https://doi.org/10.3102/00028312041001159

[48] Robert Sheehan. 2003. Children's perception of computer programming as an aid to designing programming environments. In *Proceedings of the 2003 conference on Interaction design and children*, Stuart MacFarlane (Ed.). ACM, New York, NY.

[49] Kathleen C. Stevens. 1980. The effect of background knowledge on the reading comprehension of ninth graders. *Journal of Reading Behavior* 12, 2 (1980), 151–154.

[50] Nicole Strangman, Tracey Hall, and Anne Meyer. 2004. Background Knowledge Instruction and the Implications for UDL Implementation. http://aem.cast.org/about/publications/2004/ncac-background-knowledge-udl.html

[51] F.E Weinert and A. Helmke. 1998. The neglected role of individual differences in theoretical models of cognitive development. *Learning and Instruction* 8, 4 (1998), 309–323. https://doi.org/10.1016/S0959-4752(97)00024-8

[52] Richard White and Richard Gunstone. 1992. *Probing Understanding.* Routledge, London. https://doi.org/10.4324/9780203761342

[53] Karen Worth. 1999. The Power of Children's Thinking. In *Inquiry: Thoughts, Views, and Strategies for the K-5 classroom*, National Research Council (Ed.). National Science Foundation, 25–31.

[54] Xiaoyan Zhao, Marja van den Heuvel-Panhuizen, and Michiel Veldhuis. 2016. Teachers' use of classroom assessment techniques in primary mathematics education—an explorative study with six Chinese teachers. *International Journal of STEM Education* 3, 1 (2016), 153. https://doi.org/10.1186/s40594-016-0051-2