Co-creational Education: A Project-based Flipped Classroom Workshop Series for Online Education using Drone Building to Teach Engineering Subjects

Arthur Schuchter
University of Tromsø, Norway

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Abstract: This pandemic has taught us that online education is more than a geeky addition to the educator's toolbox; it is an essential part of modern teaching. Online teaching of engineering subjects traditionally uses tools to share screens, compute and calculate mathematical examples. It also enables work on coding projects in teams and lets the students watch interactive physics simulations. However, there is no possibility to collaboratively steer and observe virtual physics experiments online. What is often missed when working on a project online is, really participating in an experiment and changing and adding your own ideas. We need collaborative competence when entering the corporate world, yet education focuses too much on individual learning. In order to make online teaching a more hands-on experience, this paper proposes co-creational shared physics simulations and virtual physics experiments including 2D drone simulations. This includes the concept of gamification because it presents a playful way for students to learn about physical aspects of drones. The approach presented in this paper focuses on teaching coding and engineering subjects co-educationally with the help of drone-building and aiming to create a platform for knowledge transfer.

1 INTRODUCTION

The world we live in today greatly depends on computers. As a consequence, the demand for people working in the technical field and especially in engineering and IT is increasing continuously. In most technical industries, as well as in many other economic fields, coding plays an integral role. It is therefore vital for students to learn how to code since it will help them meet the requirements of the future job market. Many countries have added programming to the school curriculum. There are initiatives that aim to teach computational thinking at schools and universities, but also to people without an educational background in IT. These STEM (German: MINT) incentives also try to increase the rate of women and counteract the skilled labor shortage in mathematical, technical, scientific and engineering fields (Ntemngwa et al., 2018).

Despite all of these efforts to integrate coding into our lives and schools, we tend to focus on the software aspect and overlook the haptic aspect of IT. In technical fields, there is a shift from operators turning screws to more software-based tasks. Manual labor and traditional handicraft are being neglected and deteriorate. Children often have trouble holding a pen and writing by hand because they are used to playing with computer screens instead of coloring books. Our daily reality is characterized by pushing buttons, using voice commands, and tapping on our smartphones and tablets instead of writing with pen on paper. Not only is this crippling our fine motor skills, but we also forget that all the devices we use do not run on software alone, they need functioning hardware that has to be built and maintained. It is therefore vital that we understand programming from a holistic point of view where hardware and software form a symbiotic relationship.

In order to include the haptic aspect of STEM subjects, we should favor methods of learning that include understanding something by using our hands. This concept is also reflected in our use of language: an English term for "to understand" is "to grasp". Similarly, we use the German term - "begreifen" - which includes "greifen" (to grasp). The fact that we use words describing the sense of

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touch for the concept of understanding something shows that touch is an integral part of our thought process. The use of our hands and the feeling of building something real and tangible should be a part of our educational methods. (Ntemngwa et al., 2018; Andrew et al., 2017; Li et al., 2018; Jonassen et al., 2012; Schmuck et al., 2018; Krajcik et al., 2005.

For this project, we have chosen to use drones in order to show how hardware and software aspects go together and how to teach coding holistically. The BBC Micro:bit, an extraordinary single-plate computer for educational purposes, is at the core of the drone and offers numerous teaching possibilities from block-based graphical programming to professional scripting languages like JavaScript or Python. We aim to encourage logically structured thinking in our students by teaching them to understand and work with the hardware when building the drone as well as to control it with self-written code. We rely on a problem-based learning approach where students are given a specific problem (i.e. to make the drone fly) for which they have to find solutions on their own. Our focus lies on a self-determined, self-discovered and hands-on approach for students to develop new skills intuitively and efficiently. During this project, students learn to create a real-life application with a practical purpose, while going through all stages of developing a product.

Since the start of the Coronavirus pandemic, it has become obvious that online teaching is a necessity and that it is especially important to create collaborative learning environments online. In an offline environment, working on a group project is a fairly easy task that encourages communication, collaboration and hands-on experience. In an online environment this is much harder to achieve, especially in STEM subjects. Therefore, we established a collaborative online-teaching course with the use of drones. During the course we create shared documents that are put together in teams online. We use collaborative 3D modeling with clara.io in order to create a 3D model of the drone and to encourage teambuilding. We also include collaborative programming sessions with Micro:bit where we use codeshare (high school) and github (university students). Collaborative physics experiments and simulations can be carried out online in real time where students can experiment with different variables. We use aspects of gamification which means that we apply principles of games to our exercises in order to make the simulations more appealing to younger students (Ntemngwa et al., 2018).

