Child-Drone Interaction in STEM education

An ethnographic study conducted in a classroom environment

Master's thesis in Computer science and engineering

Lovisa Grahn, Birte Großkopf

Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
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Supervisor: Mafalda Gamboa, Computer Science and Engineering
Examiner: Mikael Wiberg, Computer Science and Engineering

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Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg
SE-412 96 Gothenburg
Telephone +46 31 772 1000

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Abstract

Drones are becoming more common in a variety of areas and more integrated in people's everyday lives. One example of this is education, where drones have potential to spark children's interest and help with teaching of STEM subjects like programming. By conducting an ethnographic study at a school in central Gothenburg, this thesis aims to explore the possibilities of using drones in education and what needs to be considered when doing so. The conclusions led to a set of design considerations within the themes of safety, battery life, communication between user and drone, collaboration, touch interaction and gesture. In addition to these, a support material was created based on the instruction manual for the Tello EDU drone and the most commonly asked questions from the children during the workshop. The intention is that teachers could use this material, or something similar, during lessons where the children work with drones.

Keywords: Child-robot interaction, social robots, child-drone interaction, drones, ethnography, education, workshop, STEM.

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Lovisa Grahn & Birte Großkopf, Gothenburg, June 2022

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Introduction

Drones are being used more and more in today's society for various interactions [1] and have started to become integrated into our everyday lives [2]. There are drones that have been created specifically for children to use, some for playing and some for educational purposes [3]. The trend to use drones in education has expanded lately [4] and drones have proven to be a potential learning tool in various fields [4]. Using robots in education is nothing new, there has been studies on social educational robotics for the last 16 years [4]. This demonstrates that robots have good potential as a learning and teaching assistant for children in the classroom as well as at home [4].
In this context, the question arises as to what extent drones can serve as learning aids for children. This master's thesis investigates the child-drone interaction for education, since that is a part of child-drone interaction that has not been researched a lot. The aim is to analyse how the children interact with the drone and what should be considered when designing drones for education. The project also aims to find out if the drone is a good support material for children learning programming. This is conducted in an ethnographic study [5] at an international school in Gothenburg with children in the age of 11-13 years.

1.1 Research problem

There are gaps in the research concerning children-drone interaction, and the use of drones in education [2, 6]. Children are not considered as primary users for safety, ethical, and privacy reasons [2].
Social robots are being used in education and have proven to be a good learning aid [4]. For example, *LEGO Mindstorms*, are used for robotic education as a visual programming system [7]. One study tested how children learn to monitor programmable matter through physical activities, in this case a handheld controller from LEGO bricks used to control drone swarms [8]. This indicates that the aim of learning programming is already included in some drones [8]. Since robots are used as programming instruments, we want to investigate whether this could also apply to drones.
The STEM approach and methods are helpful for children and teachers to improve the teaching-learning process [9]. Considering that there is still a lack of support for teachers in terms of materials, technical support, teacher training, curricular options and infrastructure within the schools to make it possible [10]. Therefore, it was our intention to establish a design or set of guidelines at the end of the study that can

assist teachers in teaching programming with drones in an educational context.

1.2 Research question

This leads us to the following research questions:

- What should be considered when designing drones for programming education for children in the classroom?
- What support material for child-drone interaction should be designed to better support teaching programming?

1.3 Project aim

This thesis aims to explore the possibilities of using drones in education and what needs to be considered when doing so. To this end we conducted an ethnographic study with children, evaluating existing educational drones on the market, and exploring potential guidelines for future development of educational drones. With the conclusion based on the ethnographic study we designed support material that could be used in education with drones.

1.4 Stakeholders

The desired target group is children. Other stakeholders are teachers and parents of children, as well as Chalmers University of Technology, drone producers, designers, and other researchers.

Children

The target group is children aged 11-13 years. They are the ones participating in the study and would be asked questions about their experience.

Chalmers University of Technology

The main stakeholder of this master thesis is Chalmers University of Technology. The university supplies the guidelines for which a master's thesis must be fulfilled. In addition, the university provides a supervisor who supervises the project and supports the academic learning process and an examiner who approves and grades the thesis.

Drone producer, designer

Another stakeholder is the producer and designer of drones, whereby there is a long list of manufacturers. The *Tello EDU* Drone will be used in this study, which makes the manufacturer Ryze Technology especially important. Existing learning material of *Tello EDU* are used to support this project.

Researchers

There are some researchers in the field of human-drone or child-drone interaction who might be interested in the findings of the study. We consulted a few researchers through expert interviews to gain insights into their experiences with robots and drones.

Teachers

Teachers' knowledge and experience of teaching children is a valuable resource and they can build on the results of the thesis by using the potential learning materials as support in this subject of education.

School

For the ethnographic study, a school class was observed in a classroom setting, so the school in which it takes place will also be a stakeholder. Therefore, the results can be of benefit to the school and help to integrate programming into the learning curriculum for lower grades.

Parents

The parents will not be asked to accompany their children in this study, but it will be required that the parents sign a consent form if their children wants to participate in the study.

Lovisa Grahn and Birte Großkopf

The last stakeholder are us, Lovisa Grahn and Birte Großkopf, as we are conducting the project. We have also gained an interest in the topic of child-drone interaction. Lovisa has a Bachelor in Computer Science and Engineering from Chalmers University of Technology and Birte has a Bachelor in Media Computer Sciences from University of Applied Sciences Bremen.

2

Theory

This chapter describes the research field of working with drones and children, as well as the used framework. Child-Drone Interaction belongs to the field of Human-Robot and Human-drone Interaction within the Human-Computer Interaction. Programming is part of the STEM education, which describes the education of science, technology, engineering, and mathematics [11].

2.1 Human-Computer Interaction

The field of Human-Computer Interaction (HCI) design has historically been more focused on "design and usability of computing systems" [12, p.10]. This can be seen in Gunkel description of first, second and third wave of HCI. The first wave focused on controlling machines and making the interfaces easier to use for humans. While the first wave took inspiration from ergonomics, the second wave was more about cognitive science, information processing and communication between human and machine. Today we are experiencing the third wave of HCI, where the focus is rather on the relationship between the human and computer and in which context the interaction takes place [13].

2.2 Human-Robot Interaction

Human–Robot Interaction (HRI) is referred to as "understanding, designing, and evaluating robotic systems for use by or with humans" [14]. Interactions with robots are explored in terms of computational, social, cultural and ethical aspects [15]. In addition, the field explores what characterises a robot, what role it plays, what purpose it has and how it behaves. One challenge in HRI is to interpret the communication "between one or more humans and one or more robots" [14] and to be able to design it accordingly.

2.2.1 Social Robots

Today we are moving away from mainly using robots in the industry, towards social robots [16]. Social robots are built to function and interact directly with people in their environment [17]. Examples of these environments are offices, hospitals, homes, shopping malls as well as cities and urban streets. Other areas where social robots could be useful are within health, where they can support elderly or disabled people [17] and education [16].

Due to that social robots work with humans and in their environment the probability of accidents is higher in comparison to industrial robots [17]. This is partly due to the users and their bystanders but also due to the role that this robot fulfils [17].

2.2.2 Anthropomorphism

"Anthropomorphism is the attribution of human characteristics to non-human objects" [18] and is common throughout the HCI field [19]. The phenomenon has existed for a very long time and it has been suggested that anthropomorphism helped our ancestors to survive [19].
Studies indicate that autonomous robots are especially anthropomorphised [19] and another study showed that anthropomorphism was important for Socially Assistive Robots to function properly [20]. But there are also potential risks with anthropomorphism, especially with regards to deception [20]. Other possible risks are addiction, over-trusting and the uncanny valley [20].

2.3 Child-Robot Interaction

Child-Robot Interaction (CRI) is a sub-field within Human-Robot Interaction and have similarities with Child-Drone Interaction (CDI). Because CDI is a relatively new research area, there were not a lot of studies done at the time this report was written. By reading studies on how children interacted with robots and learned through them in a classroom, we were more prepared when doing our own study. We were also able to better notice the differences between how the children interacted with the drones compared to the robots.
Robots aimed for children are used in different areas such as for playing, mental health, in schools and in hospitals. Since children have not yet fully developed their cognitive abilities, the interaction between a child and a robot looks different compared to the one between an adult and a robot [21].
These differences might make robots more suitable in certain cases. For example, Belpaeme et al. states that when children are still developing their language skills they do not pay as much attention to linguistic errors made by adults. This could mean that children might not notice those kind of errors made by robots either. Belpaeme et al. also discusses a new view on cognitive systems, where cognition is seen as an interaction rather than a product. In this view, the two agents interacting does not need to be fully cognitive. Instead, they can fill in 'gaps' for each other when interacting.
Some examples of area where CRI has potential to be useful is within education (see Subsection 2.3.4) and healthcare. Another domain where robots are used is in the home. In a study [22] the play with one interactive robot toy was examined. One theme that came across in this paper and will be discussed more times in this report is the expectations children have on robots. In this study, the robotic toy did not meet most of the expectations from the children. One example is that the robot did not react to the children's actions as expected.
There are some technical challenges, like visual perception and action selection. So far, the gap between what the user expect the robot to see and what it actually sees

is quite big. Even though specific functions like face recognition is possible today, the perception capabilities needs to be further developed [21]. There is also the challenge to create a realistic action selection, so that the robot responds correctly when a child is interacting with it.

2.3.1 Breakdowns in CRI

In a study about breakdowns with robots it was discovered why these happen and how children react to robotic tutors [23]. The author writes about breakdowns as "when something happens that disrupts the flow of the task, there is a risk that the interaction breaks down as a result" [23].
It happens quite often that robots stop working or fall over, which can lead to disappointment of the children interacting with the robot. The problem with this is that children often focus more on the robot as a tool rather than on the actual task it is supposed to do [24]. Examples of things that led to breakdowns in the study [23], were that the children did not listen to the robots instructions or that the robot missed to explain key information. The robot could not help the children in an effective way and could not perceive what they were struggling with. Another issue the author brings up with the robotic tutor, is that it could not detect power imbalances between children, in the cases where more than one child interacted with the robot [23]. If robotic tutors would become common in classrooms, this is an issue that needs to be solved.
Before a breakdown happen, the children experience a problem with the robot. Depending on the nature of the problem, the children uses different repair strategies, trying to solve these problems [25]. When a problem with the robot in the study occurred, it could be categorised as either an active or a passive social norm violation. From the study with the robotic tutor [25], the most common active violations occurred when the robot made irrelevant comments, interrupted the child or showed dismissal through non-verbal behaviour [25]. Most passive violations occurred when the robot did not respond verbally, and in some cases when it did not act when expected (during its turn in the study). Depending on the situation, the children either tried to adapt to the robot, distract themselves from the robot or shifted focus to the human actors that were present [25].

2.3.2 Ethical risks

It also seems that children anthropomorphise robots to a larger extent than adults do. It is argued that anthropomorphisation and deception are identified as ethical hazards which suggests to avoid unnecessary anthropomorphism [20]. According to the ethical standards in robotics BS 8611, "anthropomorphism should be used 'only for well-defined, limited and socially-accepted purposes', but that in some cases it might be a necessary part of the functionality" [20]. The main risk is that users will dislike the drone rather than be deceived by it. This study discovered that reducing anthropomorphism and the associated ethical risk could make the robot more effective for some users only, and less for others. [20]
Children, especially younger ones, can feel for or build a relationship to a robot [11].

Robots can remind them of certain things like for example horses, monsters, etc. Especially when building robots, like *LEGO Mindstorms*, the children put the parts together which makes the robot come alive. This can make it harder for the children to take them apart again.

2.3.3 Children as stakeholders

Another challenge in CRI is to evaluate in a proper way, something that is harder when working with children compared to adults.
Children can take over the role as designer, stakeholders and tester of robots. In many cases the users are included in the design process at the last stage of evaluation where everything design related is decided and cannot easily be changed anymore. One study [26] involved the children during the whole design process of social robots as co-designers. The children contributed to the social behaviour of the robots by creating movement and colour patterns and deriving their personalities [26].
Child-robot interaction is investigating children's behaviour when interacting with robots [27]. Social robots offer new opportunities for children to learn, grow and play [26]. There are three different kinds of robots for children existing: commercial robots, robotic design kits and robots from design research [26].

2.3.4 Child-Robot Interaction in Education

In education there are different roles for educational robots such as teaching assistant, peer and co-learner, tutee, tutor, companion, a teaching platform and for telepresence [28]. So far, most of the research has been related in using the robots in STEM education with the main aim of introducing the children to programming and mechanics [28]. There are differences between non-humanoid robots and humanoid robots. Non-humanoid robots are more focused on function than appearance [29] whereas humanoid robot resembles the human body in appearance, joint positions and movements [30]. In this context, non-humanoid robots were rather tested in the classroom and humanoid robots in research.

Use of non-humanoid robot in the classroom

Examples of robots that are used as a teaching platform in STEM are the *Dash* [1] and *Dot* [1] robots. With the use of the robots children from age five on can easily learn block-programming. The children write code instructions in order to move the robot from point A to point B and are able to see how their digital codes are transformed in real time into tangible learning experiences [31]. Through the use of the robots, the children also expand their knowledge in algorithm thinking by understanding when the robot needs to turn, estimating the angles and distances [32].
One of the first STEM educational robots is the *LOGO Turtle*. This robot was invented by Saymour Papert in the early 1960s, who previously developed the first programming language for children *LOGO* [33]. The robot was intended to be a

[1] https://www.makewonder.com/robots/

possibility for the children to see and reflect on the result of their programming [33]. Thus, the robot reacts to the children's commands and draw lines [33].
Among the available robots on the market, *Lego Mindstorms* [2] is "one of the most popular robots" in the field of education [34]. It offers several educational setups [34]. The use of the LEGO robot and programming environment offers students the experience of learner-centred and collaborative learning, as well as peer-to-peer programming experiments [35].

Use of humanoid robot in research

Other robots like humanoid robots are still only tried out in research projects and have not been integrated into classrooms. A good example for humanoid robots are the 1.20m tall *Pepper* [3] and the 0.58m tall *NAO* [3] robot, which both are constructed similar to a human body with moving parts.
The *Pepper* humanoid robot can be used as a robot tutee for all ages. *Pepper* has a display in front of his chest and a pre-programmed movement, gesture and gaze behaviour, as well as supporting verbal communication from text to speech. During a digital mathematical game called Graphical Arithmetic Game the robot was used as an aid and co-player [25]. The robots observes the child while playing the game and asks questions in order to understand and learn more about it, so that it can support the child after a while with strategically advice [25]. These teachable agents or tutor robots are used to promote learning-by-teaching and peer assisted learning approaches, where children teach their peers and thus increase their own level of knowledge on a given topic [25]. In another study [36], the *Pepper* robot was tested as an edutainment tool. This concept is similar to the learn through play concept for teaching knowledge in an entertaining way, like games. Edutainment has become particularly interesting in the field of education for children in schools [36].
The *NAO* is used as learning aid or tutor in education and often in social settings with disabled children [34]. Since the robot is quite expensive it has been less tested in the classroom [34]. Some studies tried it as a tutor for younger students to introduce arithmetic with fun activities or to help with geography lessons. The robot can be previously programmed by the teachers using an web interface to prepare quizzes and games to the class [34]. An experiment was conducted within a class study [37] to see if the *NAO* robot could function as an authority figure in a classroom. In doing so, the robot asked the children to lower the noise level in the classroom, which immediately got all the children to listen and be quiet. In a subsequent survey, more children indicated that they would rather listen to a robot than to a teacher [37]. In addition, the teacher considers the robot as a potential assistant in the classroom [37].

Comparison non-humanoid & humanoid robot in education

Another study [34] compared the humanoid robot *NAO* with the non-humanoid *LEGO Mindstorms* with the result that the NAO seemed easier to program. The researchers argue that learning was enriched by interaction with the robot and that

[2] https://www.lego.com/en-us/product/lego-mindstorms-ev3-31313
[3] https://www.softbankrobotics.com/corp/robots/

the students found the *NAO* motivating [34]. According to the results, the *NAO* humanoid robot is better at promoting the students' motivation compared to *LEGO Mindstorms* [34].

Problems integrating robots in education

So far, robots have been used as an add-on in the classroom since the further consequences have not been researched enough. Teachers and Researchers, for example, consider that there are several problems with the integration of robots in education. The lack of knowledge of how robots work, are used and what learning tasks they could take on is a major challenge. Without this knowledge, it is difficult to properly integrate robots into the classroom and curriculum. In addition, the support through materials and the time for preparation, troubleshooting of robots is limited [28]. Serholt also states that social robots are not advanced enough to be used as tutors in education today, partly because of the frequent breakdowns of the robots and that they do not seem to sustain the levels of interaction with the children over time [24].

2.4 Human-Drone Interaction

Drones are increasingly integrated into daily life. They have a large potential and are of great importance within HCI and are expected to become more and more relevant in the coming years [38]. For this reason, it is important to study the interaction between humans and these systems. Human-drone interaction (HDI) can derive some insights from the field of human-robot interaction. Drones can be described as flying robots in 3D space, which change the way humans can interact with them [39].

2.5 Child-Drone Interaction

Child-Drone Interaction (CDI) concerns the relationship between children and drones, focusing on the educational aspects like learning programming and features such as photographing and racing [40]. However, there has not been much research on CDI so far. This is because children are rarely seen as the typical users of drones, for safety and ethical concerns [2].

2.6 Constructionism Framework

Constructionism has its roots in constructivism, a theory by Piaget [41] which states that a child learn new concepts by constructing mental models and putting together new information. To be able to truly understand something, the child must go through a specific order of learning. One example mentioned in Schweikardt and Gross, is that a child needs to learn about gravity and other planets' orbits before understanding the rotation of the earth. From this idea, Papert developed constructionism [41], a framework which establishes that letting a child build things is particularly effective for their learning process. When building something, the child's model is not just a concept in their mind, but a physical object that can be seen and discussed [41].

2.7 Embodied Programming

One of the difficulties when learning programming, is that programming by its nature is abstract [42]. A common way to teach the concept of computational thinking is to introduce concrete metaphors, for example that an algorithm is like a recipe. Sometimes programmable robots are used too. The process of removing these concrete things as the child's mental model of a concept is developed is called concreteness fading [43]. Research suggests that "bodily gestures can influence cognitive simulation more than the actions they signify" [43].

3
Background

This chapter covers the research area of drones and related work as robots, ethnography and education. It also shows the school as the user study setting.

3.1 School

Internationella Engelska Skola is a school group which was founded 1993 by Barbara Bergström [44]. One of the international schools in Gothenburg is the IES Krokslätt (see Figure 3.1). The International English School has levels from year three to year six [45] with children starting at the age of nine [46]. In each year level there are four different classes and the maximum number of students in each class are 28-32 students.[46].

The school has three important beliefs that define school life: a safe and orderly environment, command of English and high academic expectations [47]. The school offers an academic atmosphere where the teachers, head teachers and support staff help the children to concentrate and learn. With a team of highly qualified teachers, specialists and mentors, the children are encouraged in learning and challenge themselves to improve. Students have the opportunity to take additional examinations such as the International General Certificate of Secondary Education from Cambridge Assessment International Education [48]. Each student has a mentor who is the main point of contact for the children and parents. If a child needs additional support, emotional or academic help, a support team and behaviour specialists at the school are available. [49] The school is bilingual and is taught in Swedish and English. The reason why the school is bilingual is that the children should learn the English language at an early age, which will open up many opportunities for them in the future. The children grow up in an international atmosphere where their classmates and teachers come from different countries and cultures, so the children already gain a global understanding and learn different cultural perspectives. [50] From year four onwards, a majority of the lessons are taught in English, for example all science lessons are held entirely in English [44].

The Science Department bought some smaller drones for educational purposes 2021. In year level four they start learning programming with *Scratch* [1] (see Subsection 3.6.1). In year level five, they have science lessons three times a week for 70 minutes, and they have been learning Scratch for two years. In year level six, they have science lessons once a week for 90 minutes. They have already been working with Scratch for three years and start working with drones.

[1]https://scratch.mit.edu

Figure 3.1: The Internationella Engelska Skola Krokslätt where the study took place.

3.2 What is a robot?

A robot is a "mechanical device that can perform independent tasks guided by some sort of programming" [51]. They are already used in many everyday areas such as "manufacturing, medicine, exploration, security, personal assistance and entertainment" [51]. Robots are intended to replace humans in difficult or dangerous tasks such as medicine or defusing bombs. In these cases, humans control the robots via console interfaces. In private households robotic lawnmowers and vacuum cleaners are already common. Some studies show that people generally seem to prefer when a robot is more "pet-like" than "human-like" [12].

3.2.1 Educational robots

Education is one of the fastest growing industries of social robotics usage [4]. Robots have developed real potential not only as "learning or teaching companions for children in the classroom or at home" [4] but also for learners with deficits to adapt content to their abilities. They are able to learn both from and with the users and consequently enhance their personalisation. Social educational robots are defined as "pedagogical and intelligent agents" [4] that can take on the role of tutor or teacher. They are used for learning different knowledge areas such as language, literacy, artificial intelligence or programming. Various robots already exist that are adapted to the user group of learners, such as special robots for primary school or special education [4].

LEGO Mindstorms

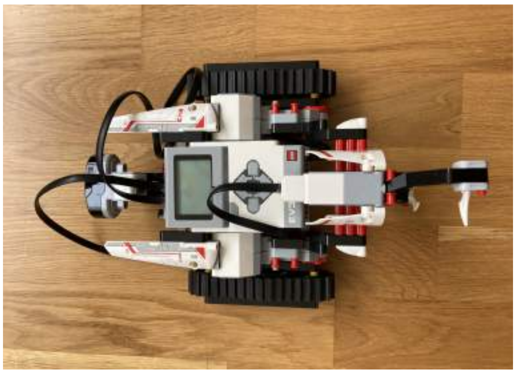
In this thesis the *LEGO Mindstorms EV3* (see Figure 3.3a) will be tested in order to compare to the educational drone later on. *LEGO Mindstorms* combines the LEGO building systems with advanced technology. The series of products are designed to be used in education [35]. The set includes a brick-shaped computer, sensors, servo motors, connector and many different LEGO pieces (see Figure 3.2a) [11]. A number of different robots can be built with the step-by-step 2D guide (see Figure 3.2b). The sensors can be used for light, sound, ultrasound and touch. With a simple and symbol-based programming interface, the robots can be brought to life and programmed to walk, talk and think [35].

(a) Unboxing the LEGO Mindstorms. **(b)** Assembling the robot.

Figure 3.2: Building the LEGO Mindstorms robot.

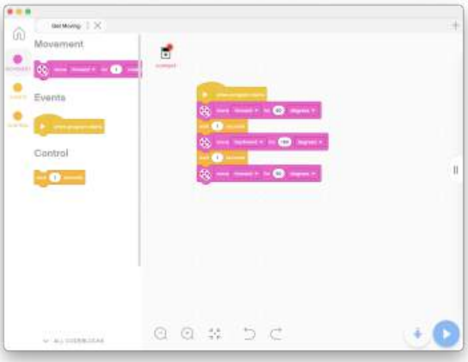
It offers the opportunity to put programming skills to the test, since everything that is programmed can be followed visually. Thus, the interactive robot acts as a producer of results from the learners' input [35]. The programming interface works differently from common visual programming languages such as *Scratch*. It uses actions instead of explanations and provides an interactive context for decision making [35]. But there is also the option of programming in Python with the use of MicroPython [52]. Various missions can be carried out with the included remote control, as well as with the *EV3 Classroom LEGO Education* [2] app (see Figure 3.3b), which can be used to control the robot from a mobile phone or smartphone.

[2] https://education.lego.com/en-us/downloads/mindstorms-ev3/software#downloads



(a) The finished LEGO robot.

(b) The EV3 Classroom tutorial.



(c) Programming in EV3 Classroom.

Figure 3.3: The LEGO Mindstorms robot and the programming interface.

Ozobots

The *Ozobot* [3] robot (see Figure 3.4a) was used in the ethnographic study. It is developed for children from the age five and up and for K-12 grades. There are two versions, the *Ozobot Bit* and *Ozobot Evo*. It can be used for coding, computer science, English language arts, mathematics, history and more. Ozobot is a programmable robot for on screen programming with *OzoBlocky* and screen free programming with Color Codes drawn with markers on paper. Using color codes basic coding concepts were learned and are recommended for beginners. The color codes represent short colour segments which indicate different functions of the robot. The robot has an implemented sensor which detects the black lines and the color codes. To improve *Ozobot's* accuracy in reading code and lines, the robot is calibrated on a black dot before each use. *OzoBlocky* is for beginners and advanced students to learn programming concepts. It is a device independent and visual programming tool.

Codey Rocky

The robot *Codey Rocky* [4] (see Figure 3.4b) has also been used in the ethnographic study. It enables children to learn programming in a playful and creative way. In the

[3] https://ozobot.com
[4] https://www.makeblock.com/steam-kits/codey-rocky

software tool *mBlock* [5], the robot can be coded with block-programming and Python. The robot has an innovative design with a two-in-one function. The display can be removed from the robot and used separately. With more than 10 programmable electrical modules such as sound sensor, light sensor, LED display, the robot can play music, follow light and imitate facial expressions.

(a) The Ozobot Bit **(b)** The Codey Rocky

Figure 3.4: The robots which were used in the ethnographic study.

3.3 What is a drone?

Drones are also known as Unmanned Aerial Vehicle (UAV) and are a type of aircraft that are similar to robots in that they can be controlled remotely [53]. Historically they have been used within the military but today they are used for a wide range of purposes [12]. Some examples of how a drone can be used is as companion, personal drone, agent, motivator or assistant [38]. It is also possible to use drones in search and rescue mission activities, for delivery, running motivation, photography, filming, way finding or as educational tool [38]. Drones can be operated indoors as well as outdoors, depending on the type of drone. Some examples of how to interact with drones are by touch, voice, video, gestures and remote control.

3.3.1 Educational drones

Drones can be used for educational purposes. There are two different types of educational drones: heavyweight and lightweight. The heavyweight drones provide good wind resistance, and therefore used for navigation in outdoor learning practices. The lightweight drones are used for indoor teaching exercises and offer the ability to do programming [6].

[5]https://mblock.makeblock.com/en-us/

Tello EDU

The drone which was used during the ethnographic study is the *Tello EDU* [6] (see Figure 3.5a). It was developed by Ryze Tech as an indoor drone which is quite small (98 x 92.5 x 41 mm) and light (87g). Designed for educational purposes, it allows children and teenagers, who can be beginners or advanced, to learn programming [3]. It supports the programming languages *Scratch*, Python and Swift.

