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.

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
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 knowledge 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

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>girls</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>boys</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>total</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>7</td>
</tr>
</tbody>
</table>

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: 8 minutes per discussion, phenomenological approach: 5 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

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

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

<table>
<thead>
<tr>
<th>Coding</th>
<th>Number of Discussions in which the Coding occurred</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer</td>
<td>6</td>
</tr>
<tr>
<td>robots</td>
<td>5</td>
</tr>
<tr>
<td>games</td>
<td>5</td>
</tr>
<tr>
<td>mobile apps</td>
<td>4</td>
</tr>
<tr>
<td>films</td>
<td>3</td>
</tr>
<tr>
<td>making</td>
<td>3</td>
</tr>
<tr>
<td>producing</td>
<td>3</td>
</tr>
<tr>
<td>transferring</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 1: Gender Distribution of Coded Statements

- girls  boys
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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”.

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
Therefore, it cannot be excluded that they informed themselves beforehand, asked their parents, etc. Nevertheless, we believe that the children probably have many ideas about how computers and other high-tech products really work. Four of our students mentioned that they persisted with their programming lessons. Moreover, 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 “unprogrammed” 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