This project is designed to work with various target groups, from primary school students to university level. (Andrew et al., 2017; Li et al., 2018) Primary school students, together with a parent, will be given a link to an easy computer game that lets you assemble an animated drone and virtually assemble the drone. For high school students we include physical calculations in order to determine whether the drone would be able to fly. This can then be seen in various simulations. Tasks for University students include coding and higher physics.

With this project we want to spark curiosity and awaken interest in IT in general, especially in young girls. We also want to show that STEM subjects can be learnt collaboratively in an online environment.

2 THE CODING CLUB AND THE AIRBIT DRONE

When you look at how the world is developing, coding is an extremely useful skill to possess. Critical thinking is required for effective programming and computer science is increasingly being recognized as a fundamental 21st-century skill that incudes logical thinking, structured thinking, oriented thinking as well as reverse thinking. (Andrew et al., 2017; Li et al., 2018; Jonassen et al., 2012; Schmuck et al., 2018; Krajcik et al., 2005; Keller, 2000; Keller, 2010). With an increasing number of businesses that rely on computer code, coding is at the heart of all of today’s technology. We know that around 70% of all new jobs will be in computer sciences, but there is still a shortage of skilled labor in STEM fields. This calls for a new outlook on teaching how to code. A child who learns how to code will have the advantage of a wider range of employment opportunities in the future, no matter which industry they decide to enter.

In this digital age, coding is a part of basic literacy. Therefore, it is crucial for kids and adults alike to understand and be able to work with the technology around them. Learning to code may seem difficult, but it is comparable to learning a new language. Coding can be seen as a technological language that no child of the future can be without. On a basic level, coding is learning to communicate with computers. It is what we use to run all the apps, video games, websites, and daily interactive digital experiences. Learning a programming language therefore gives students the knowledge to make better sense of the world around them and change the way they think about and interact with technology. Learning experiences can hugely benefit from real-world settings and applications that help the students grasp the importance and potential uses of programming in our modern world (Ntemngwa et al., 2018).

With coding, like with any language, the earlier you grasp its construct, the easier it is to learn and improve your skills. This means that teaching kids how to code should start at a young age. However, relatively little is offered on the subject of IT in primary school curricula. In Norway, there are sporadic projects on Micro:bit, beebot and Scratch, as well as on algorithmic thinking, but they are hardly ever on the curriculum. In Austria, there are tendencies to include computational thinking in teaching approaches for school children, but the definitions on “new media” and “communication and information technologies” in the school curriculum are rather vague and superficial. (Hu et al., 2009; Qin Yu-ping et al., n.d.; Wong et al, 2015; Tugun et al., 2017; Strelan et al., 2020; Bartholomew et al., 2018) Other countries have made a greater effort in including computational thinking (CT) into the curriculum. English schools make frequently make use of the Micro:bit initiative in order to develop CT in students and Chinese authorities are putting a lot of effort into establishing computer science and CT because they think that robotics and artificial intelligence will bring forth a new generation of economy (Hu et al., 2009; Wong et al, 2015).

Since the school curricula in Austria and Norway do not sufficiently deal with the subject of coding, other learning opportunities have to be created. This is why The Coding Club (codingclub.at) was founded by Arthur Schuchter at the University of Tromsø (UiT) in 2017 and then realized in Austria later that same year. It was initially meant as a recruiting tool for universities with the aim to motivate more students to enroll in a technical degree, but developed into an initiative that generally aims to attract a much broader audience to IT. At the club, basics in programming are being taught to students of all ages and various skill levels (primary school, secondary school, high school and computer science students as well as adult career changers). The workshop topics include block-based programming with code blocks, Python and JavaScript, among others. The Coding Club is a collaboration with IT companies such as Eurofunk, Kappacher and the University of Applied Sciences – the Institute of Information technology. All classes are free and accessible to everybody. The Coding Club is meant to help people overcome their fear of learning a programming language and increase their chances on the rapidly evolving job market. Recently, there has been a very successful trial run of a programming course for job seekers in collaboration with employment centers (the AMS in Austria and the NAV in Norway). The course aims to equip future employees with the specific skills asked for by their future employers (the company will prepare a list of desired skills in advance). The Coding Club also offers workshops for the AMS’s FiT (“Frauen in Handwerk und Technik”) program which is especially designed for women who are seeking to work in a profession that combines craftsmanship and technical skills. The biggest benefit of the FiT program is that women will be offered more diverse and better-paid jobs because of their newly acquired skills, which will in turn have a positive impact on the skilled labor shortage in IT professions.