(a) The Tello EDU drone **(b)** Package includes drone, mission pads.

Figure 3.5: The drone which was used in the ethnographic study.

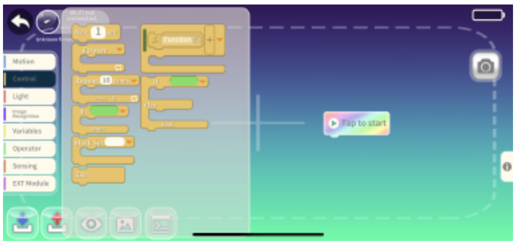
Beginners can easily move the drone using block programming with its own built in visual block programming language [3]. Multiple drones can be programmed and controlled simultaneously as a drone swarm. The included tools, called Mission Pads (see Figure 3.5b), can be used to increase programming precision and serve as orientation points and trigger mechanisms. This allows acrobatic movements and flips to be performed. The *Tello EDU* also enables many image processing functions, such as object recognition, tracking, 3D reconstruction, computer vision and deep learning technologies using AI development [3]. In addition, there is the *Tello* [7] app (see Figure 3.6a) that allows the drone to be controlled from a mobile phone or tablet and the *Tello EDU* [7] app (see Figures 3.6b-3.6d) to block program the drone to fly.

[6]https://www.ryzerobotics.com/tello-edu
[7]https://www.ryzerobotics.com/tello-edu/downloads

(a) The Tello app interface

(b) The Tello EDU app start interface

(c) The Tello EDU app tutorial interface



(d) The Tello EDU app functions interface

Figure 3.6: The app interfaces for controlling and programming the Tello drone.

3.4 Related work

This section contains similar studies in school settings, which were helpful for the ethnographic study in this thesis.

3.4.1 Ethnography in school

"Educational ethnography has become an important part of the field of educational research" [54, p.281]. There are many studies in pre-school, primary school, secondary school and universities with a wide variety of empirical and local settings as well as topics.

Its importance lies in improving school and teaching development. An ethnographic study in a school context will be conducted during the routine of lessons [55]. The ethnographers are observing the teachers and students during a normal week of school. The focus is on what the teacher and students are saying, writing and doing. The ethnographer listen, watch and take notes in the educational setting within the time frame of lessons.

Ethnography in education can focus on different areas, such as learning, teaching, social, pedagogical aspects as well as practice and theory. Through participatory observation, the students' perspective in particular can be reconstructed and attention is also paid to the teachers [54]. The focus is not only on the individuals, but also on the situation itself.

Regarding information about the ethnographic study, for a number of reasons, students should not be told the same amounts of details of the study as teachers or headmasters [56]. This is because of age-related differences in language skills and information processing abilities, but also in order to not influence the children and change their behaviour during the lessons [56].

3.4.2 Workshop in school

A lot of studies carried out workshops in schools in order to teach children programming [57, 58, 59]. Most of them where in primary schools with the children's age of 10-13. The class size differed from 20-30 students. In some studies researcher and supervisor were present as well as the teachers.
The workshops lasted about two hours, with different phases of related activities. Depending on the tasks the students worked alone, in pairs or in groups selected by the teacher in terms of cognitive, social skills and gender.
In studies like those of Gennari et al., they initially talked to the teachers about the students in order to get information and to adapt the workshop to the children and the curriculum. In addition, they conducted a pilot study with a few children and their parents or grand parents to refine the workshop afterwards [58].
Within a step-by-step approach the children were teached programming with different tools like the *Ozobot* robot [57], the paper-based generative toolkit *Tiles cards* [58] and the game design environment *AgentCubes* [8] [59].
The data was collected by photo, video, notes and questionnaires. Questionnaires were conducted before and after the workshop to gain insights in the children's perception of programming. The results show that the children seem to enjoy the participation in the workshops.

3.5 STEM education

STEM is an interdisciplinary approach that connects the fields of science, technology, engineering and mathematics. It aims to teach children the theoretical knowledge of these subjects from an early age and integrate them into realistic and relevant educational activities [60]. In this way, the learning by doing approach is used. Thereby, the students should learn "creativity, critical thinking, cooperation, problem- solving and collaborative work" [61]. In addition, the children should understand the world and gain experience in real-life situations.

3.5.1 Computational thinking

Computational thinking is an essential part of education, which is mainly achieved through programming [57]. Early knowledge in algorithmic thinking is important to get a successful computational thinking [57]. The problem-solving approach can be performed by computers and humans [59].

3.5.2 Children's programming

Since July 2018 programming is included as a part of the Swedish curriculum in primary education for all grade levels [62]. The experience of programming varies greatly between different students and different schools [62]. Students who already have prior knowledge can more easily improve and deepen their thinking, problem-solving skills and ability.

[8] https://agentsheets.com

Some children still have the impression that “programming is difficult and boring” [59]. To change this perception, new approaches are being tested that make programming more creative and fun. In a workshop [58] on designing Internet of things (IoT) tangibles, children were asked in advance if they had any experience with programming. None of them had any prior knowledge. After the workshop, the children were asked how they perceived programming. The answers were “easy, manageable, difficult” [58].
In a study [63], 5th grade students were asked how they would describe programming, where various descriptions were discovered. Programming is a way of thinking like in maths in which problems are divided into sub-problems [63]. It is also a possibility to creatively build, experiment and test different elements in a project. Students compare programming with the use of different languages, for instance when writing formal Swedish it is necessary to have the correct vocabulary without using slang, and when programming it is necessary to have the correctly typed input [63]. Another aspect they compare it to is crafting and sewing, because you can design what you want to achieve by yourself [63]. Students understand programming as a way of communicating with the computer, which has the ability to receive commands and convert these into anything different [63]. Moreover, students understand programming as a kind of artefact that produces functional things, like games, storytelling or machines. As an example, the game Minecraft [9] was compared to block programming, as it contains blocks and instructions which are likewise used in *Scratch*.

Cognitive stages of children

A difficulty with children is that their frustration threshold is very low. If “contents are too theoretical, they quickly lose the interest” [64] and if it is too difficult, they are quickly overwhelmed. Course content must be divided into many parts so that the learning level is easier. In addition, the tasks must be adapted to the appropriate age group. Some children cannot read as fast or have less experience which has to be taken into account [64]. Using the ethnocomputing, students’ interests are included in the learning content, which increases the students’ participation [62]. These interests can be, for example, sports or music. Students show more interest and engagement in programming.

3.6 Block-based programming language

Block-based programming languages are an alternative to the text-based programming language. The difference is that no typing is required, instead, predefined and colourful blocks can be assembled to form a code sequence. There are blocks for different categories as movement, control or events, loops, variables and functions. Block-based languages do not force programmers to type syntactically correct statements [65]. For this reason, block-based programming languages are perceived as easier and are particularly suitable for beginners to learn programming [65]. How-

[9] https://www.minecraft.net/en-us

ever, block-based programming languages cannot solve all issues and are less effective in advanced topics.

3.6.1 Scratch

Scratch is the most known visual, block-based programming language [65] and was developed by MIT. The primary target group is children between ages 8-16 [66] and the users learn to program by creating stories by putting blocks of code together. It offers a very simple interface (see Figure 3.7a) that is operated using drag and drop. Only specific blocks of code can be put together in *Scratch*, and prevents illogical structures from being built [65]. *Scratch* has been adopted to many other block-based learning frameworks.

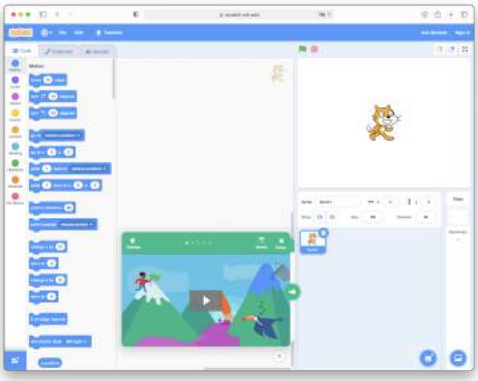
3.6.2 DroneBlocks

DroneBlocks [10] provides a programming environment that enables the teaching of STEM to students of all ages using drones. Educational drones such as *Tello* [11], *Tello EDU* and *Robomaster TT* [12] are supported. It allows block programming to be used in the *DroneBlocks* app (see Figure 3.7b) and JavaScript to be used in *DroneBlocks* code. In this case, *DroneBlocks* app is used. *DroneBlocks* is available for iOS, Android and as Chrome extension.

3.6.3 mBlock

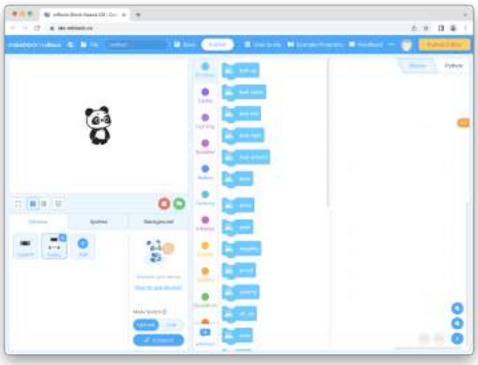
The programming interface *mBlock* (see Figure 3.7c) is designed for STEM education and is inspired by *Scratch 3*. Block programming, Python, robot programming, artificial intelligence (AI) and data science can be learned as part of the coding tool. It can be used to design stories, games, animations and program different robots. Interactive AI projects can be developed in order to recognise speech, text and emotions. Machine learning models can be created and data in real-time collected. The program can be used on a variety of platforms as PC, Android, iOS, on Chromebook and on the web.

[10] https://droneblocks.io
[11] https://www.ryzerobotics.com/tello
[12] https://www.dji.com/se/robomaster-tt



(a) The Scratch interface

(b) The DroneBlocks interface



(c) The mBlock interface

Figure 3.7: The three block programming interfaces

4

Methodology

In this section, the methods used in the design process are defined and presented. Some of the methods (MoSCoW, Questionnaire, Think-aloud, Focus Groups) were not used in the end, but were kept in the methodology chapter in order to explain them and clarify why the design process was changed.
The methods are divided in seven groups: project management, documentation, research, analysis, evaluation, ideation and prototyping.

4.1 Project Management Methods

It is important to plan a project properly from the beginning. Effective planning requires an understanding of the needs and requirements [67]. When planning, time allocated, available sources and products must be taken into account.

4.1.1 MoSCoW

The MoSCoW method is a useful technique for prioritises requirements [68, 69] and categorises the requirements in the four criteria:

- *Must have* requirements are essential for the final product and with the lack of these, the project would fail.
- *Should have* requirements are important for the project, but will only be incorporated if it is possible in the time frame.
- *Could have* requirements are desirable, but will only be included unless they require a lot of time or effort.
- *Won't have* requirements are not unimportant, but are not integrated in the current version.

4.1.2 Gantt

A Gantt chart is one of the most used project planning tools to visualise a project's schedule [70]. It provides a way to organise tasks that need to be done and is easy to create and understand. The chart contains of columns, representing days, weeks and months. It also has rows, indicating phases and corresponding tasks [70]. The expected time is visualised by a horizontal bar, where the left end indicates the beginning and start date while the right end marks the completion of the task. Important events or checkpoints can be displayed as milestones, which are illustrated with an upside-down rectangle. During the project, the Gantt chart can be adjusted

if tasks require more time and the current day is shown with a line to indicate where exactly you are in the process [70].
There are several tools that can be used to create a Gantt chart, in this thesis the free tool *Agantty* [1] is used.

4.1.3 Kanban Board

The Kanban Board is a method to keep track of the design process. A three-column table gives a good overview of the three different stages of to do, doing and done [71]. The board will be created on a whiteboard using post-its notes to write down the different tasks. By doing this, the tasks listed in the table can be prioritised. The tasks can afterwards be assigned to the team members [71]. When starting a task the post-it will be moved to the next column [71].

4.2 Documentation Method

According to Pedgley a documentation method for design work should satisfy the criteria of being a solo effort, sustainable for a long time, delimited to the subject and being able to be done in any location [72]. Diary is one example that fulfils all of theses criteria. For gathering data in ethnographic studies documentation methods are necessary.

4.2.1 Note taking

Taking notes during ethnographic studies enables getting a variety of different data [55]. Detailed information about the social settings and situation can be written down [55]. Unlike other methods of documentation, note-taking is not too intrusive [55] or causes problems with data protection.

4.2.2 Photography

Photography is a way of gathering data by capturing a specific moment, which can display the “social reality” [55, p.63]. In terms of data collection, photography is a form of raw data as it is unaffected by the researcher’s interpretation. The researcher decide on which data to record by choosing the setting, focus point and when to press the shutter [55]. Photos are sometimes described as unacceptable or too intrusive for the ones who are seen on the image and could be identified to a certain degree [55].

4.2.3 Video Recording

Video recording can capture and save more information then other documentation methods [73]. The recording itself should not been seen as a complete representation of the social interactions but more as a part of the “complete ethnographic

[1] https://www.agantty.com/en/

approach” [73], which is ideally based on theory. It also allows for the retrospective assessment of interactions. Video records are especially useful for “interpretation of emotional nuances, embodied perceptions, spatial influences, relational understandings, situational factors and temporal manifestations” [73]. Just like photography, video recording can be problematic with the data that is recorded from people.

4.2.4 Diary

Keeping a diary is useful for documenting the work and to remember when and what was done, especially during a long project. In one study, Pedgley compared two formats of keeping a diary for a design process. The author found that the most effective way was to write in the diary at the end of each day, compared to writing multiple times during the day. According to the same author, good practise for keeping a diary for your design process includes: Describing the events in the same order they happened, keep entries short and focused, include pictures of both completed models but also work in progress, make sure all pages and models are dated and numbered [72].

4.3 Research Methods

The purpose of research is to understand a particular phenomenon. In this process, answers to questions are systematically searched that lead to solving the problem and to a better understanding of the phenomenon [74]. Various methods can support research.

4.3.1 Literature Review

When conducting a literature review, the researcher collects and reads through published resources on a specific field. This can be done as a part of a research study, design project or be published as literature study. Literature reviews are useful for covering the most important areas in a topic, to evaluate what has already been done and to find research gaps [75]. It is important that the literature chosen is relevant for the project or study and comes from credible sources [76].

4.3.2 Interview

A research method to get in contact with other people is interviewing [76]. Within a conversation the interviewer can ask questions regarding a specific topic. Interviews can be unstructured or open-ended, semi-structured and structured, which depends on the interviewer’s control over the interview, the information received and the structure of the interview [12].
Open-ended or unstructured interviews are a kind of conversation about a certain topic [12]. The format of the interview is quite flexible, as the interviewee can answer freely and the interviewer does not expect a specific format or content of the answers. The conversation can get into significant depth as the interviewee may raise issues that the interviewer has not considered. Therefore a deep understanding

and complex of the topic is given and rich data can be generated. However, this makes the analysis very time-consuming.

Within a structured interview, the interviewer pre-formulates the questions [12]. The questions are mainly closed, indicating that they require an answer from a predetermined list of alternatives. The questions are asked consistently with the same wording and order for all participants in the study. A structured interview is reasonable only if the aims are clearly defined and certain questions can be raised [12].

The semi-structured interview combines the open and closed questions from the unstructured and structured interviews [12]. The interviewer starts with the pre-planned questions which are functioning as a guide through the interview and are asked to each interviewee. In this case, the answers can vary greatly, as the interviewer keeps asking until no more new information is received.

4.3.3 Observation

Observation is a research method that can be used during different stages in the design process and be done in several forms. It can be used at an early stage to gain information about the users and the context they will use technology in, as well as later to evaluate how well existing technology works and how it is being used. Observations can be done either directly or indirectly. In direct observations a researcher observe users as they do a task. When observing indirectly, the researcher goes through the records that show how the users complete the task [12]. Observations are suitable for both field studies and in controlled lab environments. When using a field setting, the researcher observes how people usually do tasks in a normal day of their lives. This is useful to understand the context or situation the user is in when using the technology and why certain things happen or why the user behaves in a specific way. This type of observations can result in a lot of data. Since not all data will be relevant, it is important to use a framework (even if it is a simple one) and set a clear focus for each observation session. It is also essential to be flexible and being able to change plans, if something more interesting and relevant to the study would happen [12].

A lab study could take place either in a dedicated usage lab or a portable one. Compared to field studies, the studies conducted in labs are more formal and can be repeated. Data is recorded in similar ways as during field studies, but there is a different focus. Lab studies are more focused on the details of what an individual is doing and not the context in which technology is used [12].

One issue that needs to be considered is the degree of participation. When conducting a study in a lab setting it is generally more suitable to be a passive observer that does not take part in the studied environment, while in a field study it can be more appropriate to be an "insider" of the group, as a participant observer. The researcher does not have to be fully an "insider" or "outsider" to the group being studied. It depends on the study, the goals set and also on ethical and practical issues where it is most appropriate to be located on the scale [12].

4.3.4 Ethnography

Ethnography describes an approach where participants are observed in their everyday setting [77]. It has its roots in social sciences where it is used to study societies and their activities [12]. The ethnographer tries to understand and capture the activities and events from the point-of-view of the people studied [78], by taking the role of a participant observer, or "insider" of the group. Within the interaction design field, ethnography as a research method has gained popularity because of the possibilities to better understand how, why and when people use technology [12].

The data gathered can be in the form of notes focused around what the participants say or do, how they behave and what the ethnographer might feel [79]. It is common to keep a diary with observations that the ethnographer fills in at the end of each session. Data can also be collected in the form of documents and pictures, to mention a few of them [12].

The participants are the main research medium. The ethnographer can take different roles [55]. As a "total participant", it is kept secret that that the person is a researcher, which has many ethical problems since the participants could not give their consent. Furthermore, as a participant in a "normal setting" [55, p.22], where the role of the researcher is known to some but not to most, in order not to alter the situation. The last role is as "observer" in a setting where the identity of the researcher is known to everyone, which has the advantage of having the consent from all participants. By being present, the ethnographer changes the situation, just as any other participant changes the situation [79]. Because the researcher has access to people's everyday live, many ethical problems arise [55].

Before the study, the researcher usually does not know what exactly to look for [56]. Things that are interesting often occur repeatedly and it is important to gather as much data as possible, within the frames of what is relevant to the study [12]. Because the researcher is not a member of the environment and therefore is not familiar with the routines, they only recognises what is interesting and remarkable at the location. Moreover, researchers are not trying to influence the participants by telling them what they are researching. The participants should not behave differently than they normally do.

4.3.5 Workshop

The workshop as a research methodology focuses on fulfilling a research purpose where participants actively participate and obtain valid data about the research area [80]. The researchers are the people who have experience about this field and act as facilitators here. In addition, they plan and prepare the activities, materials, and time frame of the workshop in advance [76]. The participants will carry out the different activities and tasks during the workshop. Accordingly, they become part of the research design process and data production with their expected and performed actions. After the workshop, a result is assumed which can be, for example, generation of new knowledge, proposals or design ideas.

4.3.6 Questionnaire

A common way to collect data is to use questionnaires. Just like interviews, either open-ended or closed-ended questions can be used [12]. Compared to interviews, questionnaires can reach more people, since they can be sent out to participants and no researcher needs to be present, more data can be gathered. The wording, length of questions, formulation of questions and response alternatives will affect the outcome of the questionnaire [76].

4.4 Analysis Methods

Data analysis is defined as "the examination, exploration, and evaluation of information with the goal of discovering patterns" [81]. Data can be analysed qualitatively and quantitatively. Which type of analysis is used depends on the initially identified research goals and the collected data [12]. Qualitative analysis focuses on the essentials and can be represented by themes, patterns or stories, where data can for example be words, pictures, quotes from participants. Quantitative data are present in the form of numbers or can be easily converted into numbers and, in the process, the analysis determines, for example, the quantity, size, extent of something [12]. In this thesis the focus will be on the qualitative analysis.

4.4.1 Affinity Diagram

One way to organise data from research is to use an affinity diagram [76]. Data that has been collected, for example during interviews or observations gets written down on sticky notes. When all of the data has been put down, the research team cluster together sticky notes based on common themes. This method makes it easier to get an overview of the study the team made and to make design choices based on actual data [76].

4.4.2 Thematic Analysis

Thematic analysis is a qualitative method of analysing and identifying topics among the data [82]. To conduct a thematic analysis, six steps need to be followed: familiarise yourself with your data, create initial codes, search for themes, review themes, define and name themes, and create the report [82]. First of all, trying to get familiar with the data by transcribing them, reading them frequently and making notes [82]. After that, the most important and interesting parts of the text are systematically coded, for example, in different colours. The collected codes are grouped into potential themes. In this process, a theme is described as a meaning within the data set that encompasses some important aspect of the collected data in relation to the given research question [82]. The researcher must determine in advance what is considered as a theme [82]. Subsequently, the themes are checked again to see if they match the codes of the entire data set. From this, a kind of thematic map of analysis will be created. The last step is to determine clear definitions and names for each theme. Finally, the final analysis of the selected topics is performed, which leads back to the analysis of the research question [82].

4.5 Evaluation Methods

Within the design process, evaluation is performed by testing the user experience of the design artefact and by gathering and analysing that data [12]. The central focus is on improving the design of the artefact. Thus, usability and user experience are taken into account. There are several different evaluation methods, the ones to be used are described below.

4.5.1 Heuristic Evaluation

A method for checking the usability of a user interface is the Heuristic evaluation [76]. Within a walk through an expert will examine the interface based on usability principles called the heuristics. The experts will give feedback and insights which can help to improve the usability of the design. For an evaluation, three to five evaluators are suggested who individually conduct their evaluation session to not bias others.

4.5.2 Think-aloud

One helpful method for evaluation is think-aloud [76]. Participants are encouraged to express verbally what they are doing, thinking, and feeling as they perform a task. There are two different methods, the concurrent and retrospective think-aloud. During concurrent, the participant expresses their actions, thoughts and feelings while performing the tasks. In retrospective, the participant does the task quietly while being recorded. Afterwards, the recording is viewed and the participant comments on his experience and can explain his intentions, strategies and reasoning. Using this method, the observer can gain insight into what is going on in the participant's mind [12] and can clarify frustrating or confusing user interactions with products [76]. A problem that could occur using this method is that the participant becomes silent when they get stuck. One way to decrease the risk of this happening is to let participants work in pairs, since they might have an easier time discussing with each other what they think is happening. To let participants work in pairs can be especially useful when the participants are children [12].

4.5.3 Focus Groups

The evaluation method focus groups is a moderated group discussion about a specific topic [74]. A group of 6-12 people discuss a topic for about two hours. The moderator leads the communication and encourages interactions and helps keeping the discussion on the selected topic. The method is called focus groups as it focuses on a specific topic and is limited to a given number of questions [74]. The conversation is very spontaneous and the questions are kept very open, so that the participants can interact naturally. The method can be used as exploratory focus groups, in which a design is evaluated and suggestions for improvement are made. It can also be used as confirmatory focus groups, in which a test of the design is carried out to establish the usefulness of the artefact [74].

4.6 Ideation Methods

Within the ideation phase, ideas for design problems are creatively developed [83]. Through applied design thinking, mental blocks can be released and creativity can be simplified [84].

4.6.1 Brainstorming

Brainstorming is a popular method to “generate, refine and develop ideas” [12, p.402]. The aim is to produce many ideas or different variants of them. One of the most important parts of brainstorming is that ideas should not be turned down or discussed during the session. Preece, Sharp, and Rogers gives suggestions for a successful brainstorming session, some examples are to bring participants with different experience into the session or to keep track of the ideas by numbering them. This makes it easier to discuss individual ideas later on [12].

4.6.2 Sketching

With the help of sketching, simple and quick freehand drawings can be created [12]. The focus is not on the quality of the drawing or details, but rather on the design concepts. Sketching helps to visualise and express ideas. It also serves as a communication tool between the team members, the designer and the artefact [83]. Through visualisation, it assists in understanding the design before proceeding to the next steps in the design process. The development of the sketches shows the history of the designer’s thoughts.

4.7 Prototyping Methods

Prototyping is the creation of artefacts with varying degrees of fidelity [76] for different purposes [12]. In fact, a prototype can be basically anything from a paper model and to a software [12]. The purpose of the prototype describes which kind of prototype to build. It is useful for example to test functionality, evaluate, user testing, discuss ideas or review criteria’s [12].

4.7.1 Low-fidelity Prototype

A low-fidelity prototype is not similar to the final product in the appearance or functionality [12]. This is only responsible for the representation of functions. The creation of the prototype is simple, cheap and quick [12]. In early phases such as ideation processes it is beneficial for testing ideas and receiving feedback for modifications [76]. Low-fidelity prototypes can be among others sketches, storyboards or paper models.

4.7.2 High-fidelity Prototype

The high-fidelity prototype includes more functionality and has a more realistic look and feel like the final product [76]. It will be required in the later phases such as evaluation. Therefore it is suitable to get feedback on functions, interactions and usability, as well as technical problems [12]. Another purpose can be to sell ideas to customers [12].

5
Planning

This chapter gives an overview of how this thesis project was carried out. Using a Gantt chart (see Figure 5.1) the overall plan was listed. In addition, a Kanban board was used to have a weekly planner with the most important tasks at the moment. The tasks were coloured green and red to indicate that they are done or not done and will be postponed to another day if necessary.