Another recent idea was to include making and coding as two sides of the same coin in order to show the relevance of making in craftsmanship and creating hardware as opposed to solely focusing on software and programming. This is how the AIRBIT Drone Project was created, since a drone is a system that is based on hardware but can be controlled by software. Drones combine the fascination of flying with modern technology and engineering. Students use AIRBIT drones from Makeadrone, produced by a Norwegian company MakeKit (makekit.no), with a programmable Micro:bit chip attached to it. The Airbit is a STEAM learning kit, STEAM being an acronym of Science, Technology, Engineering, Arts and Mathematics. STEAM education is the next generation of teaching because it engages students in a more practical and creative way of learning. It investigates scientific concepts through inquiry and problem-based learning methods used in creative processes. With the Air:bit drone, pupils can get hands-on and switch from being consumers of digital information to designers and creators. Instead of hearing about a topic theoretically, students learn about a topic while actually doing it. This increases the ‘fun factor’ and the pupils and students recognize the practical application of their knowledge immediately. Building something creates a sense of accomplishment because of the problems we encounter and manage to solve – a skill set that is needed in many areas of life. Such active learning also ensures that students retain information with greater ease. It is a fantastic way to use technology in order to create a more multi-sensory classroom, which is based on communication, innovation, and collaboration skills.

3 CO-CREATIONAL ONLINE EDUCATION FOR STEM SUBJECTS

Collaborative cultures have become one of the main pillars for companies to operate successfully. How well people are able to unite their expertise for the purpose of accomplishing shared goals impacts the outcome of a company's projects, both internally and in cooperation with their partners.

Collaboration requires creative thinking in order to solve problems, institutionalized and experiential learning, leadership, quality management, and communication with constant improvement in order to grow. Given collaborative cultures' influence on a company's success rate and efficiency, collaborative skills have been attributed increased significance on the job market. With the current pandemic situation, the demand for online collaboration has risen as soon as people have started to execute their jobs from home. Major well-known companies direct strongly at working on higher scale projects, which are only feasible my means of collaboration. Thus, enabling people to collaborate successfully, also online, is vital and will become inevitable in the future.

While collaboration seems essential in numerous jobs, the education system is still concerned with the individual rather than turning to collaborative knowledge acquisition. In preparing students for situations they will be exposed to in the working world, it is crucial to promote collaborative learning by creating co-creational learning contexts.

The concept of *co-creation* establishes a deeper connection between a teacher and a student, and also between a student and other students. The main point is to apprehend education as a shared attempt where teaching and learning is accomplished *with* the students and not *to* the students. Co-creation intersects with *active learning*, which means applying an active role, versus a passive role, for the collaboration with student and teacher.

Although active learning definitions and practices may differ, they all involve the students' interaction, contribution (physical and mental) and participation in activities to get impartations, reflections on one's own knowledge and problem-solving. Attitude and merits investigations play an important role in activities that involve discussions, writing or reading, or small group work. Elements such as the purpose of their work, or the negotiation of the content of the subject, or even the teaching approach, can enhance their working and learning process immensely. Students can figure out their favourite approach for assessment and all the different ways they can learn and work in a team. (Keller, 1983)

In this context, gamifying projects represents a means of encouraging students to work together. Multiplayer games, for example, require participants to apply collaboration competences: They work on the same goal, communicate and optimize project procedures. In educational environments, game elements tend to increase people's motivation by changing their perception towards the task to be carried out and get them actively engaged in problem-solving processes and knowledge acquisition (Zichermann et al., n.d.).

How can co-creational learning situations now be implemented in online teaching sessions? COVID-19 has taught us that online teaching is an inherent part of the modern education system. Online lectures, quizzes, discussions in break-out rooms and feedback pools are used by many institutions in order to ensure knowledge transfer and acquisition. Especially in maths and physics, flipped classroom and problem-based learning approaches are widely spread.

However, while in most educational contexts this repertoire appears sufficient to secure knowledge, practical exercises, laboratories and experiments pose a challenge to both, the educator and the students. Interactive virtual physics labs are in existence, but what they cannot master is to give students the possibility to collaboratively work online, work towards a goal, watch the outcome and interpret and deduce knowledge from the experiments.

Given the significance of co-working environments for students, we bring online physics experiments to a new level, using our drone projects as an anchor to pass on engineering and coding knowledge to students. We believe that our project not only leads to improved results as compared to the individual level, but it also enables students to foster teambuilding skills. This is critical for social aspects, since trust and mutuality are involved, and negotiating shared understanding is important. Especially online sessions need special attention to a sophisticated set of variables, which involves emotional, contextual, cognitive, social, and motivational challenge (Carle et al., 2017).

It is obvious that how collaboration is carried out differs drastically based on prior knowledge and experience. Thus, it is our objective to include collaboration at an early stage. As the book “Co-creation in Higher Education” mentions, we have to prepare our children for the future, even though we do not know what it will look like. What will happen in the education system, in the private as well as in the public one is paramount. Whereas usability is being taught in lectures, life is happening intermediately. The relevance of relationships, the relevance to the questions of our time and to the society we live in as well as the relevance of knowledge to our lives is key (Keller, 2000).

We use our drone project as an anchor to pass on engineering and coding knowledge to the students. Like in multiplayer games we created co-creational physic simulations, where everyone in a team could change and steer the simulation in real-time collaboratively. In a first step, we wanted to build a co-creational drone assembly simulation, where all the team members could build the drone together. This concept and realization can be seen in Figure 1.

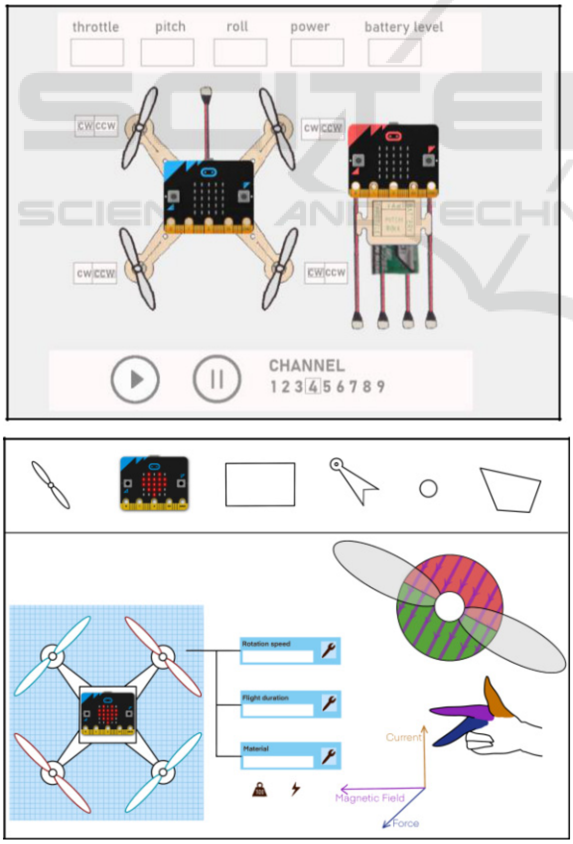

Figure 1: shared drone multi-user simulation of drone assembly and physics competences.

Building the drone often leads to problems concerning the direction of the propellers as well as the right channels. Thus, we created another co-creational simulation, were the direction of the drone, receiver and transmitter properties as well as competences such as throttle, pitch and power of the drone could be simulated. Only if the properties were set in the correct way, the drone would be able to fly. We used Unity 3D with C#, SocketIO and NodeJS to implement such a multiplayer experience.

4 EXPERIMENTS

The goal of educational method proposed in this paper ranges from elementary school kids, over high school to university students. For primary school kids the main focus of our project is to arise attention for engineering subjects with the combination of making and building a drone. For high school students, the main goal is not only to spark interest for technical fields, but also more important to achieve a knowledge transfer by using the drone project as an anchor. Mathematics, 3D Modelling, Physics and coding are competences which could be included in the overall project.

What is important for us is that the participants gain knowledge in a more general sense and not just about one topic. This is why we explain physical elements such as thrust or rotation as well as mechanical elements like tools, since both are equally important when building a drone.

During the course of our workshops we make use of Micro:Bit’s classroom tool. This tool enables the teacher to see their students’ code in real time, to release their own code to select or all students, and to interactively manage all codes on their own computer without having to check their students’ computer screens (classroom.microbit.org).

5 WORKSHOP FOR PRIMARY SCHOOL KIDS

First, children and their parents subscribe online to join the workshop. The subscription phase has to end 3-4 days before the workshop takes place, so that all students can receive their Air:bit kit in time. Next, the packages with the drones can be fetched. Then, there is an introductory Zoom meeting with the instructor who will give easy-to-understand instructions and explain tools and parts. There will be an online quiz on theoretical background knowledge that is carried out in the beginning and right at the end of each workshop in order to compare the learning progress.