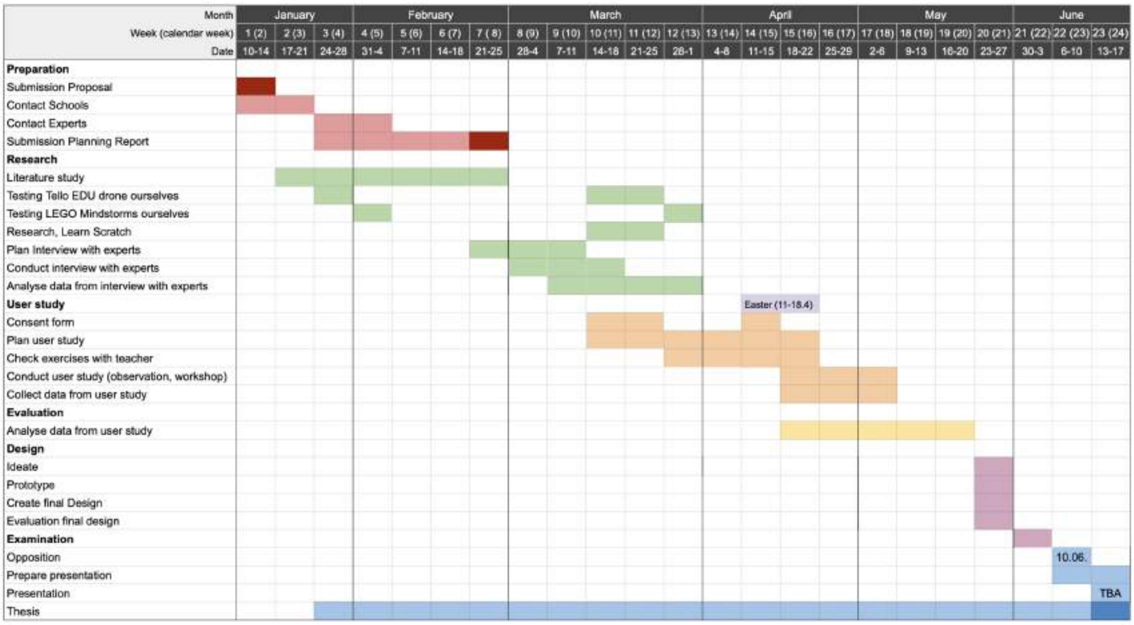


Figure 5.1: The Gantt chart displays the planning of the thesis.

5.1 Working process

The project started with a research phase, where a literature study within the HCI field, which include HRI, CRI, HDI, CDI and STEM education (specifically programming) was carried out. Existing tools for education like the *LEGO Mindstorms EV3* and the *Tello EDU* were tested in order to get inspiration on how to support children's learning in programming.
Interview with experts like teachers, that have experience of working in education and researchers, who have knowledge of robots and drones were conducted. Their knowledge in this area was very useful for the project. This gave a better insight

into how teachers educate children and work with drones in their lessons already today and helped to plan the ethnographic study at the school.
The ethnographic study was completed at an international school in Gothenburg, Sweden. The study consisted of observing how the teachers use robots in their programming education today and a following workshops with drones. For this the students collaborated in a group task by using the *Tello EDU* drone. To get a better understanding of how the children interacts with the drone, this session was video recorded. Data was mainly collected by taking notes and photos. The collected data was analysed using thematic analysis and affinity diagrams.
After analysing and identifying themes, a design was created. Ideation methods like sketching were used to create support material which could help teaching programming with drones. This was finalised in a high-fidelity prototype and evaluated.

5.2 Design Phases

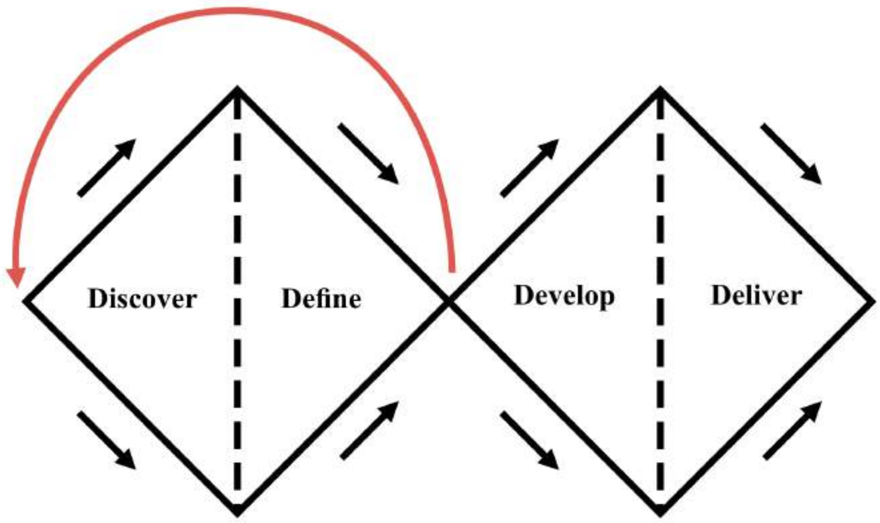


Figure 5.2: Our version of a Double Diamond Process

The Double Diamond is a framework used to inform the planning of design processes, created by the British design council in 2004 [85]. The original model consists of four phases: Discover, Define, Develop and Deliver. Discover is about divergent thinking, where the person using the model explores and tries to understand the design problem. In the Define phase, the person applies the knowledge gained from the previous phase to define the design problem. This is a convergent thinking phase. Develop is the second divergent phase, where seeking inspiration from other sources and people is encouraged. Examples of this can be to make scenarios, role playing of physical prototyping [85]. Deliver is the last phase in the model and the second convergent phase. At this stage, the person tests out different solutions, evaluates and receives feedback. The British design council encourages iteration and to test solutions at a smaller scale first, before creating final designs. The Double Diamond

model is not necessarily meant to be applied linearly and the designer can jump back to earlier stages in the design process when necessary.
In this thesis, the design phases are inspired by the Double Diamond but altered to fit the project schedule (see Figure 5.2). Due to the late placement of the ethnographic study in our schedule, more time is allocated to the divergent thinking phases. The second and third design phases could almost be viewed as iterating the discover phase, rather than going through the original define and develop phases.

5.3 Ethical Issues

When working with research participants ethical issues arises. But especially for children younger than the age of 15, who have a legal representative who makes decisions for them [86]. In addition, the study took place in a semi-public place where access and permission are required in advance [56]. The participants of the study have to agree to take part, so they have certain control over the research.

5.3.1 Consent

Before the study, it is necessary to obtain the informed consent of the research subjects involved [86]. The purpose of the consent is to protect the research participants and respect their right to self-determination [86], so it functions as an agreement between researcher and participants.
Consent must be recorded in a document that must be kept for the duration of the study. The document provided information regarding the project, like the purpose, the overall plan, the methods used, the consequences, and the risks [87]. Additionally information on the data protection and storage were provided. Thereby the document contained various check boxes asking for consent to participate in the ethnographic study, the workshop and the use of personal data for the study and research.
For the reason that the children are under 15 years old, their guardians must be asked for consent and to sign the form [86]. Nevertheless, the children are informed about the research and are allowed to cancel the participation themselves, even if their parents or other guardians allow them to participate.

5.3.2 Confidentiality

In terms of data protection, special care is taken to preserve the anonymity of individuals [56] as much as possible without compromising the purpose of the research [86]. Thus, real names are removed from the report or replaced by pseudonyms if they help to simplify the understanding of the text. This is to prevent individuals from being identified [56]. If photos are used in the final report, we were making sure that the child is not be recognisable on them. The face of the child is either not be visible in the photo or the face is pixelated. Videos or audio recordings are used only for transcribing and re-watching to be able to understand the children's interactions and problems with the drones.

5.3.3 Physical Dangers

The ethnographic study took place in a classroom environment together with the teacher that is responsible for the lecture usually scheduled at that time. Before the workshop, the safety guidelines from the *Tello EDU* drone [88] were shown within a presentation in advance. These include, for instance, be aware of your surroundings and people close to you, watch the drone while it's flying and not touching the drone when it's moving, etc.
To try out the drones within the workshop, it was made sure that it took place in a bigger room than their usual classroom. This way, the children were less distracted, do not be able to fly into objects unintentionally, and can ultimately be better able to focus on the drone. In addition, the groups were moved away from each other so that there is no risk of other classmates being too close and accidentally being hit by the drone. To ensure that the study is safe for the children, they were be equipped with aids such as cat nets, which can stop the drones in case something goes wrong.

6
Phase I: Research

The research consisted mainly of two parts, one initial literature review and interviews with experts doing research within child-robot interaction. The early research involved expanding knowledge related to holding workshops with children, cognition and social drones. Further into the literature review, it evolved into Child-Robot Interaction, social robots and conducting research that involves children.

6.1 Literature Review

To gain knowledge about the research area, a literature review was conducted. In the beginning, the focus was mainly on papers describing studies conducting workshops with children and pedagogical and cognitive papers, describing how children learn. Further into the literature review, it was narrowed down to Child-Robot Interaction. We mainly used the databases provided by Chalmers' library website. Sometimes we searched in the ACM and IEEE databases directly. These were the keywords searched for: children programming, STEM, educational robots, computational thinking, block programming, drone, HDI, HRI, ethnography and workshop. When the first part of the literature review was done, we had gain a foundation with general knowledge about our research area. One paper we took inspiration from was [8]. The children that participated in their study was a lot younger compared to the age group in ours, but it was still useful to read something on what had already been done in the Child-Drone Interaction area, with a focus on programming or computational thinking. In a lot of the papers on conducting workshops with children, the children were 10-12 years old and provided examples of how to conduct workshops in schools [89] [90] [59]. Tezza, Garcia, and Andujar states that "drones naturally spark students' interest, making it easier to engage them in the classroom". The authors mention software (for example block-programming) as a use case for drones in teaching. To help teachers use drones in the classroom, they created ten guidelines. These are quite general and seems to be possible to apply during different subjects, not specifically for programming.
The second part of the literature study was done to get more familiar with CRI (which CDI is a sub-field of) and to be prepared for the expert interviews.

6.2 Expert interviews

Five interviews were conducted for our thesis, four with experts from the field of CRI and one with two teachers from the IES Krokslätt, where our study took place (see list below for the experts). All the interviews were of a semi-structured format. The interviews with the researchers were conducted over *Zoom* [1] and lasted for 45-60 minutes. In the beginning of each interview the experts were asked for consent to record the interview and to use their data and answers with their name in this master thesis. The questions which were asked in the interviews can be seen in the Appendix A. Some of the questions were based on the researcher's papers other questions were more general, asking about the researcher's experience of doing studies with children. The interviews with the two teachers took place at the school and the purpose was to get insights on how the teachers worked with drones and general advice for us on how to work with children.

The experts which participated in the interviews are:

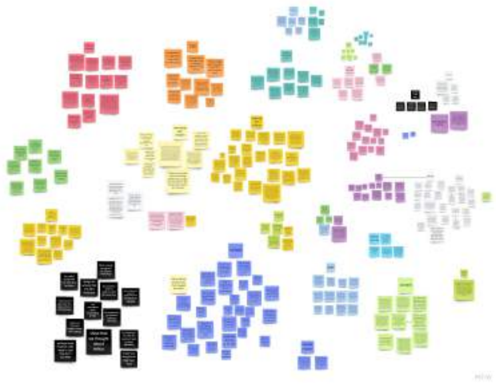
- Katie Winkle (Digital Futures Postdoctoral Research at KTH)
- Sofia Serholt (Senior Lecturer in Applied IT with specialisation in Educational Sciences at GU)
- Patricia Alves-Oliveira (Postdoctoral Research Associate at UW)
- Sara Ekström (University West: PhD candidate in informatics with specialization in WIL, teacher at Division of Educational Science and Languages and teacher at Division of Media Production)
- Manish Rauthan (Science Teacher at IES Krokslätt)
- Enas Ismail (Science Teacher at IES Krokslätt)

6.3 Analysis of expert interviews

A thematic analysis (see Subsection 4.4.2) was carried out by using the the software for qualitative data analysis *MAXQDA* [2]. The transcripts of the expert interviews were reviewed and important sections were marked by using colours and codes. This was followed by the creation of a code system. In the programme *Miro* [3], an affinity diagram (see Subsection 4.4.1) was created using post-it notes which summarises the results of the analysis.

Some findings from the interview analysis were used to plan the study in school. Other findings were derived as themes that were formulated into guidelines for the use of drones in education.

[1] https://zoom.us
[2] https://www.maxqda.com
[3] https://miro.com



(a) The initial affinity diagram.

(b) The findings from the expert interviews.

Figure 6.1: The created affinity diagrams for the expert interviews.

6.4 Results of experts interviews

After creating an affinity diagram with the interview data from the transcripts, eight themes were formed. The themes are dynamics, expectations, anthropomorphism, playfulness, safety, exploration, time and competence.

6.4.1 Dynamics

It is important to pay attention to the dynamics in the classroom. If the children will work in groups, it is good to place them with other students that will make the experience as good for them as possible. To obtain this in the study, the choice was made to let their teacher decide the groups. It is also important to think about the dynamics when designing and planning the exercises, to make it as inclusive as possible for every student. It can be helpful to teach a concept in multiple ways, to increase the likelihood that every student finds something interesting about the topic. It needs to be considered how the drones as well as other material are distributed among the students. “You have a classroom of people of participants and then you have maybe one, two drones. How would you distribute this among them so that it’s a fair, equitable, shared experience for all of them?” (P. Alves-Oliveira, personal communication, March 11, 2022).

There are also social and psychological risks that need to be addressed. Students should not feel left out, and it is important that every student gets to interact with the drone, instead of only a few. Another example of risks that could occur, would be if a child would not be able to do an exercise or control the drone the way they intended to. “Maybe someone’s not going to be able to control the drones, and that’s going to make them feel sort of, not very good about themselves.” (K. Winkle, personal communication, March 10, 2022).

6.4.2 Expectations

The expectations of the children will affect their reactions towards drones, for example if breakdowns happen while interacting with it (see section 2.3.1). “It is very easy for them to get frustrated. So you want to avoid that by setting expectations in the beginning” (P. Alves-Oliveira, personal communication, March 11, 2022). Therefore, it is essential to inform the children about our study and the reason we are there as researchers.

6.4.3 Anthropomorphism

In this context, by anthropomorphic we mean that the drone seems to have human-like abilities, such as seeing and feeling emotions, but does not have human-like appearance. Anthropomorphism can be seen as a “silent risk” because it has the possibility of changing our behaviour without even noticing it. As children are at risk of being more easily manipulated by an anthropomorphic system compared to a non-anthropomorphic one, it is important to reflect on the purpose of making a drone more anthropomorphic. In certain cases in which it is used for good reasons and is not intended to cause harm, adding human-like features to the drone might be useful to improve the experience for the children. One problem with anthropomorphism is, that it is somewhat deceptive, but it can also increase the fun of the playing. To make it less deceptive, it can be a good idea to show the children more thoroughly how the drone is built and how it works.

6.4.4 Playfulness

Kids learn and communicate by playing and telling stories. To make the activity more fun and interesting for them, the activities and evaluations must be designed in a playful way. Another advice is to stay open to whatever the children seem to like and find interesting during this study and adapt the activity to that. “Unique to children are exactly their communication abilities. And if we look at them, they are just playing, they play wherever they go, they can play outdoors, they can play indoors, they can play anywhere. That’s how they express, that’s how they talk.” (P. Alves-Oliveira, personal communication, March 11, 2022).

6.4.5 Safety

In terms of safety, the experience with the drones needs to be made safe for the children so that nobody gets hurt. When working with children and drones, many different risks arise, such as psychological, social (see Subsection 6.4.1), physical, ethical and emotional risk.
“It’s hard to escape the physical risks with drones” (K. Winkle, personal communication, March 10, 2022). A physical risk can be for example long hair from girls can get stuck in the propellers, so they should tie their hair back during the workshop. The children need to receive safety instructions to ensure that their behaviour is correct and very clear guidelines which they can follow. To this extent the drones should only be used in an open space where no obstacles are around and enough

space is given such as a gym hall. The drones are very frail, can crash into the walls and fall apart or might destroy the propellers, in that case extra propellers need to be present. A way of identifying potential accidents can be to think “what would it look like if that did go wrong?” (K. Winkle, personal communication, March 10, 2022) and try it out in a previous testing.
Children do know a lot about technology and have concerns like surveillance. For example, children can say “someone could hack in and watch me through the camera”(K. Winkle, personal communication, March 10, 2022) of the drone.
There are also emotional risks, that children are more “emotionally connected to the robot” and “build up a friendship with the system” (K. Winkle, personal communication, March 10, 2022) and can therefore be upset.

6.4.6 Exploration

Children naturally like to discover new things. It is likely that it is what they are going to do with the drones, exploring the technology and the limits of it. “Even if you give them a task, like fly the drone up and down, they will fly it all around, because they want to know the limits. [...] They are explorers, that’s what they do.” (P. Alves-Oliveira, personal communication, March 11, 2022). For example, they will check how fast the drone can fly or how high it can go, or to land it on an object. “Even if it’s negative exploratory behaviour, you can transform that in a good narrative” (P. Alves-Oliveira, personal communication, March 11, 2022). Children might be more interested in a drone race than in programming. During the workshop it will be ensured that the children can explore the drones, but in a safe way.

6.4.7 Time

Time is a challenging factor when working with drones and robots in a classroom. Teachers usually do not have that much time, which can make it hard for them to familiarise themselves with the new technologies, which takes time. “It’s also problematic because the teachers don’t have time” (S. Ekström, personal communication, March 15, 2022). During the lesson teachers also do not have the time to interact with the technology together with the children. Another challenge is that batteries for the drone do not last long, which generally only makes it possible to plan short activities with drones.

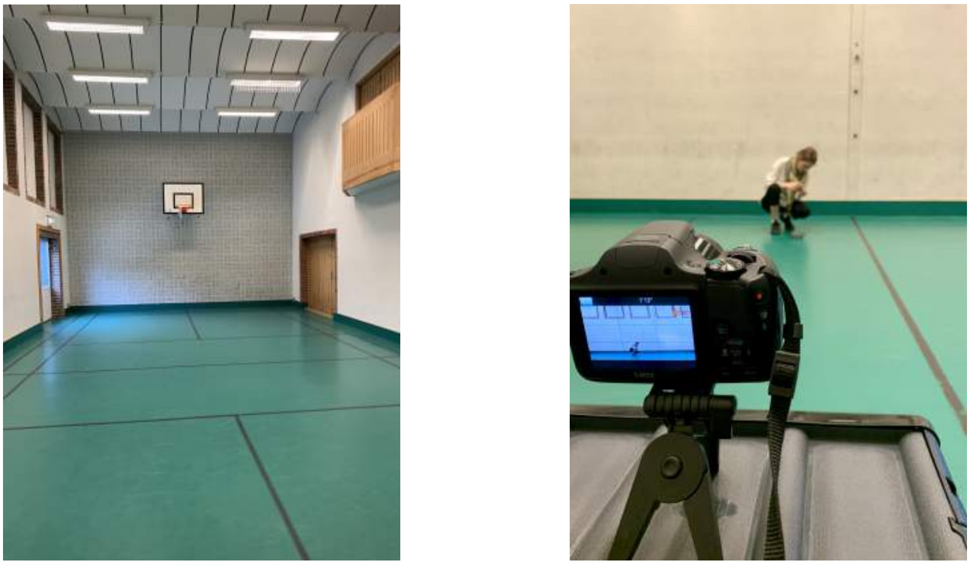
6.4.8 Competence

Sometimes teachers say that they do not know enough about robots to use them for teaching programming. Generally, this seems to be a greater issue with social robots (for example robotic tutors) than with regular programmable robots. In the case of the social robots, it could sometimes be difficult to understand why the robot behaved the way it did. “they don’t really know how its programmed, so you don’t know how to interact with it ”(S. Ekström, personal communication, March 15, 2022). Some teachers found it hard to know how to integrate social robots into the classroom. When the robots do not perform as expected, the teachers are not sure of the cause. For example, “when the robots don’t listen to the children, they don’t know if it’s because it’s a technical breakdown, or if the child is too far away, or because the other children are talking too much” (S. Ekström, personal communication, March 15, 2022). As stated earlier, this seems to mainly be a problem with social robots. When it comes to robots used for teaching programming, teachers could be concerned of how to use them during their lessons at first, but it generally works to use them in education.

7

Phase II: Familiarisation of technology

In this section we describe the familiarisation of technology phase of our study where we tested the technology to be used in subsequent phases. Before doing the study with children, the *Tello EDU* drone, *LEGO Mindstorms*, *Scratch* and *DroneBlocks* were tried out to better understand how they work. The testing took place in a gym hall (see Figure 7.1a), to make sure we would have a lot of space and without any obstacles. The majority of the interactions were video recorded (see Figure 7.1b) to be analysed at a later stage. Notes and photos were taken during the tests, as well as screen captures of the different interfaces used.

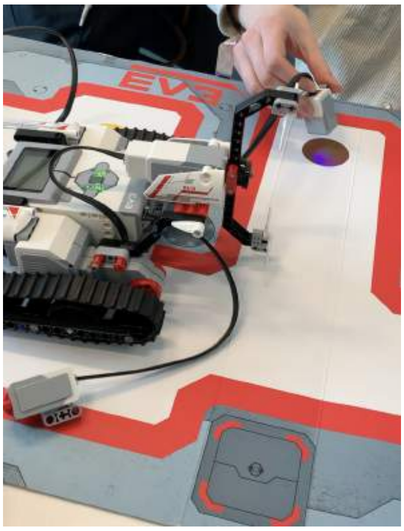


(a) Location for testing the drone. **(b)** Recording the testing.

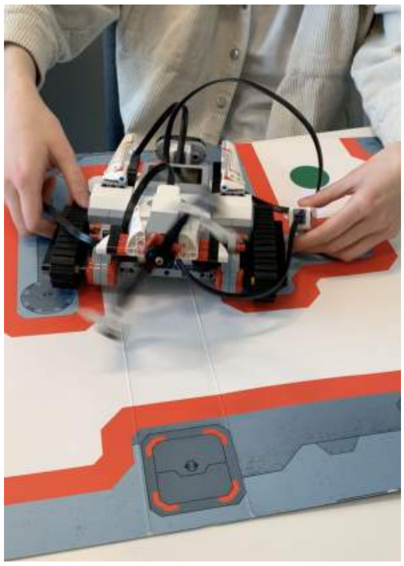
Figure 7.1: Setting of testing the drone.

7.1 LEGO Mindstorms

A programmable robot specially designed to be used in education was tested. The intention was to gain knowledge about it, to be able to compare it with an educational drone. Among the five different robots that can be built with *LEGO Mindstorms*, the Tracker was chosen. Unlike the other robots, the step-by-step instructions (see Figure 3.2a) for the Tracker were included in the packaging and the others were only available online. Following the instructions, the robot was built with the individual LEGO bricks. The *EV3 classroom* programme was downloaded and installed. A simple introduction to the programme guided through different areas (see Figure 3.3). Different sensors such as the colour and touch were tried out. The package contained a map with different colours dots on it, which can be used to test if the colour sensor recognises the colours when it is hold over different colours and react to it (see Figure 7.2b). The touch sensor gives feedback to the robot to do a certain movement when it has been touched (see Figure 7.2a).



(a) Testing the colour sensor.



(b) Testing the touch sensor.

Figure 7.2: Testing the LEGO Mindstorms robot.

7.2 Tello EDU Drone

Before conducting the ethnographic study, the drone that would be used during the workshops was tested to get to know how it works and the functionality of it. Another reason was that we wanted to learn how to program the drone ourselves using block programming, in order to know what the children would be doing. In addition, the aim was to find out how children might interact with the drones, what functions they would test and what potential problems might exist. To do this, we tried to view the testing through the eyes of the children by trying out things we suspect they would do, such as making the drone move with fast speed or do loops. We also wanted to see which programming environment would be suitable for the children and to be able to understand how it worked with drones.
Initially a list was made with different actions to be checked. These included testing the different flight modes, speed mode and camera mode. The drone was tested using the *Tello* app with the smartphone (see Figure 7.3a), tablet and controller (see Figure 7.3c), which required a smartphone. The different flight modes that were tried out were Bounce Mode, 8D Flips, Throw & Go, Using 360, Using Circle, Using Up & Away. In Bounce Mode the drone flies up and down between 0.5m

and 1.2m above the surface it started from. 8D Flips automatically flips the drone in one of eight directions, chosen by the user. The drone can start when being thrown in the air with the Throw & Go mode. Using 360, the drone records a video as it rotates 360 degrees, and Using Circle records a video as the drone flies in a circle. A video is recorded with Using Up & Away where the drone goes upward and backward. The two speed modes slow and fast have been tested, whereas the default speed is slow and the faster speed can be changed in the menu. We also found out what would happen if the drone hit a wall or the battery would run out. Moreover, it was explored whether the drone could detect a hand below, next to or above (see Figure 7.3b). For the study catnets were provided for emergency cases to catch the drone and stop it before an accident or crash would happen. The catnets were tested, one time hanging in the middle of the gym hall, like a separation barrier (see Figure 7.3d), which the drone slowly flew into. The drone flew forward until it hit the net and when trying to control the drone, it did not react. After some time, the drone landed. The second test was to throw the net over the flying drone to catch it before it flew into something. The drone stopped immediately and did not get any damage, which means it worked better to throw the net than to hang it.

(a) Test the Tello App with the phone.

(b) Holding a hand underneath the drone.

(c) Test the Tello App with the controller.

(d) The catnet

Figure 7.3: Testing the Tello EDU drone in the gym hall.

7.2.1 Scratch

Before using *Scratch* the program *Scratch 2*, *Scratch Desktop* and *Node* needed to be downloaded. First, the drone must be switched on and connected to the drone's WiFi on the computer. In order to connect the drone to *Scratch*, node terminal needs to be started and node Tello.js files can be opened. Then *Scratch Desktop* can be started where the Tello extension can be installed. After this the drone is connected and the code functions are embedded in the program. The code can now be written. The Tello functions must be linked to actions to control the drone using certain keys on the keyboard. The drone can then be started by clicking the green flag. In *Scratch* different movements like up, down, left and right were carried out. The battery status can be seen in *Scratch* by adding a code function.

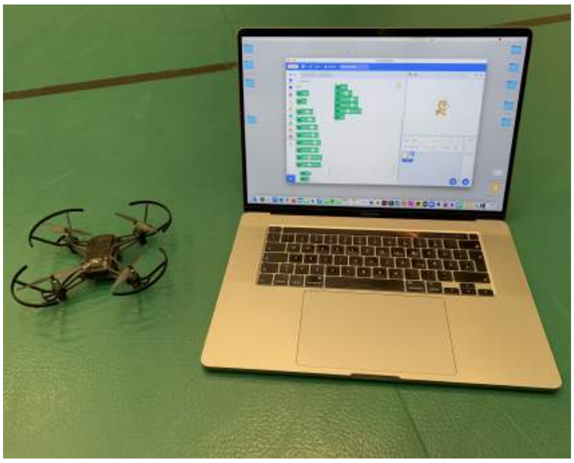


Figure 7.4: Test the Scratch interface with the Tello EDU drone.