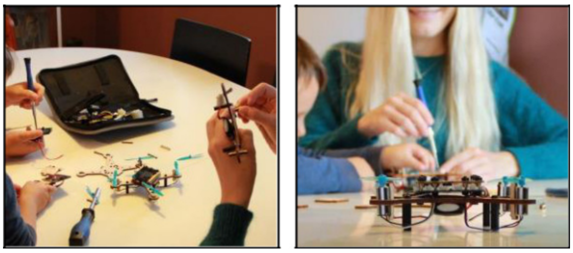

Figure 2 & 3: Impressions from a Coding Club workshop with Air:bit drones.

The parents and their child will then build the drone together (See Figure 1). If individual questions occur, breakout sessions can be held with the participants. There are online polls on how the participants are getting on with the building process.

Online sessions are held where pupils can ask the instructor questions and progress is compared.

As a next step, all participants meet in person to discuss the next steps. The drones are already fully built and now they have to be connected to the PC. The instructor will explain micro:bit and how the drone is controlled by code, focussing on how certain parts such as propellers work in order to make something fly. The teacher gives individual coaching and then shows the flying drone.

Block-based programming languages are ideal for elementary school pupils, as most of them will have no previous programming knowledge and no experience with CT. It is important not to confront the learners with too many unknown concepts at once. We want to take away the fear of programming and rectify the notion that programming is difficult to learn. Block-based languages drastically reduce the amount of syntactic padding and let the pupils concentrate on what is important at this stage of their learning process – achieving results and finding a beginner-friendly way to code. More advanced students can then use 'real' script programming language to achieve the goals.

We use a shared word document where we collect the most important information and include screenshots of problems and errors. Every participant can contribute to this word document, where we follow a „work in progress" approach. The goal is to come up with a compendium of theory and practice by the end of the workshop.

There is a feedback session and room for discussion before the final results are compared. At the end of each workshop a questionnaire is handed out to the pupils. This includes the question "Do you think you have learnt something?" so the instructor can compare the students' self-assessment to reality. To finish the workshop the knowledge quiz that is carried out in the beginning is carried out again to evaluate how much the students have learnt.

In order to be able to cope with another pandemic situation it is possible to carry out the entire workshop online. We have carried out several online-based workshops already. Since parents participate to a large extent in their children's drone project, working mostly from home and connecting with their teacher and fellow pupils online does not pose huge problems. However, with only online sessions the pupils still miss out on the face-to face interaction with their peers and their instructor which minimises the social aspect to an extent.

In coding workshops for primary school children, we focus more on the making process and not as much on the programming part. In order to successfully establish an active learning environment, exercises are carried out with parents as well as teachers assisting the children. For the Workshop itself an online meeting tool can be used, to give instructions to the students, but still parental guidance will be necessary, to ensure that the students reach a sense of achievement and gain confidence. During this process we focus mainly on encouragement and enthusiasm. Our didactical approaches include flipped classroom teaching, problem-based learning and situated learning (Tugun et al., 2017; Strelan et al., 2020).

Flipped classroom teaching is the opposite of traditional classroom teaching. The children watch a lecture online as part of their homework. They can pause and re-watch it as often as needed. Back in class, time is spent with the teacher on discussions, interactive activities, projects or exercises. The main focus in problem-based learning is that the students must figure out the solution to a given problem (i.e. "How can we make the drone fly?") on their own. Problem-based learning focuses on self-discovered learning, self-determined learning, self-evaluation and action-oriented lessons. Interdisciplinary learning is also a part of this concept. (Jonassen et al., 2012; Wood, 2003; Gallagher et al., 1992; Kolodner et al., 2003)

We follow a multidisciplinary approach, since not every pre-university student wants to become a programmer and it can and should not be the goal to push all pupils into this direction. However, nowadays CT is an incredibly valuable skill that is not only applicable to coding and similar tasks, but also to most areas of everyday life. Therefore, the project cannot only be used to teach programming skills but also to establish ties to other disciplines and subjects. Building or assembling the drone could be done in handicrafts, why the drone is able to fly could be discussed in physics, and so on. This way, pupils can learn CT while engaged in a project that ideally deals with something they are interested in.