7.3 Analysis of technology

This section contains a compilation of experiences obtained by testing the *LEGO Mindstorms EVE 3* and *Tello EDU* drone. It describes both advantages with the products but also issues encountered during the testing sessions.
The recordings from the testing were reviewed, transcribed and discussed. We compiled a set of themes and problems encountered during the testing. We took inspiration of thematic analysis, but did not do it as thorough as the thematic analysis we would do for the ethnographic study data. Since our study are related to drones, this is where the focus was. The testing of the robot was more about to get familiar with the differences between using robots to drones.

7.3.1 LEGO Mindstorms

After analysing the insights from using the *LEGO Mindstorms* three main themes were found out. These themes were building, software and potential risks. Difficulties have arisen during construction or dismantling. By using the software for robots, it was beneficial to find differences to the programming environment of drones, which could be implemented. This also prepared us for the potential risks of using robots and the possible problems that could occur during the observation.

Building

Building as well as disassembling the robot took longer time than expected and sometimes more difficult because of the small LEGO bricks. An advantage was that it was not necessary to build a completely finished robot in order to programme it. It was difficult to open the screw on the remote control to insert the batteries, therefore it was not tested. This could be problematic for children to open without the help of an adult. It was not obvious how to turn the robot off again.

Software

The software had an easy to understand guide through all of the programming steps, even though it was harder in the beginning. After the first exercises it was easy to program the robot. When the robot was about to start execute the code, it made a noise to let the user now it was about to start.

Potential risks

The robot reacts directly and moves very quickly. Therefore it can be easy to hurt yourself, by for example staying to close to the robot and touch the rotating or moving parts of it. Sometimes cables were getting in the way of the robot so that it stopped moving or turning until the cable was moved away, whereby the fingers should be moved away from the robot very quickly as it moves again immediately. Even if the injuries are not serious, it is important to be careful when using it. It is necessary to be aware of what inputs (cm, degrees) are given in the code, because the robot might move faster than expected depending on which units are used. On the other hand, the robot will barely move if the input is too low.

7.3.2 Tello EDU Drone

Through the use of the *Tello EDU* drone we identified five themes: software issues, potential risks, unclear problems, design factors and way of controlling the drone. The main focus was to understand what potential risks could arise in order to avoid them during the workshops. It was also important to find out what questions and problems were encountered during usage, so that we could understand when the children would have similar issues. Figuring out which problems that are associated with the programming environments was useful in order to better explain them to the children. A few design factors and control of the drone could help guide the children in the use of the drone.

Software issues

In *Scratch* the drone could do simple movements such as take off, forward, backward, left, right, rotate and land. It was not possible to do flips or to change the speed. The possibility existed to display the battery status of the drone in the interface, which was selected by clicking on a checkbox. However, this was not shown very obviously and could be difficult to find for children. It would be more helpful, if it was already integrated in the interface. After the drone hit a wall or the catnet, it could no longer take off. This appeared to be a *Scratch* problem as it stopped responding and had to be restarted. This required restarting node.js, *Scratch Desktop* and adding the extension. Restarting *Scratch* was therefore very time consuming. In addition, it was very easy to forget to restart everything and only restarting *Scratch* made the drone not take off either. It was not visible when the code was executed or for what reason it could not be executed, as no feedback was given in the program.

Potential risks

A majority of the crashes seemed to be due to not recognising how the drone was positioned which made the drone go in the opposite direction of what was expected. For example, the drone faced the other side and suddenly go backwards instead of forward and hit a wall. Sometimes you could already see that the drone was going to crash into the wall, but it was too late to react and you could not get it to stop. We realised that we often tried to talk to the drone and shouted for it to stop or fly in a different direction, but of course the drone did not react to that. It is possible that the children would react similarly and are not able to react quickly enough to prevent crashes.
The drone did not indicate if an obstacle was close to it and for example did not detect the hand at the sides or above the drone. But on the other hand the drone could detect the hand underneath and automatically moved up and a little bit sideways. Children are likely to test this out, which is a potential hazard as the drone moves away without knowing which way it is moving or not recognising the hand.
When programming the drone in *Scratch* it took some time to perform the next step, during that time the user could press a button for another instruction. What could happen is that the children try to make the drone do a movement several times, thinking that it is not reacting, which could lead to the drone making this movement more times than planned and possibly end up somewhere else than intended.
During the testing we were surprised how fast the drone moved towards us and we always jumped away. We had the same reaction when we launched the drone, we always took a step back. We also noticed that the fast speed is extremely fast. For the workshop, we need to make sure that the children have a lot of space so that they do not accidentally fall over something if they step back too far.

Unclear problems

There were uncertainty as to why the drone did not work in some cases. It could have been because of wrong code, no connection or low battery. We noticed that we were quickly annoyed and confused by this as we did not know what the problem was. When the drone flew higher, it could no longer turn and got stuck, so it had to land, which took some time.
We did not understand how much battery the drone required to take off. In some cases it functioned with only a few remaining percent, in others it stopped at 30%.

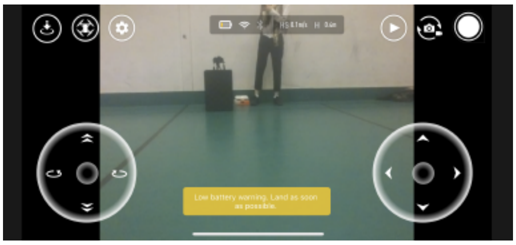
It was impossible to predict when the drone would stop because of low battery. The battery ran out quickly, which could cause difficulties during the workshop and requires more batteries to be available.
During the tests we used two drones and two computers. Therefore, two drones were switched on at the same time and it became unclear to which WiFi which drone was connected. This could cause a problem with more drones in the classroom and it should definitely be explicitly indicated which drone has which WiFi.
Initially, it was not clear how the docking station worked. We were thinking that all three batteries were charged at the same time, so we took batteries out without knowing they were not even charged. After a while we realised that the batteries were charged one by one and that the remaining ones were put in a queue. The first battery was charged and marked with a blinking green light and the others were orange. By the time the first battery was charged, the light turned into solid green and the lights that belonged to the next one started blinking green.

Design factors

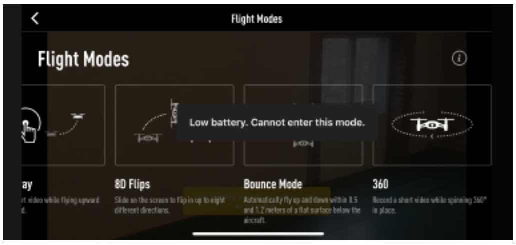
The button that turns the drone on and off was not very easy to find at first. It was also difficult to press because it was placed on a small surface between the propellers. This could be more visible, for example, differentiated from the rest of the design of the drone, using a different colour or material. Children might also not be able to find it easily. In addition, the colours of the drone were sometimes incomprehensible and had to be looked up, but in the meantime the colour had changed again. One observation was that the light on the drone turns purple when the drone is connected to the computer, which is helpful to know to ensure that the drone is connected.

Way of controlling the drone

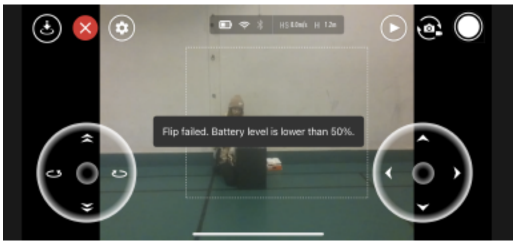
After testing to control the drone using the tablet, smartphone and the controlling connected to the *Tello EDU* app and the programming tools *Scratch* and *DroneBlocks* it was discovered which was easy or difficult to use. It was a bit difficult to control the drone with the tablet, since the screen was too big whereas the smartphone size was closer to a physical controller like in gaming. Controlling the drone with a phone or tablet required watching more on the interface to understand the lever instead of watching the drone flying. The two levers were sometimes frustrating to use and hard to navigate with. While using it we often forgot which direction or side the drone was moving towards. Therefore the drone crashed into walls more often, compared to the other alternatives. After using it another time it became easier, since we were a bit more used to it. Using the *Tello EDU* app we also spend more time looking down at the phone since the interface had a short introduction for each mode and for settings. For example, to change from slow to fast speed it was required to use a slider. On the one hand it is not possible to accidentally switch to high speed, on the other hand it is more difficult to switch back to slow speed. Something that would have been useful to have in the interface, would be some kind of emergency stop where the drone immediately stops moving or lands. That the user had to look down on the controller, was mainly a problem with the tablet and smartphone controls. The *Tello* app displayed a pop-up message when the battery was low and that the drone can not perform a certain mode or movement (see Figure 7.5).



(a) Tello app displays low battery.



(b) Tello app displays mode not working.



(c) Tello app displays flip failed.

Figure 7.5: The Tello app displaying error messages due to low battery.

With the physical control and the keyboard when programming this was not really a problem, since we did not need to look down as much. Using the controller it was easier to control the drone and to understand the directions since it felt more natural and reminded us of playing video games. In addition it was more fun because the drone moved more smoothly and we could watch it while it was flying, without having to look down on the controller.
In contrast, it was much easier to control the drone from the computer. In *Scratch*, different keys on the keyboard could be linked to codes. This way, the drone performed certain movements when a key was pressed. When no new instructions were pressed, the drone remained in the same position and was very stable. This allows you to think about the next move and focus more on the drone. However, it took some time until the next execution was carried out. However, in *Scratch* only simple movements such as forward, backward, sideways, rotation, up and down can be performed.

7.4 Learning's from the technology

Getting familiar with the technology which would be used during the ethnographic study was helpful to get prepared for the study. *Scratch* did not seem to be very suitable to use for drones in education since it was relatively complicated to connect, get started and also due to the software breakdowns. The first safety rules for the workshop were derived as having enough space (since we think it is common to take a step back when the drone starts), checking the battery status to know if everything is possible to execute and to throw a catnet on the drone if something would go wrong. Batteries run out quickly, so extra batteries and charging stations must be available.

8

Phase III: Ethnographic study

This chapter covers the ethnographic study in the school. This includes the planning of the ethnographic study, observation during science lessons (where the children programmed different robots), creating exercises for the workshop, the workshop with drones, analysing data from the ethnographic study and iterating on themes based on the data.

8.1 Plan for ethnographic study

To plan the ethnographic study we prepared by reading papers on ethnography, especially regarding methods for the observation and ethics [56].
We decided to start by observing science lessons to gain better knowledge on how teachers currently include drones in their lessons. The intention was to discover how children interact with drones in a programming context, which interactions are easy or difficult, how they react while using the drones etc. The aim was to get insights on how drones for children in education can be better designed. The observation helped to understand the whole experience, such as the learning environment, the dynamics between students and teacher and to see how children learn. Another purpose was to determine how much experience the students already had in block-based programming in order to estimate which activities might be too easy or too difficult for them. These results were used to adapt subsequent activities to their level of experience.
After the initial observations, we conducted and observed a workshop more specific to our research questions, involving programming of drones. The aim of the workshop was to evaluate existing drones for education and for the children to try out the drones in a fun programming experience. The focus was on how the interaction looked like, for example difficulties the children had when interacting with the drones but also what they found exciting about them. Moreover, to see how children react when they write code that will make the drone fly, or how they react when the drone does not launch. As well as seeing the reaction if the children would crash or destroy the drone. These results are intended to improve the design of drones and support material for education.
For the ethnographic study, information sheets and consent forms (see Appendix B) were used to inform about the purpose of the study and to get the participants' approval to take part in the study. It was also used for getting consent to use the photos and data about the participant in this master thesis report. The information sheets and consent forms came in two versions, one aimed for the children and one

for their guardians. Both versions were sent to the children and the parents to sign, before the study took place.

8.2 Conducting observation

The study was carried out within three weeks in the science lessons of two classes in year 6 of the International English School in Gothenburg. There were 16 students in each of the classes as it is the normal curriculum for science classes. The student were in the age range of 11-13 years. In the beginning of the first lesson we were introduced to the children. We introduced ourselves briefly, with our names, where we come from, which languages we speak as well as which subject and university we study. Following that, we explained the reason for our participation and what we were planning to do. This was explained as our final project to become engineers and attend lessons to understand how they learn in their science classes and what they do in terms of drone robots. After this, we informed them that we would be sitting at the end of the classroom taking notes and if necessary helping out and being available for questions. In this observation we took over the role as observer.

Figure 8.1: The science classroom where the observation took place.

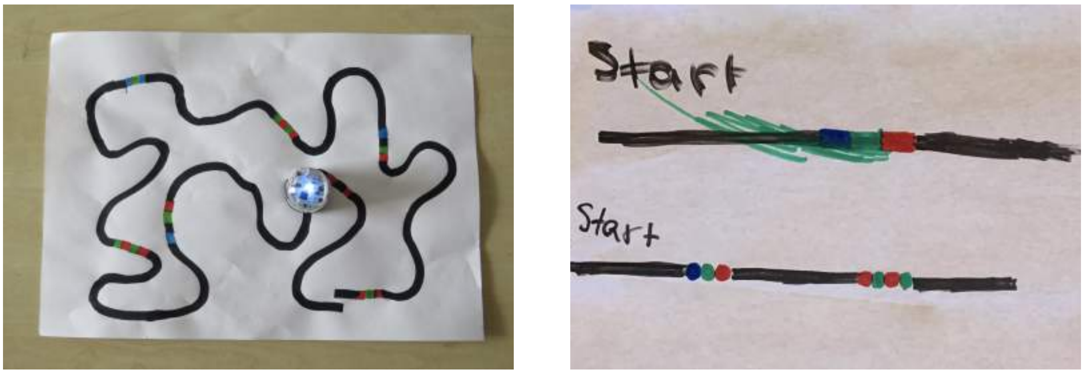
In the first two weeks, two science lessons of 90 minutes in each class were observed. The lessons covered the programming of two different robots, *Ozobot* (see Figure 3.4a) and *Codey Rocky* (see Figure 3.4b). Observation was carried out by both of us sitting in the back of the classroom behind the children, listening and observing. Data was collected from notes and photographs. The notes were made in notebooks including quotes from children and the teacher, the children's behaviour and interactions with the robots. At the beginning of the class, we quickly sketched a seating plan and wrote down each child with a "C" and a number. This helped us to write down notes and quotes about the children more quickly during the observation and to keep an overview. After a while, some of the children did not notice us any more. While the children were working on their tasks, we also walked around and had a closer look at what they were doing and asked them what they were currently trying out. Photos were taken before and after the lesson when the children were not present. The photos were more a snapshot of the environment as it looks before and after the technology have been integrated into the lesson. Moreover we took photos of the classroom and materials which were used, such as robots, worksheets and children's drawings.

8.2.1 Lesson 1: Colour Coding

The lessons started in the morning, as the first class in their schedule. The first class was complete with 16 students, but one student was missing from the second class, so they were only 15. The first lesson focused on colour coding with the robot *Ozobot* (for a description of *Ozobot* see Subsection 3.2.1). Within a brief introduction by the teacher the class was asked what they knew beforehand about programming and what programming can be used for. The teacher also asked what programming languages they already knew of and what they thought about programming. Following these questions a video to the topic *What is programming?* was presented.
Afterwards, it was explained what an algorithm is, using examples that children can understand, such as the preparation of a sandwich or the daily routine of a person. These examples were presented as code sequences. To integrate the class, a question was asked about their daily routine, such as when they eat breakfast. To conclude, the students were asked who had already used *Scratch*, out of 32 students in the two classes, 31 had used it.
The *Ozobot Bit* was introduced in two videos and the instructions on how to use it were explained by the teacher. The robot has a sensor which detects different colours and can follow coloured lines. Before using the robot, it needs to be calibrated on a black dot. For drawing a track for the *Ozobot* to follow, a black pen, different coloured pens and white paper are needed. A black pen was used to draw lines, and coloured pens to draw small dots or squares as colour codes. If the line is too thin a second line can be drawn next to the other without a gap. The drawings should have a clear beginning and end. The robot could use the track from both directions, however the codes would have a changed order and execute a different action. Different colour combinations represent different colour codes which indicate to the robot, for instance, to speed up or slow down. On a whiteboard, the teacher demonstrated an example for the children. In order to start the robot the button need to be pressed one time, otherwise it turns off again.
The children are divided into groups of two and each group received one robot, coloured pencils and white paper. The color codes were looked up online [1]. In the first lesson the task was to draw their initials as a track with five different color codes which the robot should follow. After completing this task, students could draw a new track of their choice (see Figure 8.2a).
Since the students did draw lines with different thickness. the robot could not detect all tracks which made the children frustrated. In the figure the first line cannot be detected by the robot, because the line was too thick, but the second line was working (see Figure 8.2b). For the robot to move on the line, the letters needed to be drawn more round without sharp edges and have some kind of connection between the letters. After that lesson the teacher adapted the task for the next lesson, due to the reason that it took the students more time drawing the tracks

[1] https://files.ozobot.com/stem-education/ozobot-color-codes.pdf

then trying out the robots.



(a) Children draw their own track. **(b)** Examples of lines.

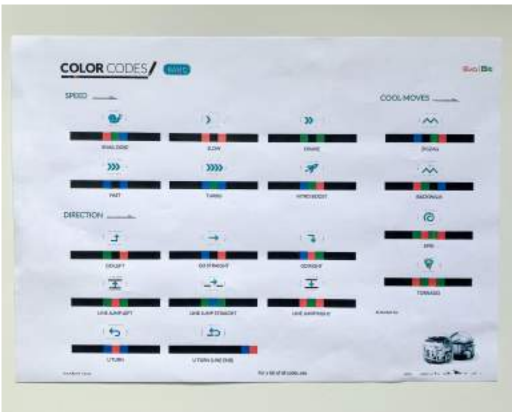
Figure 8.2: Children's drawings for color coding the Ozobot.

The next class received two worksheets and an information sheet for the colour codes (see Figure 8.3a). One task was to insert any colour codes into a finished track with gaps (see Figure 8.3b). Another task was a bowling alley where the colour codes were missing. Bowling figures were distributed, which the robot had to bowl over (see Figure 8.3c).

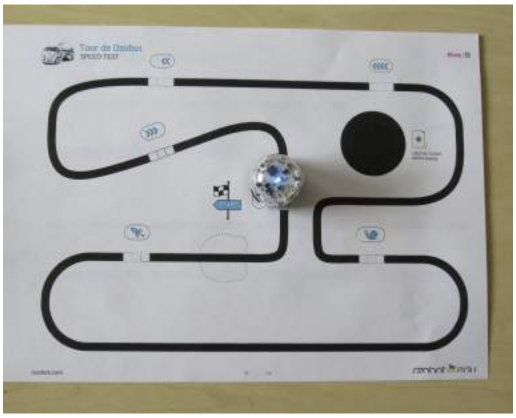
8.2.2 Lesson 2: Block programming

The second lesson was about testing the robot *Codey Rocky* (see Subsection 3.2.1) and working in the programming environment *mBlock*. At the beginning of the lesson, the teacher briefly repeated what programming is, what it can be used for and why one needs programming. This time the groups of two students were chosen randomly. On the projector the screen of the teacher was presented, showing how to find the software and how to download it. The tool which was used was *mBlock*. The children were instructed to find the website and open the tool, while the teacher waited until everyone was ready. Many students had problems doing this and needed help from the teacher or asked questions. An alternative to this programme was shown, *Mlink* [2], which works as a Chrome extension and does not require a download. In the software the robot which will be used needed to be selected first.
When all the students had opened their programme, an explanation of the actual task was given by the teacher. The students are supposed to code the robot *Codey Rocky* and let it dance to a music of their choice for 30-60 seconds. Each group received one robot and one cable to connect it to their Chromebooks. First, the code for the robot had to be written. The robot had three buttons which can be programmed so that the robot executes certain instructions when they are clicked. The teacher gave the instruction that one button needs to be programmed as a stop. In addition, the robot has a display that can be designed with pixel drawings, which can be used to add emotions to the robots' movements. After that, the robot was connected to the computer with the cable to receive the code. The robot has a body

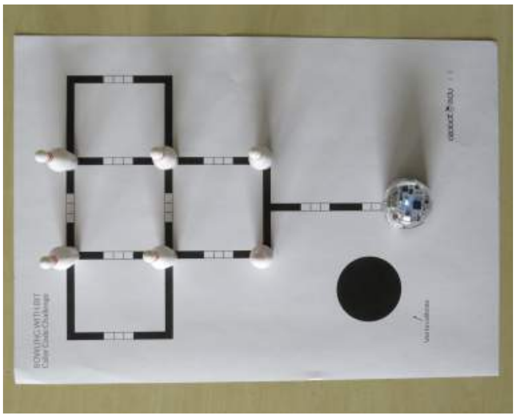
[2] https://chrome.google.com/webstore/detail/mlink/jmmkbcfakiendpnceenfanaebjenjene



(a) The Colour Codes



(b) The Track exercise



(c) The Bowling exercise.

Figure 8.3: The Worksheets which were used to test the Ozobot.

with wheels and a separate display which can be connected or removed (see Figure 8.4). For testing the robot, the cable had to be removed again. This revealed a few difficulties, such as connection errors, broken cables or plugs. Some children could not decide or find a suitable song, so the teacher showed them examples.

Figure 8.4: The Codey Rocky with the plug and the cable.

Most of the students programmed at their desks and then moved to the floor to have more space for testing the robot. Some of them tested the robot on the table, but since the table was too small, the robots fell off several times. After some time, the robots drove further distances under the desks and around the classroom, to the extent that the children were also allowed to go out into the corridor for more experimentation.
At the end of the first lesson, two groups showed their dance performance with the robot to their music. Everyone stood up and watched with excitement. In the second class, the teacher encouraged the children to go through an obstacle course at the end of the lesson. Plastic cups were used as a track. The task was to drive the robot inside the cups without touching them, at the end of the track was a pyramid of cups that had to be pushed over by the robot. A number of children were very motivated and excited, so they quickly tried to write a suitable code for it. In the end, two children tried to drive the robot in the track while the rest watched in anticipation.

8.3 Planning of workshop

After getting advice from the teachers and expert interviews, an initial workshop was planned. This plan was changed after getting insights into science education from the observations and figuring out that a different exercise would work better. To this end, we worked on how to divide up the 90 minutes of a lesson. We brainstormed how a lesson is structured, which parts are needed and how long each of them takes. The different parts of the lesson were introduction, coding, presentation and feedback. In addition, it was considered which exercises could be used for programming the drone and was tried out, which is explained in the following text. An evaluation method was thought of as well. The workshop plan as well as the the exercises, tools, materials and presentations to be used for this purpose were discussed with the teacher in advance and adapted if necessary.

8.3.1 Create Exercise

The initial idea of an exercise was to do an obstacle course with the drone in the gym hall (see Figure 8.5). The idea was to combine something fun with programming, that they perhaps do not usually do. The children had to figure out, like a puzzle with a time limit, which way or code would work best to fly through the obstacle course. The idea behind this was that the children can solve the obstacle course in different ways without having only one correct solution. But in case children get stuck and struggle with the task an example code could be provided. For this we thought that the kids would be inspired to work together as they could discuss their ideas. One example of obstacle course was tried out to see how we were imagining it and if it actually works. To test it, one of us built the course, while the other one programmed a code in 10 minutes which made the drone fly through the obstacle course and presented the result afterwards. For the workshop the idea was to have a warm-up with some general questions about the drones, such as *What do you think a drone can be used for?* Following this was thought of having a short introduction on drones and programming them, explanation of the task, 15 min of programming time, results shown each one by one and in the end evaluation. However, it was already known that this plan would be adapted after the observation. Therefore, no proper obstacle course and an example code were created.

Figure 8.5: The obstacle course which was tried out in the planning exercise session.

After the observations we talked with the teacher about the exercises the children were doing with the robots again and brainstormed about which task worked out well and which ones the children seemed to enjoy the most. Then we compared it to our initial exercise idea for the workshop. Through observation, we discovered that the children were more motivated and explorative when they were allowed to try out their ideas as opposed to doing predetermined tasks where they tended to be bored or stopped working quicker. Based on the study by Alves-Oliveira et al., the use of robots in the classroom encourages children's creativity towards unconventional thinking in STEM [92]. Children require space to explore their creative potential [92]. Furthermore, playing is an important part of the child's development, which is referred to as open-ended exploration involving the children's spontaneous exploration [26]. This should be included in the workshop activity.

For this reason the decision was made together with the teacher to have a choreography as the exercise during the workshop instead. Each group could explore the programming environment and try out different movements of the drone as they want to. The task was to create a maximum two minutes performance with the drone. We noticed in the observation that the children had difficulties finding songs and preferred to programme the robot rather than choose songs. For this reason, the decision whether to use a song to their performance was left to them. The initial idea was to use *Scratch* as work environment since the children used *Scratch* for a few years already. During the familiarisation of the technology, we found out that it was very complicated and time-consuming to connect *Scratch* to the *Tello EDU* drone. Moreover, the teacher told us that they are using *DroneBlocks* since it was easier to use. For this reason, we decided together with the teacher to use *DroneBlocks* as a programming tool instead of *Scratch*. Compared to this, *DroneBlocks* only has two settings for connecting the drone, which seems to be more child-friendly.

8.3.2 DroneBlocks

In order to be prepared to use *DroneBlocks* (see Subsection 3.6.2) as a programming environment for the workshops, we tested the programming environment with the drones. *DroneBlocks* has a similar interface to *Scratch*, but even more simplified. The first step is to connect the drone to the computer via WiFi. Afterwards the *Tello* drone can be easily connected to *DroneBlocks* by clicking one button in the upper navigation bar. There is also the option to choose which drone to use, *Tello/ Tello EDU* or *Tello Talent*. *DroneBlocks* offers different functions in the vertical navigation bar as takeoff, navigation, flip, loops, logic, maths, variables, functions and land. The movements which were tried out were take off, fly (forward, backward, left, right, up, down), yaw (right, left), flip (forward, backward, left, right) and land. Units can be selected between in and cm. The horizontal navigation bar gives information about the battery, attitude, ToF distance, Pitch, Roll and Yaw. In the software the code is placed in a sequence which the drone will follow. When code is written the drone can be started by clicking on the toggle menu icon and launching mission. While the drone is executing the code, it can be watched without having the need to look at the computer. During the execution of the code, a red button abort mission is displayed in the middle of the interface to stop it. In addition, an overlay of the code indicates which part is currently being executed. This way of controlling and interacting feels the safest and easiest for working with children. In addition it allows for controlling the drone with the keyboard, the same way a jump-and-run game is played on the keyboard. Children probably would enjoy this and could experiment more.

8.4 Conducting Workshop

The third lesson focused on the programming of the *Tello* drone. Within a workshop the children got the opportunity to take part in a motivating learning experience. The workshop was structured in four main parts: introduction, programming, presentation and evaluation.

8.4.1 Part 1: Introduction

Initially, the children were given a brief 20 minute introduction to the topic of drones in the science classroom. For this introduction a presentation was shown, with a short video [3] of 45 seconds about the *Tello EDU* drone. It explained the different usages such as block programming in *Scratch*, different movements like flying up, rotating, flipping, intermediate programming with swift, swarm flying with multiple drones, and advanced programming with Python.
Following this, the children were informed about the safety guidelines and rules (see Figure 8.6a) which they had to follow during the workshop to prevent them from hurting themselves or someone else. The six safety guidelines were (1) to stay away from rotating propellers and motors, (2) watch the drone at all times, (3) land the drone when a low battery warning is displayed, (4) don't fly too close to yourself,

[3] https://www.youtube.com/watch?v=Ma5XgFe9SSQ

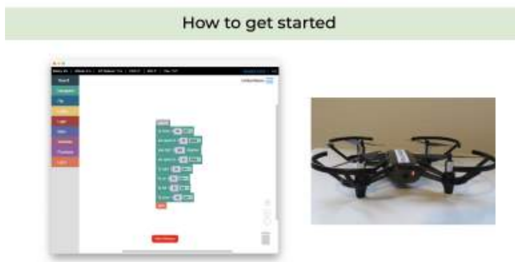
your classmates and other drones, (5) remember that it takes some time for the drone to react and (6) only fly the drone in open spaces. In addition, students with long hair were advised to tie their hair back in a braid so that it would not get caught in the propeller. Hair ties were offered in case they did not have any with them.

Afterwards the actual task of the workshop was presented. The students had to work in groups and design a choreography to be performed by the drone. Those who wanted could use a song as a background for the drone to perform to. The exercise was programmed in *DroneBlocks*. At the end of the lesson, the aim was to watch the performance of each group.

The teacher introduced the drone which would be used. He demonstrated how to switch on the drone, how it lights up and how it is connected to the computer. For that purpose, the teacher showed his screen on the projector so that the children could follow along in the process. First he connected the drone to the WiFi. After this, he asked the children to open their Chromebooks and, following him step by step, to open the programme. To do this, they searched for *DroneBlocks* on the internet and opened it as a Chrome Extension. There he showed which button to click to connect the drone. As a quick example, the teacher created a code, with three lines of code, and showed how the drone executes it.

Afterwards, the remaining part of the presentation was shown. One more time, the steps how to connect the drone to the programme and how to runt the code were shown as screenshots. At the end, an example code with corresponding video was shown (see Figure 8.6b). In this video, the drone performs to the song “Turkish March” by Beethoven. Lastly, the teacher announced the group constellations of one to three students, which were divided beforehand with the help of the teacher.

(a) The Safety Rules



(b) The Example Code

Figure 8.6: The Presentation slides which were displayed in the beginning of the workshop.

8.4.2 Part 2: Programming

For the second part of the workshop, everyone left the room and took their Chromebooks and drones and walked to the gym hall (see Figure 8.7a). The initial plan was to hold the workshop in the gym hall on both days, but due to scheduling conflict the second workshop was held in the dining hall (see Figure 8.7b). Compared to the regular classroom, the dining hall offers more space, so all the students could spread out and have a larger area in which they could fly the drone. Beforehand, the gym hall was divided into six sections using cones. The dining hall was not divided up, as the tables were arranged in rows, each group was assigned one row of tables. The children were asked to sit down for a short introduction before the programming session started.

(a) The gym hall

(b) The dining hall

Figure 8.7: The two locations where the workshops took place.

The teacher repeated the task and the amount of time they had for it. In addition, the children were made aware that each group has its own section in the gym hall, which should not be crossed, so that accidents are prevented. The teacher assigns the individual groups to different sections. Everyone received a drone and charging cable. This session was recorded on video. The two cameras used were Canon Powershot SX 540 HS and GoPro hero4. In the first class, one group did not want to be recorded, so they were placed in a corner of the room to ensure that they were not included in the recordings. In the other class, all the groups were recorded. The cameras were placed to record one to three groups at the same time. The cameras were placed further away from the children so that they did not feel observed or were distracted by the camera.

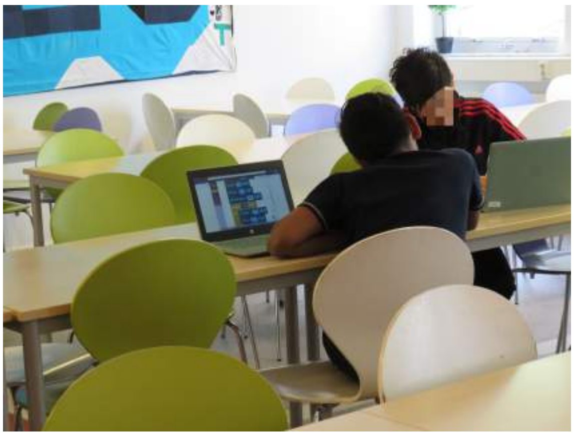
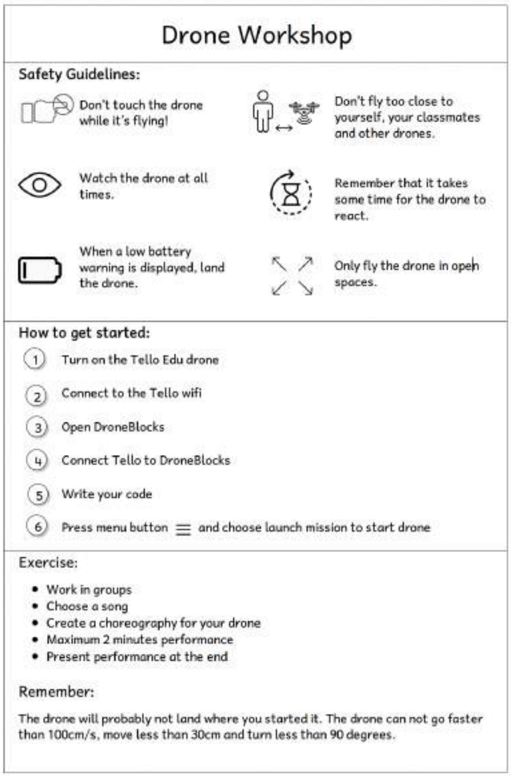


Figure 8.8: The children programming the Tello EDU drone with DroneBlocks.

To ensure that the children remember the task, the safety guidelines and how to connect the drone and the task was summarised on a worksheet (see Figure 8.9). The worksheet was created in Worksheet Crafter [4] using a basic school font and layout designed for education. The worksheet was handed out to each student. The groups had 40 min time to be completed the exercise.



Drone Workshop

Safety Guidelines:

- Don't touch the drone while it's flying!
- Don't fly too close to yourself, your classmates and other drones.
- Watch the drone at all times.
- Remember that it takes some time for the drone to react.
- When a low battery warning is displayed, land the drone.
- Only fly the drone in open spaces.

How to get started:

1. Turn on the Tello Edu drone
2. Connect to the Tello wifi
3. Open DroneBlocks
4. Connect Tello to DroneBlocks
5. Write your code
6. Press menu button ≡ and choose launch mission to start drone

Exercise:

- Work in groups
- Choose a song
- Create a choreography for your drone
- Maximum 2 minutes performance
- Present performance at the end

Remember:

The drone will probably not land where you started it. The drone can not go faster than 100cm/s, move less than 30cm and turn less than 90 degrees.

Figure 8.9: The worksheet used for the workshop.

8.4.3 Part 3: Presentation

Towards the end of the lesson, the groups showed their performances. In one class all groups presented, in the other because of time constraints only those who wanted to. The performances were also recorded, except for the group who did not want to be filmed. The teacher provided a drone which had not been used before so that it still had battery left. The class was sitting on the bench in the gym hall or at the tables in the dining hall while the group that presented went to the centre. The teacher helped them connecting the drone to the Chromebook and *DroneBlocks*. The drone was placed in front of them and the class. Most of the groups presented without music, but three groups had music.

8.4.4 Part 4: Evaluation

This was followed by a ten min feedback session. While the children were either waiting for the teacher to fix connection problems or charging the drones, the children

[4] https://getschoolcraft.com/en/

filled out the evaluation paper. This was conducted to understand the children's opinions and thoughts during the workshop. For the reason that conventional methods such as interviews and questionnaires are more difficult to conduct with children, coloured papers were used on which children wrote their opinion about programming drones. In the first workshop, the children were simply told what topics they should write their opinions on. However, many children kept asking what they should write. So the second workshop was changed and the children were also given small pieces of paper with two questions (see Figure 8.10) they should answer. These questions were:

- What was fun/ not fun today? Why?
- What did/ did not work with the drones? Why?

Figure 8.10: The questions and papers distributed for the feedback session.

8.5 Analysis of ethnographic study

All gathered data from the ethnographic study were used for the analysis. The notes from observation were rewritten in a digital document. The discussion recordings we did to talk about what happened during the lessons were transcribed and read through. The video recordings from the workshops were watched by focusing mainly on the interaction between the children and the drones, what their face and body reactions were towards drones. In addition we looked at the dynamics of the groups, how they worked together, how they worked on the task, which roles in the group they took on. The evaluation papers from the children were written digitally in Miro. All these notes were merged to one big document, to allow an better overview.
A thematic analysis was conducted with this gathered data. Reading through the

data again codes were inductively created. These codes were marked in the text in colour and displayed in a list of all codes. Afterwards, we went through the text again and checked whether other codes had to be added that were missing. After going through the six steps of thematic analysis (see Section 4.4.2) a first version of themes was formed.

The two research questions "What should be considered when designing drones for programming education for children in the classroom?" and "What support material for child-drone interaction should be designed to better support teaching programming?" were revisited, to see if the themes are answering them. Our first set of themes were relatively technical and did not focus as much on the drone design for children in education or on possible problems where support can be useful. The codes were sorted relation based (focusing on who did what) rather than activity based (in which context the children did something). This made us to review our data and create an affinity diagram of all created codes, to bring out new connections and categorise them. This lead us to generating some additional themes. To create the affinity diagrams, we used Miro. Following this we formulated titles and descriptions for these new themes.

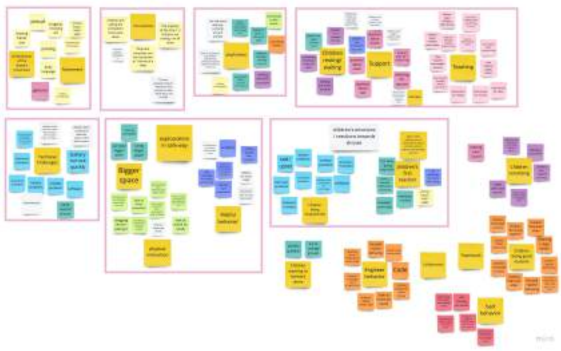


Figure 8.11: Affinity diagram ethnographic study. This image gives an overview of the method applied.

8.6 Results of ethnographic study

Below are the results obtained after analysing the data from the ethnographic study. These results helped to form the basis for the design considerations and support material presented in the result chapter.

8.6.1 Results from observation

These are the results of our observations during the lessons before the workshops. These did not include any drones, only the programmable robots *Ozobot* and *Codey Rocky*. The four themes of results include (1) technical challenges, (2) lesson adaption, (3) anthropomorphism and (4) explorative behaviour.

Technical challenges

Using the robots in science lesson some technical issues were faced. First children had problems with understanding the software which was used as programming environment. When children opened the tool, the default language was sometimes Chinese and not clear enough for the children to understand where to change this setting. In addition the correct robot needed to be selected, but sometimes children accidentally chosen the wrong ones, which changed the features. Therefore children often asked the teacher for help and are needed to wait more often until he could help them. It seemed that the children were bored then, since they could not continue working with the robot and did nothing else while waiting for the teacher. In the meantime the children started more often talking to other children or distracted them.

While using the robots in school children try the robot immediately without understanding that they need to move the robot to the floor, since the table is too small for the robot to move a lot. This leads to robot falling off the table relatively often. When the children let the robot run and it hits an object and can't get away, they put it somewhere else, or they kick it to the side with their foot. The problem is that the robots are not sturdy enough and can break easily.

The *Codey Rocky* requires to connect to the computer by cable in order to send the code to the robot. The children often forgot the order of what had to be done first, whether writing code or connecting robots, so that the robot did not work. Other times, they wanted to test the robot as quickly as possible and pulled out the cable rapidly. Because of this, the next time the robot was connected, connection problems occurred because the robot was not disconnected properly and the plugs and cables broke very quickly. The robots are intended to be used for education and children, and have a cute look and can be programmed with a child friendly programming language but are not really designed or build accordingly for them.

Lesson adaption

Using robots in education the lesson needs to be adapted since the robots are not always functioning as expected or children have unexpected problems with these. During the observation the initial plan of the lesson was changed after the first class. The idea was to draw their initials and own track which the *Ozobot* should follow. However, the children draw inaccurately so that the robot cannot recognise the lines through the sensors and either stopped or went the wrong way, which frustrated the children. Apart from that, the children ended up taking more time drawing the track than for using the robot. Consequently, the lesson for the next class was adjusted using worksheets instead of drawing tracks. For the worksheets, the children only had to draw the colour codes and thus had the opportunity to solve more different exercises, as these were quicker. Another observation was that it was easier for the children to work together when they did not have to share materials, otherwise they argued and fight to much about it. In the first class, the children had to share a robot and pens in pairs, whereas in the other lesson, every child received a robot and pens to work better.

Anthropomorphism

Many times it was seen that children pretended that the robot has feelings and they respond to them. For example, they petted the robot or gave it a kiss when it fell off the table. In other cases, they claimed the robot was angry or threw pens at them. We never observed this behaviour towards the drones.

Explorative behaviour

An important take-away was that the activities need to take into account the children's creativity as well as their individual interests and motivations and allow room for exploration. For example, some children used bigger paper (A3) to draw bigger tracks. Other children went into the corridor to be able to drive a longer distance with the robot. The children made an effort by designing facial expressions for the *Codey Rocky* to match the code.

8.6.2 Results from workshop

To derive the themes based on our data, we had to iterate and go back to the data multiple times. Affinity diagrams were created by moving around post-it notes in Miro, trying to discover patterns that we might have missed the first time. These were among the first set of themes that were created. In the result chapter, the final themes can be reviewed. The seven themes described below are (1) embodiment of the drone's movement, (2) inclusiveness, (3) playfulness, (4) technical challenges, (5) support, (6) physical interaction and (7) children's reactions towards the drones.

Embodiment of the drone's movement

The children did different kinds of movements to show how they wanted or expected the drone to move. Sometimes they did it to show other children what they meant or for themselves. The most common movements involved hand or arm gestures, for example moving their arm and pointing to different directions where they wanted the drone to go. To show when the drone would do a flip, it was common to make a loop, either by pointing one finger (like they were drawing in the air with that finger) or using the whole hand. It was also relatively common to rotate the hand, making a shape that they were pretending to hold the drone and turn it. Another form of movement was to use the whole body to show where the drone should go, for example showing by taking steps (and thereby show the exact path of the drone) and jumping, doing a pirouette or pretend that they were about to do a flip themselves to show where they wanted the drone to flip. It seemed to be more common to use their whole body when they were using the drone in a more open place and discussing where the drone should fly, compared to the smaller arm movements that were made when the children worked by the tables or did a movement by themselves.

Inclusiveness

When working together with the drone only one computer could be connected to the drone. This made the children take away the computers from each other. Sometimes only one child at the time could code and try their code out while the others were watching. To learn programming it is important that everyone is included and is coding.

Playfulness

Throughout the ethnographic study, we observed that the children often were jumping, dancing, walking around and playing with different objects (for example a swing in the gym hall). Children express their ideas through walking the choreography instead of writing it down. It also helps children who need to move a lot and cannot sit still for too long. Children enjoy playing video games with controllers and created a code which allows them to control the drone from the laptop.

Technical challenges

Some things that led to the children becoming frustrated was that the battery time ran out very fast, that it was hard for them to correctly connect the drone by themselves. Children and the teacher did not understand the problem when the drones were not working as expected, for example not starting or not doing flips. Something that could help would be, if the software (for example *DroneBlocks*) were communicating why the drone would not do something. For example, the drone will not execute certain parts of the code because the battery is too low, or if it's a syntactic error etc. Children did not understand what the different colours of the drone meant, so this information was not helpful but rather confusing. Also the colours changed too quickly to actually recognise it. Children were for example unsure if the drone was charging or not. It is important to have the right amount of cables and batteries for activities with drones in schools. Since the battery time is low, it puts a big responsibility on the children to turn the drone off when not flying it. If the battery time was longer, it would allow the children to explore more and hopefully learn more with the drone. Since batteries are relatively expensive and a school would need many batteries to successfully do an activity with drones, it makes it less accessible for all schools to use.

Support

We observed that a lot of the time, the children did not take time to try to solve a problem themselves, most often they shouted for the teacher for help. One issue was that the teacher cannot help every student at the same time. This leads to the students needing to wait longer to get help so they get bored, tired and stopped working. Something that might help the children is some additional support material, which can guide and encourage them to figure out their problems and questions. Lessons might be needed to adapt if the drones are not functioning as expected. The distributed material should not be limited and be divided fairly.

Physical interaction

A lot of different ways of picking up or touching the drone were observed. Some examples of these are carefully moving the drone by pinching it with a few fingers, moving it with the foot and holding the drone in their palm. We could observe that children are trying out the limits of the drone and exploring in a potentially riskful way. Children tried to start the drone from different places like their body, the floor or tried to land on their body, on chairs. After seeing that the drone moved away when holding the hand underneath, the children tried to make the drone move by putting the hand on the sides of the drone. Since the drone doesn't have sensors at the side and cannot detect the hand, it can be a potential risk.

Children's reactions towards the drones

Once the drone started, the most common reactions among the children were cheering, smiling and moving away from the drone. It was also relatively common for the children to say something a long the lines of "Look!" to other children or the teacher. After a while those first emotions started to wear off and the children either generally behaved more focused on the task or switched to talking to their classmates. In general, the children frowned more when technical problems appeared rather than showing emotions like smiling. The children were also looking for the teacher, waiting, and resting their heads on their hands. The most common technical failure was that the drone did not perform all the steps in the code due to low battery. When the drone did not work as expected the children often explained to the teacher that it worked before. The children generally did not understand why the drone could not perform the steps in the code, especially if the drone had successfully done it before. This was most apparent with the "flip" movement, which we could see in almost every evaluation from the children: a lot of the children (look up exact amount) thought the flips was the most fun thing about the drone, while the most boring thing was when the drone did not do what they expected from it (mostly different kinds of flips). As the battery started to get low, flips were the first things that did not work. That could be the reason that flips were mentioned so often. A lot of the time the drone could still do regular movements such as moving forward or backward. This is also related to setting correct expectations. During the first class we did not tell the children to turn off the drone when they were not using it, to the same extent that we did in the second class. The first class seemed more disappointed than the second class.

Explorative behaviour

In *DroneBlocks*, the user can program the drone using block-programming, but the drone can also be controlled from the software using the keyboard of the computer. This was nothing we told the children about, but one group managed to figure this out and tried it once. This was seen through the workshop recordings. One child seemed to have the hands on the keyboard of the Chromebook while the drone was moving. The drone moved in a way that it must be controlled by the keyboard and not programmed, since it moved much faster, without waiting for commands. When the drone received commands from *DroneBlocks*, it was relatively slow and it took some time for the drone to receive a new instruction and to perform it. It was not possible for the drone to turn as quickly as it did in the video, if it was programmed using *DroneBlocks*. However, this was something the group only tried out for a while. The remaining time of the workshop and when performing their choreography they programmed the drone.

9

Phase IV: Design of Support Material

In this chapter, the design process for the support material is presented, from ideation and prototyping to evaluation. The final design of the support material can be viewed in the next chapter.

9.1 Ideation

During the ethnographic study we discovered that the teachers had no need for support in the form of support material since they had good support materials already. However, the children can require additional help as the teacher cannot assist them at all times.

Since the children had the same questions and problems more often the topics which should be included in the support material are given. These topics were connection issues, battery issues, question regarding the drone and the software, safety instructions, and example codes. In the workshops, we were able to see how the children's code was developed and could estimated what level of difficulty they had. Based on this, we came up with example codes.

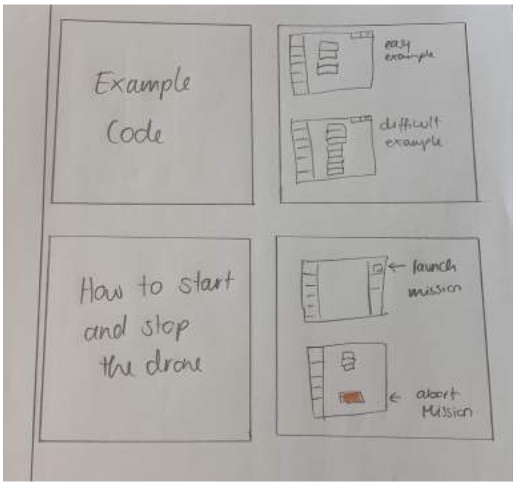
While programming the drone, the children had the *DroneBlocks* interface opened on their computer. For this reason a digital support material would not be ideal since they have to switch back and forth between these two applications. Using a physical material allows the students to see the problem and the explanation at the same time. In addition, a tangible interface would support collaborative learning with a classmate [93]. The support materials can be designed to provide the opportunity for a shared space for collaborative activities, allowing students to interact with each other more easily than with a digital version on the computer [93]. For this reason the decision was made to do an physical support material.

9.1.1 Brainstorming

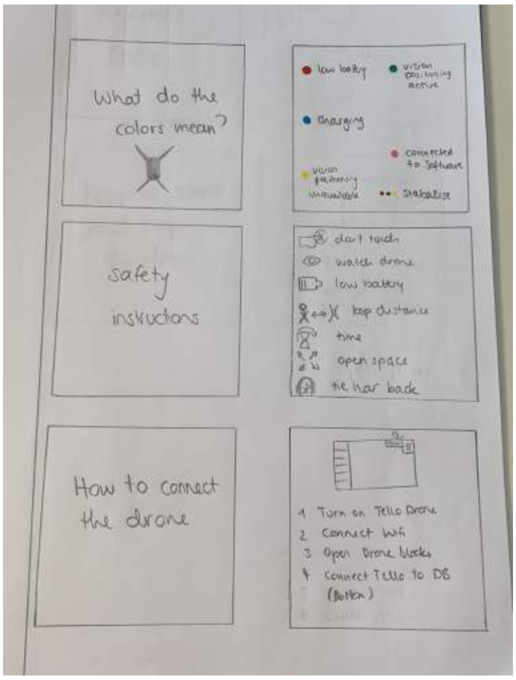
In a brainstorming session, possible ideas for supporting materials were considered and listed on a whiteboard. Some ideas we came up with at the beginning of the project were an application or a small booklet. These were discussed again and quickly decided that they would not be suitable. The most appropriate idea was to create advice cards which can help the children while programming the drone.

9.1.2 Sketching

These first ideas were quickly sketched with a pencil on white paper. We thought about the questions children often asked and how we did answer them during the workshop. From that, the first five ideas of cards (see Figure 9.1) were sketched. Each card has a question or title on the front and a explanation or example on the back side. These include an example code for the drone, process of starting or stopping the drone, the information on what the individual colours indicate, safety rules while working with drones in school and the process of connecting the drone to the software.



(a) The first two ideas



(b) Additional ideas

Figure 9.1: Initial sketches of the support material.

9.2 Prototyping

During the prototyping stage the layout of the advice cards were defined. The cards should be in the size of A6 like regular flash cards. The layout of the cards should be simple and clean, in order to not overwhelm children. In the workshop we noticed that the worksheets for the children had too much content on one single page. It varied a lot, some of them read the sheet quite careful, others looked at it shortly. This is why we think that if the cards are reduced to the most important facts, they can help the children more quickly. While the workshop was going on, some of the children took the worksheet again and read through some parts of it again (see

Figure 9.2). One reason for this could be that they have forgotten how to connect the drone, what safety rules they should pay attention to or to review the task. Exactly this kind of information would be provided by the advice cards.

Figure 9.2: Children reading worksheet during the workshop.

In the low and high-fidelity prototype the tool *Figma* [1] was used. During the design process, more ideas for different cards appeared which covered other questions or problems. The content of the cards were based on the data from the ethnographic study.

9.2.1 Low-fidelity prototype

The sketches were subsequently designed more clearly in the tool *Figma*. Using a simple standard font in black and minimal details, the first rough content and layout ideas were created as a wireframe. To illustrate the security guidelines, icons that were found online were used to see if they supported the content. Screenshots of the interface of *DroneBlocks* was used to explain different steps in the program like how to connect, start or stop the drone. Two different versions in portrait and landscape format were created (see Figure 9.3). This version was to see if the layout, font size and amount of information per card was accurate. Following this, it was decided which design would be more appropriate as a tool. The choice was made for the landscape design, as the information is larger, a small margin remains where the children can hold the cards and the cards are more similar to the usual flashcards.

9.2.2 High-fidelity prototype

From the wireframes a nicer version was created with in total 13 advice cards. Adding a school and child-friendly font already helped to change the layout and to make it look more as support material for education. For this version, own icons (see Figure 9.4a) were created using the tool *Affinity Designer* [2]. The icons were mainly used to support the text of the security guidelines. In addition, arrows were created to point out certain buttons in the software screenshots. A drawing of the drone was created to show which colour of the drone is referred to.

[1]https://www.figma.com/ui-design-tool/

[2]https://affinity.serif.com/en-gb/

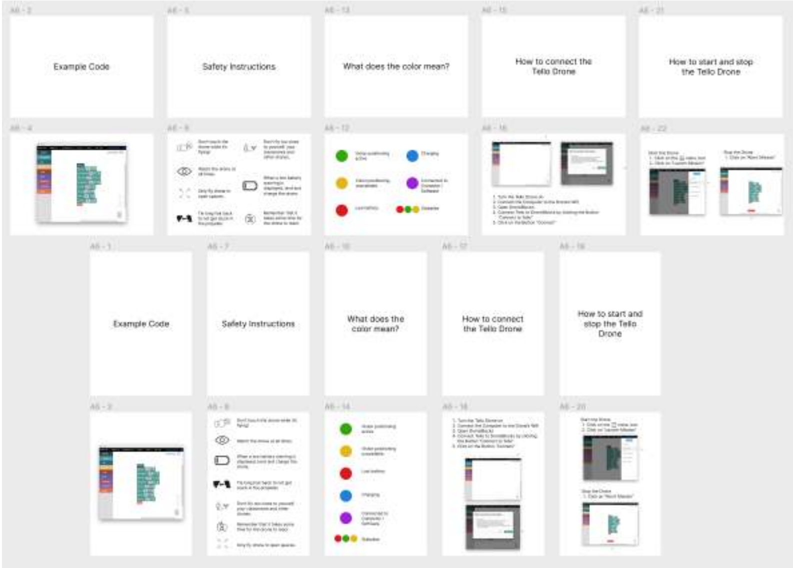


Figure 9.3: Two versions of wireframes (landscape & portrait)

9.3 Evaluation

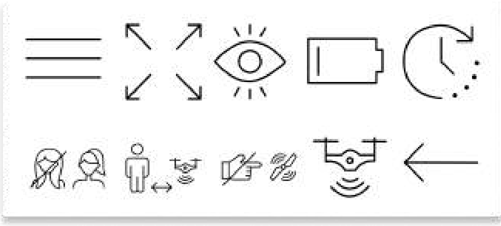
For evaluating the support material design two teachers were asked to look at the design and give feedback. The first evaluation was more focused on the design of the cards, while the second one was more related to the drone related content.

9.3.1 Evaluation on advice cards as support material

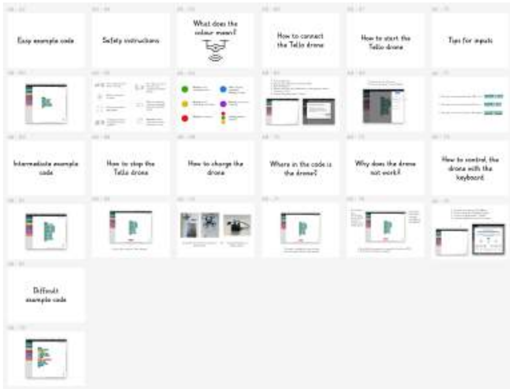
Based on the Heuristic evaluation method (see Section 4.5.1) the first evaluation was carried out with a teacher. This teacher did not work at the school where the study took place, but she is creating her own supporting material which was of interest. The session was held over *Zoom* and recorded. The digital version in *Figma* and the physical cards were presented to the evaluator. Initially the evaluator could freely look at the design. Following this, questions were asked and in the end the teacher had the possibility to give extra feedback and suggestions on improvement. Predefined questions on the topics of quality of content, potential effectiveness as a teaching-learning tool and easy of use were selected (see Appendix C). After the evaluation session, the recording was transcribed. In the following, the answers are summarised with quotes.

The learning materials seem to be suitable for children due to it's design, focus on the main content and concise questions and answers. The learning objective to provide tips about the drone are recognisable. The learning materials are user-friendly since they offer visual presentation of photos and screenshots that underline the text. Instead of using a lot of visuals or heavy design, the learning materials are reduced to the essential.

> *"Yes, it is suitable for children because it is very descriptive, simply visualised, very clearly structured and only the most important or only*



(a) Icons created for the prototype.



(b) The digital version in Figma

(c) The printed version

Figure 9.4: The High-fidelity prototype

> *the central contents aligned with the topic are visualised."*

The learning materials support the children in their learning process and can therefore be a good opportunity for task-based learning. With their various degrees of difficulty, the material offers the possibility to respond to the individual prerequisites of each student.

> *"So yes, you have differentiated it threefold, for example, by having different difficulties, levels or codes. You can then respond to the individual requirements of the students. You can look at how weak or strong the children are and respond to the corresponding teaching and learning goals of the children."*

The cards allow the children to solve a problem or question they have, either independently or together with a classmate, without the help from their teacher. By using tip cards, the children work more independently compared to if they would just ask the teacher for help.

> *"So we call them advice cards, which the children can get on their own to work independently, but also cooperatively with their partner. So they work in pairs and the teacher functions as a cooperative learning facil-*

> *itator. In other words, these are cooperative forms of learning. At that moment, the teacher only acts as a learning guide, so to say and accompanies the learning process of the students. In this way, the children work independently on their projects and use the advice cards to help themselves. This is called an autonomous or self-determined learning process, which is also relevant for later professional life."*

Similar teaching materials, such as these advice cards, are also used by the teacher in lessons. These were used to help students who have problems solving the task on their own without showing the result. The cards are not distributed to each pair but placed in the classroom so that everyone has access to them and they have to be shared.

> *"I have, for example, advice cards that are differentiated so that students who have problems solving the task independently can get tips and suggestions from. Although they are not given the solution, they are given help, so to speak, on how they can work further in order to continue their learning process independently. And of course it has to be practised to use such materials with children. But if you point out that the cards can help them, they actually use them. With some I have three to four cards, but I usually only have two to three of them. They have to take turns. Apart from that, not all the children look at the same card at the same time, so they have to be patient."*

9.3.2 Evaluation on the content related to the Tello EDU drone

For the second evaluation, another teacher was asked to give some feedback and advice on our support material design with a larger focus on the content related to the drone. This teacher was from the school where the workshops were carried out. For this evaluation an interview was conducted. Since it was in the school's corridor, the interview was not recorded, only written down. The form chosen for the interview was semi-structured, to provide the possibility to ask more questions, for example when the teacher suggested improvements. The teacher looked through all advice cards one by one and gave feedback on each card, e.g. whether something would work good or if something else could be added.

Generally the teacher thought it is a good idea to make cards with the most common questions about the drone the children had. In addition, he thought almost all of the important questions asked by children are covered.

> *"Looks good! Answer almost all the questions (the children had)."*

The teacher mention some improvements which could be added to the support material. For the how to stop the drone advice card it can be good to say also, that the land command is necessary to have in the code.

> *"You could have that it's compulsory to have this command" (points at*

> *start and land drone command).*

On the tips for inputs card it can be added, that the default unit is inches, which can be changed to centimetre, since children do not understand inches.

> *"There are in inches and they (the children) can not relate to these metrics."*

Another safety instruction to only fly the drone indoor, since it is a indoor drone can be included on the safety instructions card.

> *"You could add to the safety, to only fly the drones indoors, not outside"*

For connecting the drone it is important to understand what happens when the drone is actually connected. So another step on the list can be mentioned, as once the drone is connected you can see the details of the drone (how high the drone is, how far away it is, battery, etc.) in the navbar. So the children know these information before starting the drone.

> *"Yes but also, you probably could write what would happen. Especially focus on battery"*

On the three Example codes, How to charge the drone, Where in the code is the drone, Why does the drone not work? advice cards the teacher had no more improvements.

To the question "How could you use this support material in class?" the teacher said he would also make such cards and make a set of cards which would be held together with a rubber band and distributed to each pair.

> *"I would make these cards. I would make sets of it. I would put them in different order: safety, checking the drone etc. Then go step by steps. Each group would have one set. If you can't find your question, then you can come to me."*

10

Results

This chapter shows the results of this master thesis. These are based on the findings of the ethnographic study. The results are presented in the form of design considerations and an example as support material for education. In this chapter the results are described in two sections, one for each research question:

> *RQ1: "What should be considered when designing drones for programming education for children in the classroom?"*
>
> *RQ2:"What support material for child-drone interaction should be designed to better support teaching programming?"*

10.1 Research Question 1

Several aspects need to be considered when designing drones for education. Since there has not been much previous work on drones for education, the design considerations have been broader. Apart from the use and programming, the school environment and the behaviour of the children have to be taken into account. The design considerations are intended to make programming more engaging for the children.

This part answers the first research question in the form of design considerations designing drones for programming in education:

> *"What should be considered when designing drones for programming education for children in the classroom?"*

These design considerations were formed after conducting a thematic analysis and an affinity diagram, using the data from the ethnographic study. Out of this, six design considerations were created: (1) Design for safety, (2) Minimise the impact of short battery life, (3) Consider communication between user and drone, (4) Consider the possibility of a collaboration programming tool, (5) Consider design for safe touch interaction for children and drones and (6) Capitalise on advantages of gesture based interactions.

In the following, the design considerations are explained with quotations and pictures from the ethnographic study. In the descriptions and quotes the children are presented as “C” with a different number attached to it for each child. Teacher is shortened to “T”.

10.1.1 Design for safety

Safety is important when working with drones in order to avoid accidents. Three kinds of risks were identified: physical, social and emotional risk. Physical risk can be to get hurt by the drone, whereas social and emotional drones hurt the children in their feelings.

Physical risks

Generally the children were very careful around the drone. Most of the time the children were very cautious when picking up the drone. Sometimes they seemed to be using as few fingers as possible.

> *C4 is picking up the drone carefully, “pinching it” with a few fingers.*

Other children moved the drone by pushing on the propeller guards instead of grabbing the whole drone, either by using their hands or their feet.

> *C11 pushes away the drone with their hand (on the floor, like sweeping it away).*

> *C8 moves the drone with their foot.*

Sometimes they were extra cautious by telling their group members to wait with turning the drone on until they were not touching it anymore.

> *C14 gets up and carefully turns the drone around by poking it and dragging it by the propeller protection. C14 says “Do not turn it on!”. They go back to their group members.*

During the workshop one accident occurred when a child tried to touch the drone before the propellers had stopped properly.

> *The drone flies down and is about to land. C22 wants to take it and reaches for the drone before it has landed completely. The drone sits on the table but the propellers are still rotating. One of the propellers hits the finger. C22 says “Aaaah, that hurt!” (Translated from Swedish to English) and quickly pulls the hand back.*

Social and emotional risks

When coming to social risks, as with any other form of group work in school there is a risk that the group dynamic will not be very good, for example that someone will be feeling left out or that the group has a hard time working together. It varied how well the groups worked together, some groups worked really well and took turns coding and they discussed with each other to plan the choreography the drone would do in the workshop.

C2 says "flip?" and the C1 nods.

C15 asks which direction they should put it. The group members answer and C15 turns it around.

C1 and C2 take turns of coding.

Other groups had a harder time to collaborate, but all of the groups finished the task to program a choreography with the drone. The most common things the children argued about were the drone and the computer that was connected to the drone.

C13 tries to take C14s computer three times to look at the code, C14 takes it away. C14 puts it back and C13 turns it around to look at it.

10.1.2 Minimise the impact of short battery life

Since the current battery life is relatively short, the children do not have much time to learn and try out new programming concepts with the drone. The majority of the battery time was spend connecting the drone and debugging the code. A longer battery time would empower children's exploratory behaviour and might help to make abstract programming concepts more tangible, since the children would have more time to experiment and try out different code.

During the workshops the children were disappointed and annoyed of the short battery time.

"The battery ran out but it was fun to program it and to see it do what you wanted it to do."

"It went pretty good, but the battery life sucked."

Sometimes during the workshop the battery was already empty before even starting the drones. They were trying to use it but the battery seems to have run out. More drone had run out of battery, so the children sometimes got a second drone while the other one was charging.

They tried it, the battery of the drone was empty, and got a new one. Looked really sad, upset, nothing worked, happy when the drone started.

Children were told to charge the drone while they are not using it, so that it does not run out so quickly. Some children followed this advice really good and had always connected it to the computer to charge while they were working on the code or choreography.

C16 is charging the drone but it still does not work. "We are trying! But it doesn't work".

Due to the reason that the battery was too low, the drone could not perform certain movements, such as the flips. In the beginning when the children had time to work on their code the flips worked. But after a while and especially when presenting the choreography the flip did not work anymore since the battery run out.

> *"Almost everything worked instead of the flips at the end because the drone had 40%." (from Evaluation)*

> *"Nearly everything worked except in the end we couldn't do the flips since the drone only had 56%." (from Evaluation)*

> *"It didn't flip when it was low battery." (from Evaluation)*

10.1.3 Consider communication between user and drone

The communication between the drone and the user is lacking some aspects. During the workshops it was observed that the WiFi number for the drone is not visualised obvious enough to find for the user. There is no indication for the user when the drone is about to start and for which reason the drone is not working as it should. The drone design could give the user more information in form of feedback on these topics to simplify using the drones.

WiFi

Connecting to the drone's WiFi was not always so easy for the children. The children were unable to find the correct WiFi from the drone or connected to the wrong drone of another group.

> *T:"Did you connect?" C19:"Yes" T:"Where? No." They checked the WiFi number of the drone.*

The drone itself does not have a good label for the WiFi. The WiFi number of the drone is on a sticker placed inside the drone, which can only be seen when the battery is taken out. As the children need the WiFi while using the drone, this was not possible to see. For this reason, the WiFi number was attached to the drone for the workshops using a labelling device. In this way, the children could quickly and clearly identify which WiFi belonged to which drone.

The children and teacher were also unsure how far away the computer can be from the drone to still be able to connect through WiFi.

> *T:"Maybe it is too far from WiFi?"*

Connecting the drone

Connection problem was one of the most recurring problem during the workshops. Children had a hard time to connect the drone correctly. Especially after changing the connection of the drone from one computer to another child's computer. The problem appeared that the drone was connected to one's WiFi and for the other one's software. One group also had the problem that one Chromebook did not work at all with the drones (which didn't work with robots either on that Chromebook). Another group accidentally tried to connect to a wrong drone.

> *C4 had problem to connect the Chromebook to the drone. A warning message was displayed at the WiFi settings. They asked Birte how to connect then. Birte asked "Did you try to connect the drone to another Chromebook?" They had not tried it, but they did it after Birte gave the advice.*

> *They cannot connect the drone, but they have not turned the drone on and tried connecting to the wrong drone of another group.*

Launching the drone

The drone is lacking any kind of identification that it is about to start. An example which could be integrated is from the *LEGO Mindstorms*, which makes a noise when the code executes and the robot runs. During the workshops it was seen that the children were surprised when the drone was starting and didn't expected that. Therefore their reaction towards the launch of the drone was mainly screaming, jumping to the side or holding their arms in front of their head.

> *The drone starts, nobody expected that, C13, C14 are screaming. C13:" Ey Mr., ey Mr., move!"*

> *They all take a step back when the drone starts. The girl stands close next to it and runs away and argues about it.*

Some children were also not sure how to start the drone, since the launching button is hidden in the navigation menu.

> *T:"Excuse me, how do I start it?"*

Debugging

The programming interface for the drone is missing any feedback about errors. It would be an advantage if the interface communicates why the drone does not execute certain code instructions and what kind of error it is. Usually when executing a program, some kind of error message is explaining why the program did not run. If a sequence of the code does not run, it can help to let the child know if it is due to a low battery, not having a drone connected or if anything in their code is wrong. The *Tello app* that was used during the second phase, for example, provides feedback through a pop-up message about low battery and why the drone cannot perform the flip or another mode (see Figure 7.5). Something similar to this example would be beneficial for the programming environment of drones. This would avoid breakdowns (see Subsection 2.3.1) that frustrate the children and prevent them from progressing.

In the beginning of the workshop the children did not understand why the drone was not working as expected.

> *"The drone did not work that was not fun. The codes that we gave the drone did not work. I don't know why." (from Evaluation)*

> *“When the flip didn’t work, I wish it did. One flip worked when the loop didn’t work, I don’t know why.”(from Evaluation)*

After a while, the problem occurred more often that the drone could not do flips but had previously done flips.

> *T:“Back flip, flip left. Backwards. It didn’t do anything!” C9:“Yes it’s stupid.”*

> *C11:“But it flipped earlier.” during presentation*

> *“But there where things that didn’t work, as for example that if didn’t work, when my group wanted it to work. [...] It didn’t do the things that wanted it to do, as for example doing flips.” (from Evaluation)*

> *“The only thing that didn’t go well was that the drone didn’t flip when we wanted it to flip.” (from Evaluation)*

10.1.4 Consider the possibility of a collaboration programming tool

Programming of drones could offer more possibilities for a collaborative experience. For learning programming it is important to write code yourself. By creating features that would either allow the children to work on the same code or to change the drone’s connection to different computers, programming with drones would have the potential to be a more collaborative and fairer experience for the children. *GitHub* [1] for example is a programming platform for collaboration which enables users to work together on their coding project.

During the workshop, it could be observed that the children took the one computer that was connected to the drone, from each other. It was also common that only one or two children in each group (that usually consisted of three children) were having the computer and writing the code. Sometimes conflicts arose when more than one child wanted to have the computer that was connected to the drone.

> *C17 wants to take the cable from the drone out of the Chromebook from C16, who took the laptop back and said “Ey”. They are discussing.*

Although other groups have worked well together (see Figure 10.1), however, they had to take turns in programming.

> *Only two children have Chromebooks, but the third one is still participating and helping.*

> *When the drone lands, they are all looking at the code together.*

[1] https://github.com

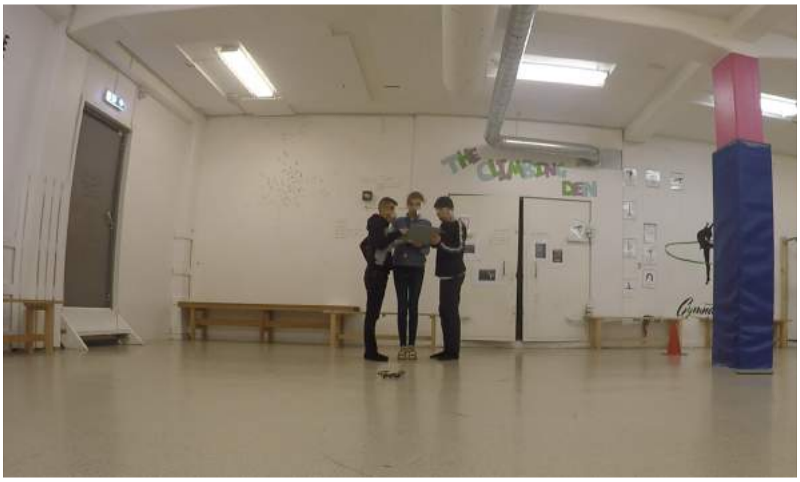


Figure 10.1: Children working on the code together.

Some students try to help each other. Therefore they need to take the Chromebook from the students who needed help and show what they want to explain.

> *C13 is taking the Chromebook from C14 and is helping them, by showing how to connect the drone to the Chromebook.*

10.1.5 Consider designing for touch interaction for children & drones

While using the drones in the workshop it was seen that children tried touch interactions with the drones. For example children seemed to want to poke the drone from underneath, while it was flying in the air. After doing this, the drone was flying up and a bit to the side. Therefore that children do not know if the drone will detect their hands and react to their interaction, it should be considered to think about a safe touch interaction.

> *C22 is holding their hand underneath the drone. The drone flies higher, C22 stands up and tries to reach it again. C22 sits down again. C22 and C23 (C24 too after a while) hold their hands out, like they wanted the drone to land on one of them. The drone just flies higher up and stays a while in the air before going down.*

Figure 10.2: Children try to touch the drone from underneath.

Another example is that children tried to hold their arm next to the drone to see if it detects their arm as well. Since the drone is lacking sensors at the side, the drone will move on, even if an arm from the children is in the way which can be dangerous.

> *C22 and C24 hold their hands underneath the drone while it is flying. They are looking at the drone from underneath. C22 stands up and holds their arm next to the drone, it looks like they try to see if the drone would recognise the arm. The drone does not respond.*
>
> *C26 tries to poke the drone from underneath, but they do it slowly so the drone flies a bit further up in the air.*

Figure 10.3: Children try to touch the drone at the sides.

The *Tello EDU* drone does have a flight mode called “Throw & Go”, where drone starts slowly and the user throws the drone upwards in the air, where the drone flies as usual. It also has the possibility to land on the palm of the users hand with mode “PalmLand” setting. These modes are not possibly to programming using

DroneBlocks. In some exploratory behaviour, the children wanted to launch the drone from their hands, which the manufacturer Ryze Robotics [94] advises against. The teacher stopped the child before the other members of the started the drone.

> *"Don't do it put it down". C13 puts down the drone, the drone starts and they all look excited.*

Figure 10.4: Children try to start the drone from their body.

During the workshop it could be observed that children try to land the drone on a different object instead of the desk or the floor. Another, less dangerous example was a child holding up a chair in the air to let the drone land on it, instead of the table where it started from.

> *C22 puts the chair up and catches the drone on it.*

Figure 10.5: Children land the drone on a chair.

10.1.6 Capitalise on advantages of gesture based interactions

Supporting gesture based interaction would open up for taking advantage of the tangible medium that the drone is. It was relatively common during the observations to see children using their hands, arms or sometimes their whole bodies to show each other how they wanted the drone to move. Sometimes the children did a gesture for themselves, either at the same time the drone was doing something or to plan how they wanted the drone to fly. But most of the time, the gestures took place when the children were communicating with each other and they used the gestures as a complement to explaining how the drone moved or how they wanted it to move. Apart from making gestures, the majority of the children also stopped working to walk around, jump or play. Embodied programming might provide a natural outlet for movement.

The children did several different kinds of gestures when interacting with the drones. A majority of these were discovered when reviewing the recordings from workshops. These gestures can be divided into categories depending on in which context they were used and with which body parts.

Flip gestures

The Tello EDU uses different flight modes whereas flips the only programmable mode in DroneBlocks is so far. The Flips were the part of programming the drones where the children were most happy and excited about it. In the evaluation the children mainly mentioned the flips why it was fun to program the drones.

The most commonly used gesture was to indicate that the drone should do a flip. This gesture was used when the drone was about to do a flip, to explain to the other classmates where in the code the drone should do a flip or when it did not perform a flip. The flip gestures were differentiated in three movements: hand gesture, pointing finger and whole body movement.

By a hand movement it is meant that the children use their flat hand and only move or turn their wrist to indicate a flip. Another hand movement seemed as if they were turning the drone with their own hand, shaping their hand as if they were grabbing something.

> *C1 does a loop, like a half circle with their hand. "It's not flipping."*

Figure 10.6: Children using their hand to represent a flip.

Often, only one finger, the index finger, was used to point to the position where the drone should do a flip.

> *C1 draws a circle in the air with their index finger two times and points to the floor when the drone is landing.*

Figure 10.7: Children pointing with a finger to show a flip.

> *C11 is pointing to the drone. "It should flip! Mr it's supposed to flip!". C11 is trying to explain to the class where it should flip.*

More rarely, the whole body was used to represent the movement of a flip. The arms, legs and head were used to express this. This was performed in very different ways, such as a sort of forward roll, a sort of dive and a jump.

> *C10 is leaning the upper body back and then turn forward with their head first and doing a movement with the whole body like doing a dive.*

Figure 10.8: Children use their whole body in the form of a roll to represent a flip.

C10 is doing a movement with the whole body, standing on one leg leaning forward and doing a dive movement.

Figure 10.9: Children use their whole body in the form of a dive to represent a flip.

C1 is rolling the arms around each other for a couple of rounds and then moves one arm and the head to the side when the drone flips.

C18 is jumping up and moving the head forward downwards.

Figure 10.10: Children jumping as a flip gesture.

Direction gestures

Another common gesture was describing the direction of how the drone should move. These gestures were often accompanied with discussions between the children and can be divided into three categories: pointing, hand gestures and walking.

The pointing gesture typically consisted of the child pointing with their index finger and moving their arm in different directions where they wanted the drone to move.

> *C1 points to one side and the other side.*

> *Then C1 points with their index finger forward and then to the left side.*
> *The drone flies forward then left.*

A similar but slightly different gesture for showing direction is to use the whole hand instead of only the index finger. It differs if the hand is straight or more relaxed.

> *C11 is showing with their hands what the drone should do (straight arm pointing with the flat hand, turning to one side, still straight).*

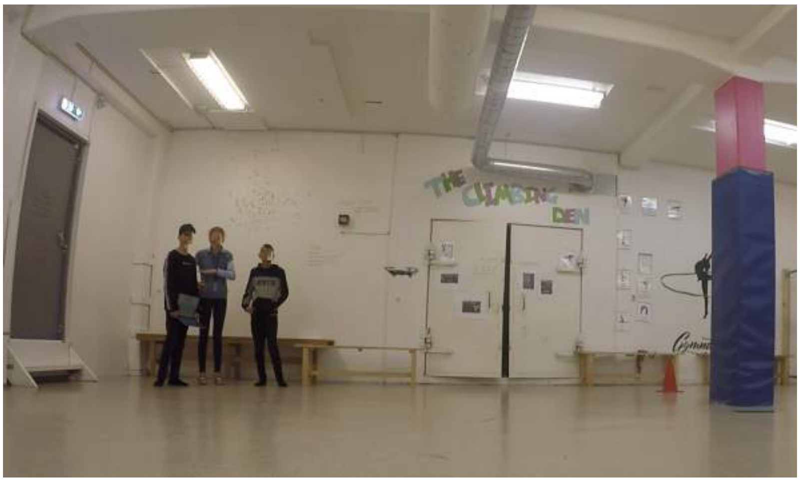


Figure 10.11: Children using a hand movement to show the direction of the drone.

> *C11 is showing with their hands again (straight arm, turning to one side, to other side, in the middle, waving their hand, rotating wrist).*

While the previous gestures for direction generally was made when the children stood still in one place (or relatively still), walking was more of an embodied movement. It was typically used for measuring more exactly how the drone should move. Measuring by walking was often made by using large steps.

> *C10 went straight, then to one side,to the other side and measured the distance (big steps like 1m). The whole group follows and walks around how they want the drone to fly.*

Figure 10.12: The children walking to show the direction of the drone.

> *C10 starts measuring by walking again, to one side, turns around, to the other side, turns around and looks at the group.*

Figure 10.13: Children checking the direction with their group members.

Placement gestures

Placement gestures are similar to direction gestures, but only used when discussing from which point the drone should start. The only type of placement gesture we observed was pointing.

> *They point everywhere where they want the drone to go or start. They also point while putting the drone to a new start point. They are standing by the computer and pointing more.*

> *C4 is pointing to the drone and where they want C5 to move it. C5 is standing up, C4 moves their hand to the other side and talks to C5. C5 takes the drone carefully from the top and goes backward and looks at C4. When C5 asks something C4 shows C5 with their hand in front of C5, they go a bit in front and place the drone.*

Figure 10.14: Children using gestures to describe the placement of the drone.

Other gestures

Other gestures that were used were not easy to recognise or to understand what they were supposed to symbolise compared to the movements explained earlier. These movement were different ways of moving the arms or hands.

> *C12 does a movement with straight arms, like playing volleyball.*
>
> *C12 does a movement with straight arms and rolling the hands towards the body.*
>
> *C10 does an arm movement up and down, which looks like a wave or roller coaster.*
>
> *C10 is doing a claw gesture like he holds the drone.*

10.2 Research Question 2

Support Material for teaching programming with drones is necessary for the children to encourage them to solve problems on their own. Children have the habit of asking the teacher for help when they are faced with a problem without first trying to solve a problem themselves. However, the teacher cannot help all children at once. To avoid children having to wait and getting bored, other support is needed. Additionally, children get frustrated and disappointed quickly if something is not working as expected. In order to prevent this the support material can help them understand the drone better and it's problems. Support material is intended as a solution to provide additional help for the children, to guide them and to encourage them to solve problems and questions themselves.

In this section the second research question about support material for CDI will be answered:

> *"What support material for child-drone interaction should be designed to better support teaching programming?"*

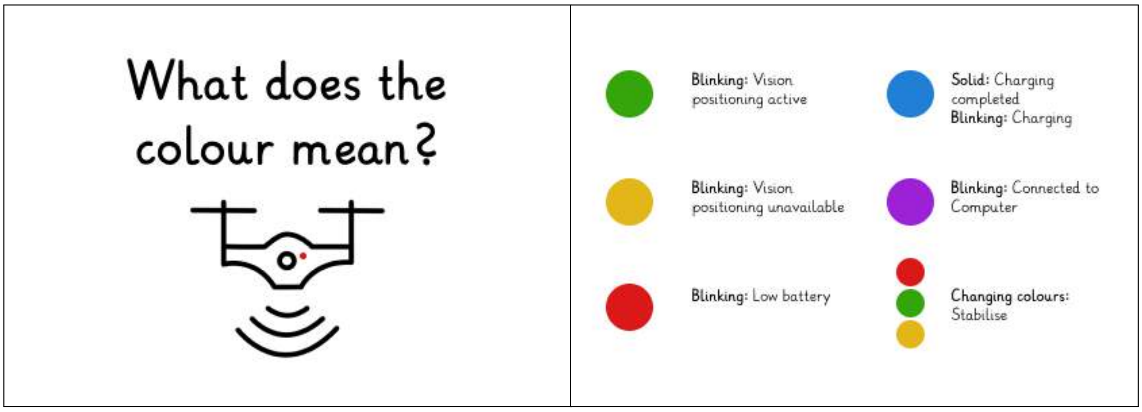
For this purpose, examples of a support material have been created. The support material should function as advice cards. When the children get stuck, they should look at their cards for the right question and try to solve their problem with the help of the answer. The cards are supposed to help them quickly and remind them of issues they have forgotten in order to remember them for the future. In this way, the cards are not only to help them but also to try to give the children more information about the drones. The distributed material should not be limited and be divided fairly. Each student should have their own support material, so that they understand the problem on their own and can work without the help of others.

The support material includes frequently asked questions from students, hints on exploration and play functions, safety design considerations and additional tips and examples.

10.2.1 Frequently asked questions

Children faced most of the times the same issues over and over again and therefore are asking the same questions again. These questions were included on the advice cards to help them without needing to ask the question to the teacher.

What does the colour mean?



(a) Front **(b)** Back

Figure 10.15: Advice Card 1

The children do not understand what the colours are supposed to communicate and therefore they are not able to use the additional information. For instance, the children did not know if the drone was charging or not, and if it was connected to the computer or not. In this case, the colour of the drone could provide them with a hint to help them further.

How to connect the Tello drone

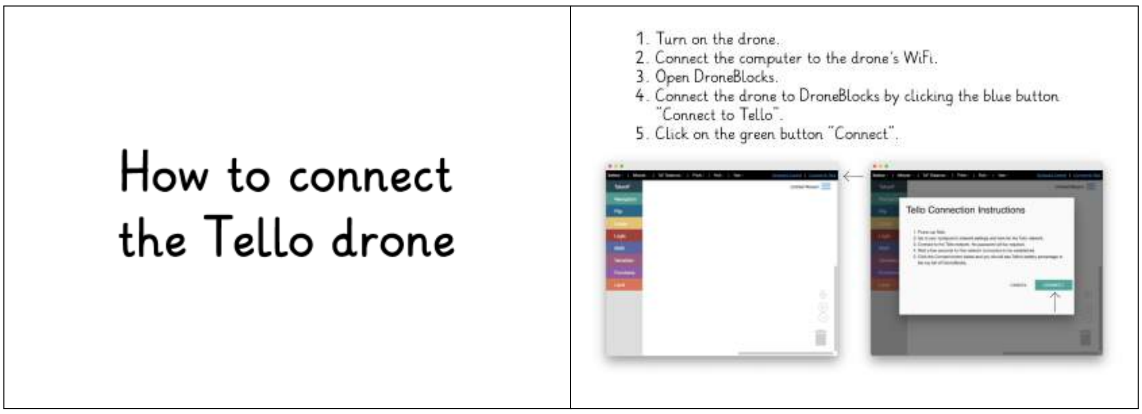


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Figure 10.16: Advice Card 2

The first problem children got in touch with is connecting the drone with the computer and the software. Often children were unsure if they were connected or not. The change of the Button from “Connect to Tello” to “Tello” which indicates that the drone is connected to the software, should help them.

How to start the Tello drone

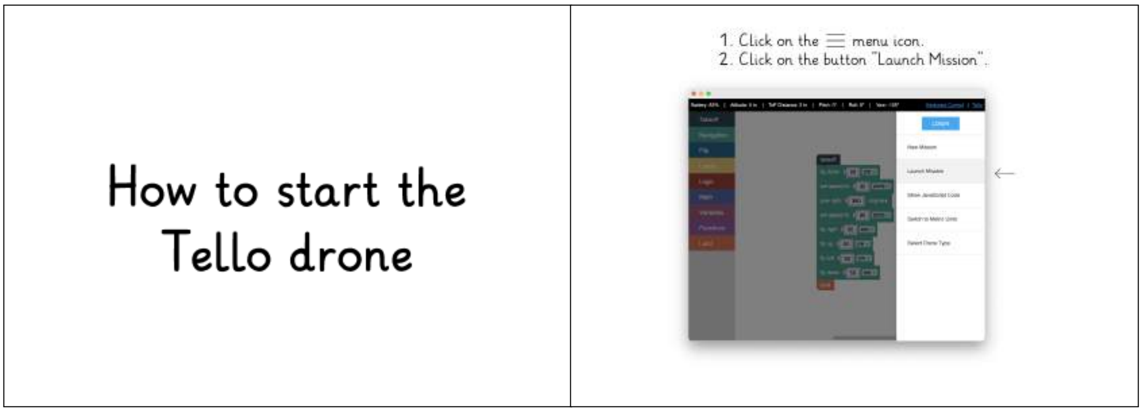

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Figure 10.17: Advice Card 3

Starting the drone within the software is not as obvious, where children could need extra support to find the correct button.

Where in the code is the drone?

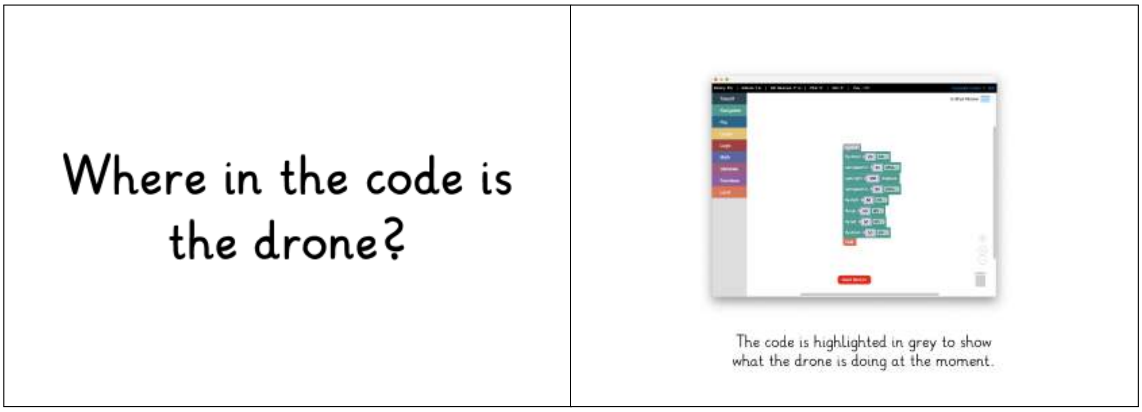

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Figure 10.18: Advice Card 4

Understanding which part of the code the drone is currently preforming will help the children to better understand programming, working with drones and problems. The children should be able to follow the drone and the code.

Why does the drone not work?

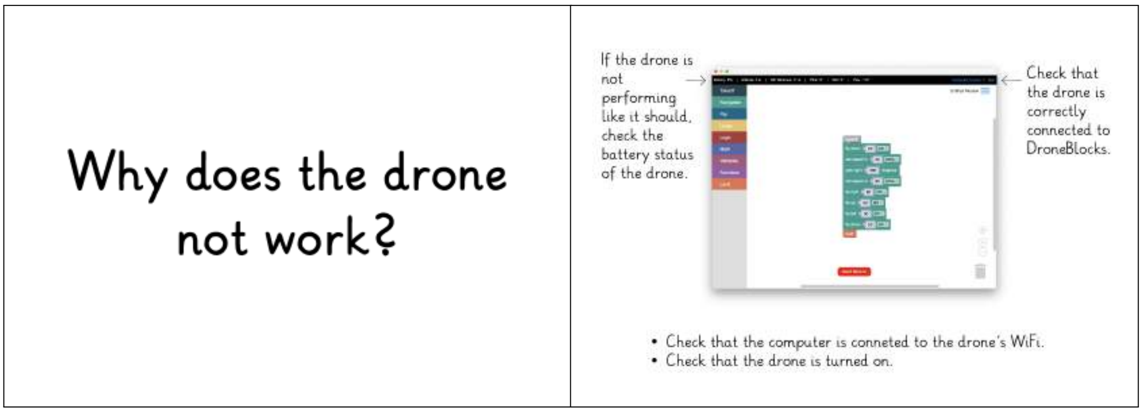

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Figure 10.19: Advice Card 5

The problem the children got the most annoyed from was not understanding why the drone does not work as expected. Most of the times these problems were due to low battery, turned off drones, connection or WiFi issues. These technical failures lead to children got upset, disappointed and frustrated. The children generally did not understand why the drone could not perform the steps in the code, especially if the drone had successfully done it before. Frequently mentioned in the evaluation was the fact that the drone did not work as expected (17 of 32 children said this), especially that the drone did not flip (10 of 32 children said this). As the battery started to get low, flips were the first things that did not work. That could be the reason that flips were mentioned so often. A lot of the time the drone could still do other movements. The cards should help them to understand potential problems and to get an idea of which steps they can test to solve it.

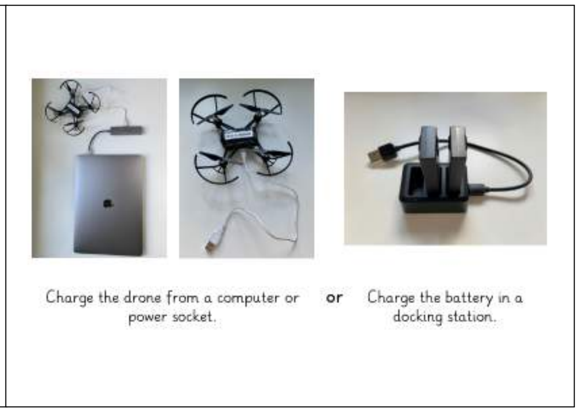
How to stop the Tello drone?

(a) Front **(b)** Back

Figure 10.20: Advice Card 6

In emergency cases the children need to know how to stop the drone immediately to prevent accidents. The children learn to add a code segment which lands the drone, but not know how to stop the drone while its executing the code.

How to charge the drone?



(a) Front **(b)** Back

Figure 10.21: Advice Card 7

Since the drones have such short battery life's they need to be charged quite often. Children were motivated to charge the drone while not using it. Therefore they should know all options on how to charge the drone.

10.2.2 Exploration & Playfulness

To encourage the children's exploratory behaviour, a card with instructions of how to control the drone with the computer's keyboard was created. When reviewing a recording from one of the workshops, it was discovered that one group figured out how to do this by themselves. Perhaps it could be useful to test how it looks when the drone fly a certain way before coding it.

How to control the drone with the keyboard

Children enjoy playing video games with controllers or on the computer. A possibility exists where they can control the drone themselves with the keyboard, in the same way they would control a player in a computer game. Children should be allowed to use their playful, explorative behaviours in a safe way. In this way, the children keep the excitement of working with drones.

10.2.3 Riskful Exploration, physical interaction

During the workshops, the children were given worksheets where the safety instructions could be viewed. It is still important to tell all the children about the safety rules before any exercise with drones begins. As a complement to the initial safety review, these cards with safety instructions were created.

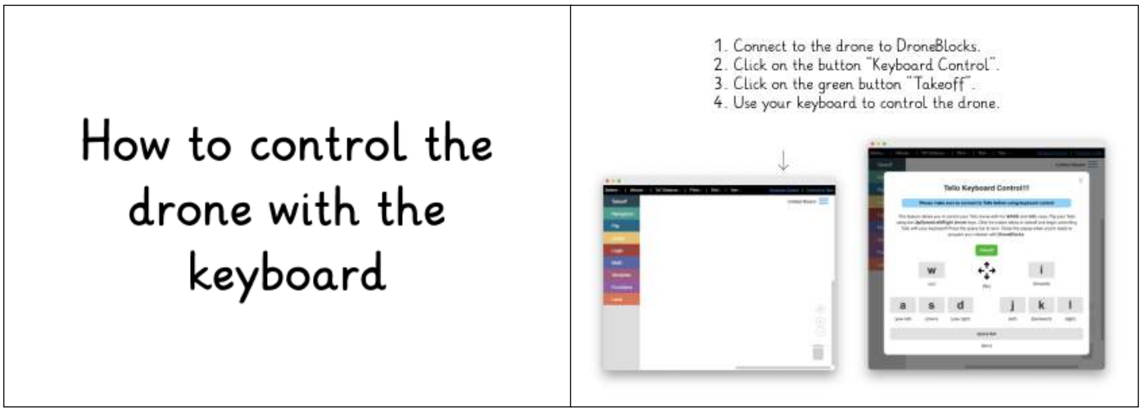


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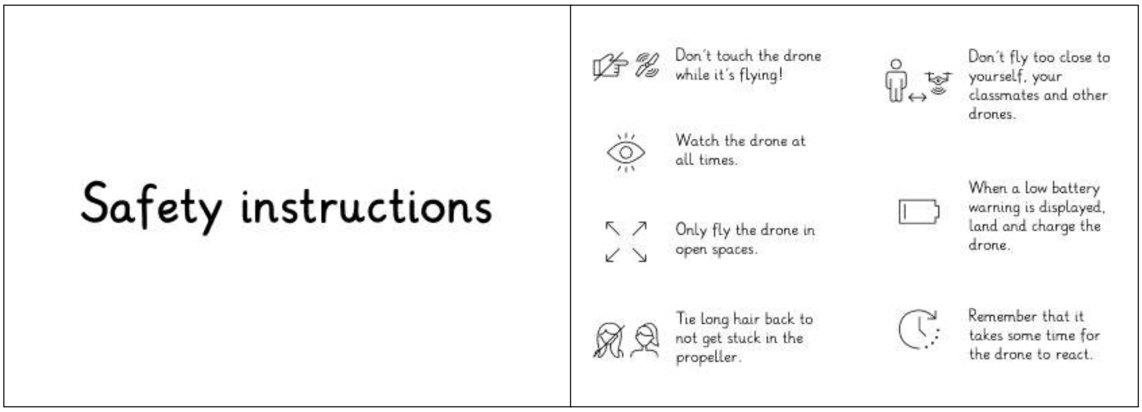
Figure 10.22: Advice Card 8

Safety instructions



(a) Front (b) Back

Figure 10.23: Advice Card 9

Following safety design considerations is very important when working with drones. For this reason, it must be assumed that the children do not forget these rules and can always review them. We could observe that children are trying out the limits of the drone and exploring in a potentially riskful way. For example, they tried to launch the drone from their body or to land on it. In addition, they tried to hold their hand underneath and next to the drone. However, the drone does not have sensors on its sides so it cannot detect the hands, which can be a potential hazard. All without thinking that they could be injured in doing so. For a safer experience, enough space must be available to use the drone. This also allows the children to engage in exploratory behaviour. Due to miscalculating the distancing and drone movements, the drones more often crash into walls. The children should be aware that if they follow the design considerations, they will protect themselves and other classmates and if they disregard them, they will endanger others.

10.2.4 Tips & examples

Additional advice can be useful for the children to better understand the drones. The children were not sure that some inputs are not working and should not wonder about why the drone is not moving, if it is wrong input. Example codes can help them to start coding, to get an inspiration of how the code could look like. During the observation we could see what kind of codes the children created, so the examples also refer to these.

Tips for inputs

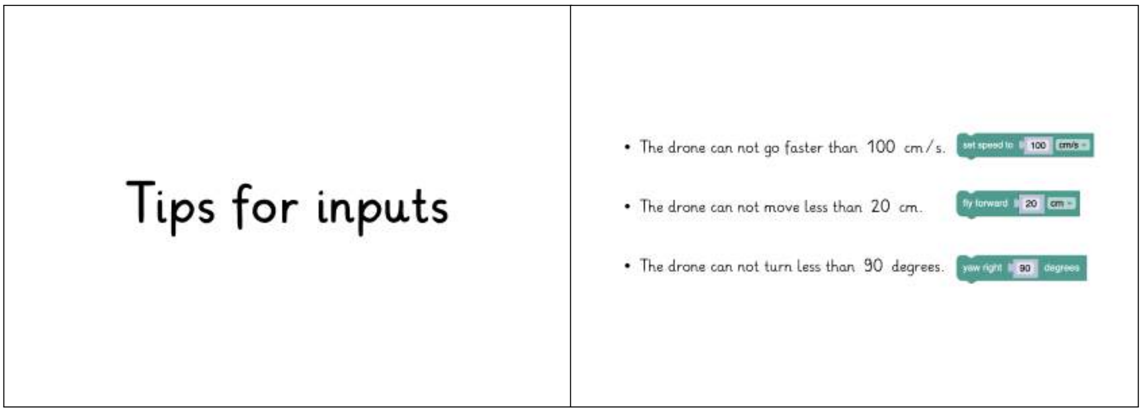


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Figure 10.24: Advice Card 10

To provide the children an understanding of the limits of the drone, inputs that count as boundaries have been listed. The drone can not go faster than 100 cm/s, move less than 20 cm or turn less than 90 degrees. The purpose is to reduce the children's disappointment when the drone does not fly as fast as they have entered or to prevent them from becoming frustrated when the drone barely moves because they have not entered enough values.

Easy example code

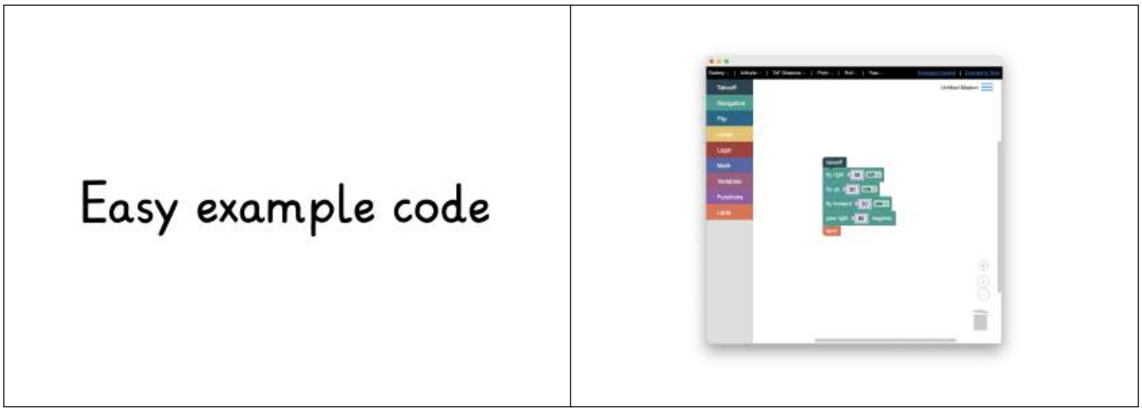

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Figure 10.25: Advice Card 11

In order to simplify the children's introduction to their first code, a simple example could be a practical help. One way is for the children to rebuild this simple code and test it with the drone. In doing so, they learn to use the programme and understand how the drone reacts to the code.

Intermediate example code

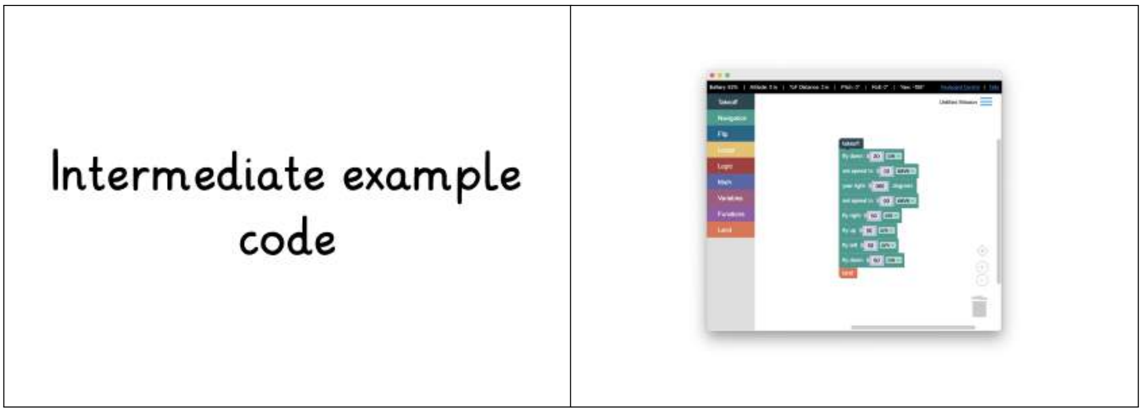

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Figure 10.26: Advice Card 12

To take a next step from the simple example, this one was chosen. A longer code is used to add different inputs for the movements. This is intended to show the children that the inputs can be changed individually.

Difficult example code

(a) Front **(b)** Back

Figure 10.27: Advice Card 13

To encourage the children to explore and try out different features, a difficult example can be helpful. This example includes functions such as loops.

11

Discussion

In this chapter, the research questions are discussed together with reflections on drones in the classroom and the methodology used. Finally, limitations during the project and potential future work is presented.

> *RQ1: "What should be considered when designing drones for programming education for children in the classroom?"*
>
> *RQ2:"What support material for child-drone interaction should be designed to better support teaching programming?"*

11.1 Design Considerations for creating educational drones

To answer our first research question "What should be considered when designing drones for programming education for children in the classroom?", a set of design considerations that can be used as support for designing drones for education. These were constructed based on our data from the ethnographic study. The data was in the form of notes, pictures and transcriptions from recordings. All recordings were done during the workshops.

We managed to derive these design considerations, but have not been able to discuss them with drone designers or evaluated these guidelines. To truly know if these design considerations are useful they would need to be evaluated in some way.

11.1.1 Limitations of drones in the ethnographic study

During the ethnographic study the battery was one of the main problems. Not only that the battery life for the *Tello* drone is very short, but we also experienced problems when charging them. A charging station we used did not seem to work and it was sometimes difficult to know if the problem was with the batteries, charging stations, cables or the drones themselves. The short battery life made it harder to teach programming than we expected. It took time for the children to get started with the drones. In theory, it might not sound like it would be complicated, but put in practice it takes more time than one might expect. Connecting the drone seemed to be complicated. Most groups of children needed help with connecting the drone.

When the teacher has to help every group, it leads to some waiting time for the children. During our first workshop we were not very clear with that the children needed to turn off the drones when they were not using them. A consequence of this was that the battery ran out quickly, sometimes before they had managed to test a lot of programs with it. Some children turned on the drone and while they struggled to connect the drone to the software, the battery already had lost some amount of battery.

One of the pre-programmed moves that the drone could do was a flip. When going through the evaluation papers from the children, a lot of comments were made regarding the flips. To the question “What was fun today?”, the flips were frequently mentioned and to the question “What was not fun?”, one of the most reoccurring answers was “when the flips did not work”. When the flips did not work anymore it led to disappointment among the children. If we were thinking about doing this ethnographic study again and what we could have changed it would probably be getting more batteries and chargers. In addition, the evaluation could have been created different, to get more feedback from the children on specific topics. Initially the children could get more information on the drones in order to understand how to use them even better, like explaining the different colours of the drone.

After the workshop a lot of feedback from the children showed them enjoying programming with the drones and would like to have the possibility again. The feedback from the children was generally very positive.

11.1.2 Using drones for embodied programming

During the workshop it was observed that many children used gestures to express their ideas. Especially when the children wanted to explain to their classmates or the teacher what kind of movement the drone should perform. In addition, gestures were made at the same time as the movement of the drone, which were supposed to express exactly that. Since the children used embodiment that often it is assumed that embodied programming could have a potential to be applied to programming of drones. This could lead to more interest and motivation from children towards programming.

11.2 Design of Support Material for programming drones in school

To answer the second research question “What support material for child-drone interaction should be designed to better support teaching programming?” one example of support material was created. Through the expert evaluation we learnt that advice cards are already effectively used in schools, to support the learning process. They can be a good method for supporting the students in working with drones. During the evaluation, the teacher agreed that the questions on the advice cards were indeed the most frequently asked ones and would provide good support. This is inline with what we discovered during the literature review, where it was stated that children learn better when using physical materials [93].

It would have been interesting to see how the children were using the advice cards while programming the drones and how they integrate the cards in their learning process. This is one possible support material to assist in drone programming, there are certainly other suitable ones. At the beginning, other ideas were considered as support material, such as a small booklet or an application. However, it was decided not to use them. For the reason that the children do not need all the answers at once rather only one. In a small booklet the children would have to search longer for their answer and it would be more unhandy. The application was not implemented as the children already have the programming environment open on their computer and should not have to switch between two programmes. The support should be offered at the same time while they are programming. Since the ethnographic study was relatively late in the time plan of the thesis, there was not much time left to develop and refine the design. Due to this reason the design was created within one week and could have been of higher fidelity if given more time. For example, the advice cards could have been printed on thicker paper and laminated.

11.3 Reflections on Drones in the Classroom

When planning the ethnographic study, one expectation we had was to see how drones could potentially be used to teach and practice programming concepts in a more tangible way compared to classic coding. During our observations we became aware of some of the obstacles to achieve this. The study took place at a school that already used robots and recently started to incorporate drones in their programming education. If we would have conducted our study at another school, our results may have included more obstacles. For example, the teacher in our case were already familiar with using both different kinds of robots and drones in lessons. If the teacher are not familiar with the drones beforehand, things like having batteries fully charged for each lesson and connection problems might be larger.

However, we do think that drones have a potential to be useful in programming education. During our observations, we could see that the drones captured the children's interest, perhaps even more than the robots the children used during the lessons before the workshop. Similarly to robots, drones are tangible and it can be beneficial to use physical object to grasp more abstract concepts like programming.

11.3.1 Adaptions to robots & drones within education

Serholt et al. says that when conducting studies with Social Robots in schools, it is important that the robots are physically sturdy and have taken into account the "unpredictability in children's behavior" [25]. This is something we could observe during the lessons when children used the robots and also discussing with the teacher after the lessons. Even if the robots are adapted to children by having a zoomorphic, cute appearance, some parts of the interaction is not very well-adapted to children's behaviour. One example of this is that some physical parts of the robot can be fragile and easily break if a child would drop it, such as the *Ozobot's* thin plastic wheels. Another example is how the robot is connected to the software. In the case with the *Codey Rocky*, the robot needed to be connected via a cable to transfer the code from the computer to the robot. But if the cable was not disconnected correctly, for example if it was just pulled out of the computer, there would be connection problems the next time the child would try to connect the robot to the software.

Similar to educational robots, it is a advantage that drones for educations are relatively sturdy. Since the workshops only took place during two lessons, we can not say if the *Tello EDU* drone is durable for a longer period of time. During the workshops, one drone hit the ceiling in the gym hall and fell down on the floor. Another drone crashed into a wall, but the teacher caught it before it hit the floor. None of these drones seemed to be damaged afterwards.

During the observations that took place the two weeks before the workshops, we could see that some educational robots were not durable enough. Examples of these are thin plastic wheels that broke when a child dropped them from their desk on to the floor and ports used for connecting and charging that had been damaged. In one class, when the drones were introduced to the children, one child was sceptic about if the drones would stand the class using them.

11.3.2 Anthropomorphisation in robots vs. drones

One observation finding was, that the children seemed to anthropomorphise the *Ozobot* and *Codey Rocky* to a larger degree, compared to the drone. Since we had read relatively many studies on social robotics in classroom settings, we managed to spot this, even if it was in a smaller scale. In this study, the robots did not interact with the children automatically. They had to be programmed by the children to make sounds and move etc. But some kids could still be observed playing with the robots in different ways, for example pretending that the robots were doing things, acting in certain way or expressing feelings. For example the *Ozobot* throwing pens and the *Codey Rocky* having feelings. Some of the kids displayed affection toward the robots, especially the *Codey Rocky*, for example saying that they wanted a robot like that or that it looked really cute. These kinds of behaviour only took part during the lessons with robots, not when the drones were present. The drone seemed to viewed by the children more as a tool compared to the robots. This could also be seen when the children were holding the drone. In a lot of cases, the children could be seen holding the drone carefully, with just a few fingers. One reason for this could be, that we started the workshop by explaining safety instructions for the drone. With the robots, children were less careful in using and carrying it.

11.4 Methodology

For the reason that CDI is not very researched yet, there was a lack of resources at the beginning. Therefore, many things were derived from CRI and wondered if this could apply to drones as well. The methods selected at the beginning of the project were changed during the process and four methods (MoSCoW, Questionnaire, Think-aloud, Focus groups) remained unused. The project management method MoSCoW focuses on the prioritisation of requirements in projects. The intention was to use it during the design phase. Since our design specifically used the content from the ethnographic data, there were fewer questions about must haves and won't have's. This method would have been more useful for a digital prototype. The research method questionnaire was not used since we discovered that the conventional methods are more difficult to carry out with children. Expert interviews and papers suggested other ideas to gather data from children. At the beginning, the plan was to conduct the study in a separate room so that only two children at a time would come into the room to complete a programming task in a shorter time. The idea was to record the session and use the think-aloud method while the students were working on the programming task and explaining what they were doing. Since the workshop was carried out during the lesson all students were working at the same time programming the drones. So, it was not possible to record the children to be able to understand what they are saying. This was also due to the noise level of the drones and children talking to each other and shouting for someone for help. The focus group method was planned for evaluating the final design. Due to lack of time, this evaluation method was changed. The fact that we were only in contact with three teachers, but this method requires more people, was problematic. Therefore, this method was not used, but a heuristic evaluation and an interview where we could ask the teacher to evaluate the design. Having more time, a co-design session with the teachers would also have been very interesting.

11.5 Limitations

In the beginning of the master thesis, there were still regulations in place relating to the COVID-19 pandemic. This brought some uncertainty to whether it would be possible to conduct the study in a school. We had some refusals from schools due to greater COVID-19 cases in schools, but it was still possible for us to find a school where we could do the study without problems. Otherwise it did not affect our end result too much, since we were already used to having online meetings.

Since we had to adapt our ethnographic study to the school's curriculum and programming of robots, the ethnographic study took place quite late within this project. The topic of programming robots and drones was not taught until the end of April. This lead to having less time for working on the design than anticipated. During the study, the original plan had to be changed due to a scheduling conflict with another class, as the gym was not available at the time of the second workshop. Therefore the second workshop was held in the dining hall and the two conducted workshops were under different settings and could differ in the results. In the beginning, it was said that we were making sure that the location for the workshop would not have any obstacles. The dining hall had more obstacles then a gym hall. But still we were able to conduct the workshop without getting effected by that or having any kind of problems with obstacles. The children were still divided and got enough space for using the drone. Instead of having a separated space like in the gym hall, they had each a few tables in a row, where they were able to sit and program and to place the drone far away from them and other classmates as well as drones.

For the ethnographic study eight drones were available, so that each group had one drone and two were extra. The extra drones were meant to be used for the presentation at the end, so that the battery remains full. However, because some of the drones were already empty before the children could actually test them, they were used beforehand. In addition, there were only a few extra batteries, which were also quickly used up. We had a docking station where three batteries could be charged one after the other and a charging cable that could be connected to the drone. All groups received a charging cable and the teacher had a few extra. However, this was not enough to charge the drone and batteries so that they could be used throughout the entire workshop. Having the opportunity to use the drone for longer time could have changed the experience for the children.

To record the workshops we only had two cameras, which made it difficult to record all group at the same time. Therefore the data could have been more and possibly lead to more findings. Due to the noise level and that the camera had to be quite far from the students to capture more groups with one camera, we ware not able to understand what children actually said on the video recordings. In addition, we were only three with the teacher, so we could not focus on all groups at the same time and know more problems from observation or talking to the children.

The scope of the project was limited to a study within one school. Consequently, the results may be completely different in other schools. Especially since these students already knew about block-programming before, which made it easier for them to transfer this to programming the drones. This might also change the outcome with children who have no prior knowledge of programming. Therefore other children could have face more problems using the drones which would could lead to more design considerations and examples for the support material.

11.6 Future Work

This study took place at a middle school in Gothenburg during a total of six lessons, with each lesson being 90 minutes. In total, 32 children participated in this study. We have provided the first steps towards research in this educational context. Our research questions form both design considerations for the design of drones but also of support material for the context of the classroom. With our contribution, drone designers can now develop and informed approach to new iterations keeping in mind the observations condensed in the design considerations and themes. Our work informs next steps in research through design, and can inform the evaluation of new systems.

While there are evident risks in the use of drones in the classroom, we have also identified great potential in using them as tools for education. The proposed support material is a starting point for teachers and other interaction designers to develop their own approach to the material and collaboratively build upon each other's experiences. Drones were used during two lessons in our study. To further explore the potential for use of drones in education, it would be interesting to see studies conducting during a longer time period and with different schools. We also encourage more studies related to embodied programming with drones, since we saw a potential for it, based on the children's natural movements when interacting with the drones.

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Conclusion

In this thesis, we examined what needs to be considered when designing drones aimed at education and what support material could be useful for programming in the classroom. This was done through an ethnographic study that took place in a middle school in central Gothenburg. A set of design considerations were created based on this study. Support material was created to facilitate usage of drones during programming lessons.

The design considerations are divided into six parts: safety, battery life, communication between user and drone, collaboration, touch interaction and gesture. One of the biggest problem found when using drones in education is the short battery life. It also took relatively long time to get the drone connected to the block-programming software. This led to the children only using programming concepts which they were already well familiar with. If drones were to be used to introduce new programming concepts, they would need to be easier to get started with. It would also be preferable if the battery lasted longer so that the children could learn by trial and error when using the drones.

Since drones need to be flight in open spaces and are quite loud, they are generally not suited for classrooms. In this study, the school's gym hall and dining hall were used for the drone workshops. The need to be in a different classroom could be something that complicates using drones in schools.

The initial plan included studying how the children worked with drones during a lesson before holding our workshops. This was not possible due to restructuring of the lessons and instead we observed how they worked with the robots *Ozobot* and *Codey Rocky*. However, this allowed us to study the differences in the children's behaviour towards the robot compared to the drones. From the observations, it seems like the robots were viewed in a more anthropomorphic way, where children sometimes acted as if the robots had emotions. We could also see that the children were playing with the robots to a greater extent. The drones were generally more treated as a tool and with more respect (they seemed to be more thrilled or frightened by the drone, at least in the beginning).

We also observed that the children used gestures to describe to each other how they wanted the drone to move. Most often with their hands or arms but sometimes using their whole bodies.

This thesis offers first steps in the use of drones in education. Even though there are evident risks using the drones in classrooms we discovered a great potential for using them in programming education in schools.

The proposed support material is a starting point for teachers and other interaction designers to develop their own approach to the material and collaboratively build upon each other's experiences.

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A

Appendix A

A.1 Expert Interviews

The structure and questions from the five conducted structured-interviews are shown here:

A.1.1 Introduction & Formalities

At the beginning of each interview we started the same way with a short introduction about us, what are thesis is about and asking about consent to record the interview and use the data. In the end we said thanks and let them know if we use some data from the interview.

Short introduction

We are doing our master thesis at Chalmers University of Technology, within "Interaction design and technologies". Our topic is about "child-drone interaction" and we will do an ethnographic study and workshop in a classroom setting (ages 10-12) to see if and how drones could be useful for teaching programming and create a prototype for some kind of teaching aid for this.

We got your name from our supervisor, since we were looking for experts working with social robots. We looked at your papers and thought you did interesting studies especially about ethical risks.

Consent

Before we start with the interview we have some questions about consent. Are you alright with recording this interview? The recording will be used only for transcribing the conversation in written form. We will use the data to plan our workshop and to create our final design. If you say something which can be useful for us to use in our thesis, we would write about the findings in the final report. Can we use your name in the final report of our master thesis connected to your sayings or do you want to be anonymous or pseudonymous? The participation in the interview is voluntary. You have the option at any time to cancel the interview and withdraw your consent to a recording and transcription of the interview.

When we start the recording we will ask you about consent again, so that you just say yes if you are alright with all of this.

Now we give you a short interview about the interview. We would like to talk about ethical risk assessment, Accident investigation and ethical risk from anthropomorphism.

End of interview

Do you know of any other researcher or other person working in the field that could be interesting for us to either talk to, or just look into their work? Thank you for your time and the interview. If we have something we would like to use in our thesis we will send you an email again.

A.1.2 Katie Winkle

You did a PhD in robotics in Bristol robotics laboratory, right now you are researching at KTH "robots designed with children for children" and "the feminist design of social robots". Are you currently working on these two topics or do you research something else?

In the paper RoboTed you talked about the ethical hazards and risks of RoboTed and the associated possible solutions.

- How do you recognise or assess ethical risks?
- How did you come up with these solutions to the risks? Did you use specific methods?
- What ethical risks do you have in mind with robots which could be similar to drones?
- (How do you think educational drones can be made less riskful for children?)

In the paper Robot Accident Investigation you mention that "Humans behaviour plays an important role in certain robot accidents".

- What do you think are the most common mistakes from human behaviour in robot accidents?
- Can you think of an (mock) accident scenario in a school context using educational robots?

The study Assessing and addressing ethical risk from anthropomorphism was done at a non-vulnerable group, you wrote that it seemed like it would be similar on vulnerable groups.

- If we would make the drone more "social", do you think there would be differences between how easily deceived children would be in comparison to adults?

We saw the study on DroEye: Introducing a Social Eye Prototype for Drones where Chalmers was involved, and they put an eye on drones. In the paper we could see that some anthropomorphism was useful to get the participants more motivated to do tasks.

- What do you think about anthropomorphic drones?

In the paper Boosting Robot Credibility you talk about robots to change gender norms. We will work with drones and children in the age of 10-12.

- What do you think is especially important to do to increase the girls' interest in Computer science, robotics and drones?

We saw on your website that you are currently working on robots designed with children for children at KTH.

- What have you experienced so far when working for children in CRI? Do you have any suggestions for us working in CDI?
- Do you have any tips for us, special things to look for (when we do ethnographic study in a classroom) or something that would be important to remember when designing the tasks for the workshops?

A.1.3 Sofia Serholt

Most papers focus on the primary user, the students, but in this paper you focus on the teacher's view on the use of empathic robotic tutors in the classroom.

- Can you tell us more about the teacher's view on robots in education, like any kind of problems, advantages, concerns they have?
- What are the most concerns of teachers when integrating educational robots into the classroom?
- What part of the interaction with robots teachers seem to struggle with?
- What do you think robots could be used in education for?
- What do you think are advantages of using robots in education?

In the study you explored what caused breakdowns in children's interaction with robotic tutors.

- What part of the interaction with robots seem children struggle with (most)?

The study explores children's retroperspective perceptions of the child-robot relationship in an educational setting which focuses as well on breakdowns.

- Can you tell us more about what causes breakdowns?
- What kind of breakdowns did happen?

- Can you think of similar breakdowns that could happen with drones in the classroom?
- How did you tackle those breakdowns? How to avoid them?
- How did the breakdowns cause children to like the robots less or be less motivated?
- Was the questionnaire a useful method to gather information from children?
- Did childrens' answer enough?
- Should it be more visual (like a scale)?
- Was the group discussion a useful method to gather information from children?

The study was about finding key ethical issues and long-term consequences of implementing classroom robots for teachers and children in primary education.

- What are the most ethical issues and consequences for teachers and students when implementing classroom robots in education?
- How to tackle ethical risks with robots in the classroom and children?

A.1.4 Patricia Alves-Oliveira

- What are you currently working on?
- What, in your experience, are the biggest differences between working with children compared to adults?
- What do you think are advantages and disadvantages when working with children?
- Do you have any advice for us, what we need to pay attention to when working with children?
- How does the design process differ when designing for children in comparison to adults?
- What do you need to consider when designing for children?

The paper was really interesting for us, since you were not only working for children but also included the children within the whole design process.

- Could you tell us a bit more about the design guidelines for child-robot design?
- How did you identify those guidelines?
- Did you use any specific method?
- Can you think of more or other design guidelines for child-drone design?

- Could you tell us a bit more about the observations you did in the classroom setting?
- What unexpected things did you find out when observing?
- Do you have any suggestion, advice for us when observing children in a classroom setting?

In the paper you talk about the humanization of robots, where the literature review shows mixed opinions about it.

- What do you think about anthropomorphic robots?
- Can you mention some advantages or disadvantages with anthropomorphism (especially in education)?
- How does the interaction change between a robot and a child if the robot is anthropomorphic vs non-anthropomorphic?

In the study you worked with children on robotic teaching assistants for use in the classrooms.

- Why do the views from children and interaction designers on robots differ?

A.1.5 Sara Ekström

- What are you currently working on?
- What, in your experience, are the biggest differences between doing a study with children compared to adults?
- Do you have any advice for us, what we need to pay attention to when working with children?
- What do you think about educational robots in the classroom?
- Can you tell us more about problems/ difficulties and positive examples when integrating educational robots in the classroom?
- How might the relationship between teachers and students be affected when introducing educational robots in the classroom?

In the paper it's mentioned that some teachers have a lack of knowledge of how to use certain technology, which is a challenge for using robots in education. We are planning to do some kind of teaching aid that could help teachers to incorporate drones in their lessons for teaching programming.

- What part of the interaction with robots teachers seem to struggle with?
- Do you have an idea on how to support teachers including new technologies such as educational robots?

- What do you think robots could be used in education for?
- What are challenges when designing activities with robots?

Nowadays children generally know a lot about technology.

- Are there any particular interactions with robots that children seem to struggle with?
- What possibilities and difficulties can you see with introducing drones in education?
- What did the process for designing the in-the-wild study look like?
- What did the plan look like?
- What is important to think about when doing an in-the-wild study with children?
- What other things are especially important or helpful to think about when doing a study in a classroom setting?
- Do you have examples of ethical problems and risks that can occur while doing classroom studies?

A.1.6 Manish Rauthan & Enas Ismail

- How long do you work as a teacher?
- Which subjects are you teaching?
- How old are the kids usually?
- Why did you buy the drones?
- Does someone at the school have experience with it or did you get inspiration from another school etc.?
- Did you already use drones in science class?
- Have you taken part in a research project before? Or do you have research studies going on right now?
- What do they think about it?
- Which drones do you use at school?
- How do you teach with drones already? (or plan to do it)
- Which learning material do you use? (or plan to use)
- If accidents have already happened, how do you handle it?

- What do you think about accidents when planning lessons?
- Are there other things that might be good for us to know?

B

Appendix B

B.1 Information & Consent Form

The following pages show the information sheets and consent forms that were sent to the children and their parents. First the children's version is shown, followed by the parents' version.

B.1.1 Children's Information & Consent Form

Participation in master thesis study
"Child-Drone Interaction in STEM education"

We, Birte Großkopf and Lovisa Grahn, are two students from the Interaction Design and Technology master program at Chalmers University of Technology. We are writing our master's thesis about "Child-Drone Interaction in STEM education" and will do a study at IES Krokslätt in Mr. Rauthan's science class in year 6 during weeks 16-18.

We wonder if you would be willing to participate in this study. Please read the information below. Feel free to ask any questions about the study before deciding whether or not you want to participate.

PURPOSE OF THE STUDY

Through this project we want to understand how drones are used for teaching programming in schools right now. We will sit in the back of the classroom, watching two of your science lessons and take some notes. Also we want to see how you interact with the drones when programming. Drones can make programming more creative and fun. We hope that it will be exciting and interesting for you to work with the drones during the workshop.

PROCEDURES

During week 16 and 17 we are joining two science lessons. In week 18 we are planning a workshop, in which groups of 4 students work together on a 10-15 min exercise. The exercise will be to program the drones using Scratch. The workshop will take place in the school's gym hall.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary. If you participate in this study, you can at any time change your mind and choose to not participate anymore, without any consequences. Before doing the workshop we will ask you again if you want to participate.

POTENTIAL RISKS

Since the project uses drones, it is important that you follow the safety rules for working with drones. We will inform you about the safety rules, how to use drones and potential risks before the workshop. It is important to keep your distance from the drone, since there is a risk that you could accidentally get hit by the drone and hurt yourself. There will be safety goggles, first aid kit, hair bands and catnets (to stop the drones) in the gym hall. We and the teacher will be there during the whole workshop. If an accident happens, we will contact your parents.

CONFIDENTIALITY

If you participate in this study, some information about you will be used for our thesis. For the project you may be videotaped, photographed and have your voice recorded. If photos are used in the final report, we will make sure that you will not be recognizable on them. Your face will not be visible in the photo or edited out. The video recording will only take place during the workshops and are only for getting a written version of the conversations taking place and re-watching to understand the interactions with the drones.

To protect your information and keep you from being identified, we will keep it as anonymous as possible. We won't use your real name and will replace it with a different name.

Your personal data will be kept on an external hard drive, without access to any cloud storage. We as the conductors of the study and our supervisor will be the only ones given access to the personal data. The data will be saved until the end of the project and will then be removed. At any time during or after the experiment, you can ask to destroy your data.

Our Master thesis will be published via Chalmers University of Technology. A research paper based on the study might be published later.

If you have any questions, please contact us or feel free to ask us when we are at your school.

Conductor (Students):
Lovisa Grahn: granl@student.chalmers.se
Birte Großkopf: birteg@student.chalmers.se

Responsible Supervisor:
Mafalda Gamboa: mafalda.gamboa@chalmers.se

Consent form

I have read and understood the information about the study. I understand that participating in the activity and being safe means I need to follow the behaviour code and safety rules.

Child

Name of the child:

☐ I agree to participate during the observation.

☐ I agree to participate in the workshop.

☐ I agree to talk to Birte, Lovisa or Mr. Rauthen (or another teacher) if I am not comfortable at any time before or during the activity.

☐ I agree to being photographed during the observation and workshop.

☐ I agree to being filmed during the workshop.

Place and date:
Signature:

We need your consent form back by the latest **8th of April 2022.**

B.1.2 Parent's Information & Consent Form

Participation in master thesis study
"Child-Drone Interaction in STEM education"

We, Birte Großkopf and Lovisa Grahn, are two students from the Interaction Design and Technology master program at Chalmers University of Technology. Currently we are writing our master's thesis on the topic of "Child-Drone Interaction in STEM education". In this context, we will conduct a study at IES Krokslätt in Mr. Rauthan's science class in year 6 during weeks 16-18.

We wonder if you would be willing to allow your child to participate in this study. Please read the information below. Feel free to ask any questions about the study before deciding whether or not to allow your child to participate.

PURPOSE OF THE STUDY
Our thesis aims to explore the possibilities of using drones in education and what needs to be considered when doing so. We will do this through an ethnographic study with children, evaluating existing educational drones on the market and exploring potential guidelines for future development of educational drones. Through the study we aim to understand how drones are currently used for teaching programming in schools. By observing science lessons in year 6 we will gain a better knowledge about how teachers include drones in their lessons. We intend to discover how children interact with drones in a programming context and how drones for education can be designed better. The children that participate get the opportunity to take part in a motivating learning experience. Physical artefacts like drones can be useful to teach, otherwise relatively abstract concepts, like programming in order to make the learning experience more creative and fun.

PROCEDURES
During week 16 and 17 we are observing two science lessons for each 90 min. In week 18 we are planning a workshop, in which groups of 4 students work together on a 10-15 min exercise. This exercise can be for example writing a code sequence in the programming language Scratch that lets the drone fly up and down. The drone which will be used during this workshop is the Tello EDU, which is developed for educational purposes and is small, light (98 x 92.5 x 41 mm, 87g). The workshop will take place in the school's gym hall.

PARTICIPATION AND WITHDRAWAL
Your child's participation in this study is completely voluntary. If your child participates in this study, he or she may subsequently withdraw from it at any time without consequences of any kind. Before doing the workshop we will ask your child again if they want to participate and will pay attention during the exercise if your child still wants to continue with the activity. If you no longer wish your child to participate, notify one of us via email (see contact details below).

POTENTIAL RISKS
Since the project uses drones, we will inform the children in advance about safety guidelines, how to use drones and potential risks. By participating, your child may be exposed to certain risks such as getting too close and accidentally being hit by the drone. To reduce these risks and to make the experience safer, we will provide safety goggles, first aid kit, hair bands (to tie their hair back if needed) and catnets to stop the drones. We will supervise the children while they are doing the exercises with the drones and the teacher will be present during the whole workshop as well. If, nonetheless, any of this should happen, the child's guardian will be contacted.

CONFIDENTIALITY

If your child participates in this study, some information about your child will be used for our thesis. As part of the study your child may be videotaped, photographed and have his or her voice recorded. If photos are used in the final report, we will make sure that the child will not be recognizable on them. The face of the child will either not be visible in the photo or edited out. The video recording will only take place during the workshops and are used only for transcribing and re-watching to be able to understand the children's interactions with the drones.

In terms of data protection, special care is taken to preserve the anonymity of individuals as much as possible without compromising the purpose of the research. Thus, real names are removed from the final master thesis report or replaced by pseudonyms if they help to simplify the understanding of the text. This is to prevent individual children from being identified.

The personal data of the children will be kept on an external hard drive, without access to any cloud storage. Unauthorised persons will not be able to access the data, we as the conductors of the study and our supervisor will be the only ones given access to the personal data. Data that has been collected and processed within the project will be saved until the end of the project and will then be removed from the hard drive. At any time during or after the experiment, you can request that all data collected during your child's participation be destroyed.

Our Master thesis will be published via Chalmers University of Technology. A research paper based on the study might be published later.

If you have any questions, please contact us:

Conductor (Students):
Lovisa Grahn: granl@student.chalmers.se
Birte Großkopf: birteg@student.chalmers.se

Responsible Supervisor:
Mafalda Gamboa: mafalda.gamboa@chalmers.se

Consent form

I have read and understood the information about the study. I have been given the opportunity to ask questions and I have had them answered. I may keep the written information.

Guardian

Name of the guardian:
Name of the child:
Telephone number of the guardian (to call in case of an emergency):
Anything else you think we should know:

☐ I consent to allow my child participating in the observation.

☐ I consent to allow my child participating in the workshop.

☐ I consent to photos being taken of my child during the observation in class.

☐ I consent to photos being taken of my child during the workshop.

☐ I consent to video recordings being taken of my child during the workshop.

☐ I consent to the processing of my child's personal data for use and publication in the master thesis report.

☐ I consent to the processing of my child's personal data for publication of a research paper.

Place and date:
Signature:

We need your consent form back by the latest **8th of April 2022.**

C

Appendix C

C.1 Heuristic evaluation questions

C.1.1 Quality of Content

- Is the material appropriate for children?
- Are the learning objectives clear?
- Are all questions on the cards clear and understandable for children?

C.1.2 Potential Effectiveness as a Teaching-Learning Tool

- Does the material present opportunities for task-based learning?
- Does the material meet the different teaching and learning styles (individual needs)?
- Do you think this support material is a method for children to solve their questions and problems without the teachers help?
- Do you use similar teaching material in school?

C.1.3 Ease of Use (for Practitioners and Learners)

- Does the material present information in appealing ways?
- Do the photos and icons support the information?
- Does the material provide flexibility in its use?
- Does the material support self-directed learning?

C.1.4 Comments

- Do you have any more feedback you want to give?