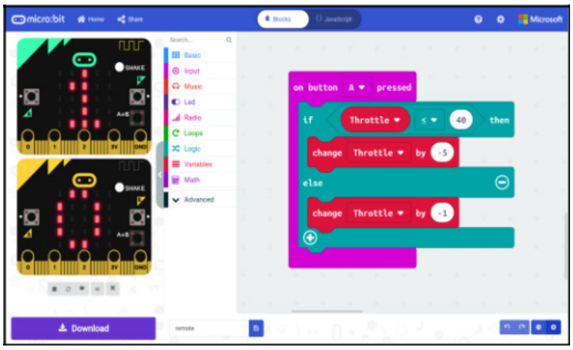

Figure 4: Example of simple block-based programming example for primary school kids.

6 WORKSHPS FOR HIGH SCHOOL STUDENTS

The main goal of these workshops is that the high school students gain knowledge in the fields of 3D modelling, mathematics, physics and coding. In comparison to the previous workshops for primary school kids team building and social skills are also focussed on because we do not only want to achieve knowledge transfer on the engineering fields we also want that we „create" „better" students who work better in teams. The other main difference is that the students are put into a co-content-creation role by being a part of the overall theory documents. We adapt the pipeline of the overall project-based learning process by reversing the overall pipeline, i.e. the first time we create a document about the drone, we present the ready-built drone and let the students reassemble the drone and all the single parts by documenting the reassemble process writing down the important steps. (Krajcik et al., 2005)

This is a useful example of the reverse order of our approach because we use project based learning to the students and not only „flip" the classroom. The process shows also how education is done.

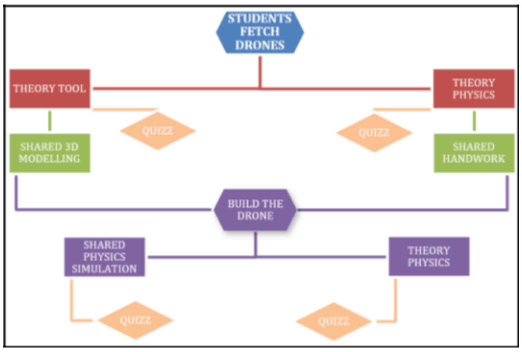

Figure 5: Workshops on Highschool students with the subject of drone construction.

To obtain useful results in our workshops we included quizzes about a topic before a session and after a session about the knowledge, the students should have gained. Input sessions were held live and were recorded as well. In order to achieve more interactivity for the recorded videos we used the tool vizia.com to create interactive videos, where we include quizzes in the recorded sessions. In some occasions some groups were only educated with interactive videos to compare live education and interactive video education.

Figure 6: Example of JavaScript for the Airbit.

7 WORKSHOP FOR UNIVERSITY STUDENTS

The basic structure of workshops for university students is similar to the one for primary school students (online subscription etc.). First, the students get instructions from the teacher. Then they build the drone while the teacher helps to circumvent problems. During this stage, we focus on the making process, and only after the drone is completed, we begin with theoretical topics such as physics (e.g. key factors such as throttle, rotation, or mechanics).

Then, we begin with a block-based pre-tested example, where we explain components like the channel, where the remote control of the drone is and how the drone works. At this step, we explain concepts like signals and frequencies. We focus more on the makekit block-based code to program the Micro:bit and explain simple programming tasks like if and loops (see Figure 2).

Next, we let the participants fly their drone. Most of them crash it at the first attempt, so we have a feedback session on flying the drone and on how to change code fragments and steering components in the code. We discuss the changes and let the students fly the drones again. During the workshop we create a shared document as a theory and error handbook of the drone, where every student is free to add and adapt information.

The workshop described in the previous paragraph is an offline workshop where students meet and mostly work on their project on campus. Of course, the university workshops can also be held purely online. In offline workshops, we focus on team building and on establishing social skills, while in online workshops we focus mostly on knowledge transfer. The current pandemic revealed the necessity to extend the supply of online courses and to improve digital teaching methods. Norway is a pioneer in online teaching and has been offering a large variety of digital University courses over the past ten years. This is partly due to the fact that campuses can be widespread over a large geographical area. This means that there are generally a higher number of online students. One example is the University of Tromsø with its campuses in Tromsø, Narvik and Bodø.

However, workshops that are held exclusively online have one major disadvantage: The loss of social interaction, especially for first-year university students, which is very hard to compensate. The feeling of belonging to a study group and to make friends who share common interests must not be neglected. As a consequence of the large supply of online education, even students who only live a short distance from University prefer to stream their lectures from home, which often results in deserted campuses.

With university students we specifically focus on team building, social skills, and communication, which is why we devote as much time to knowledge acquisition itself as to creating a knowledge-transfer platform for the students. We also want to highlight the importance of hardware in a software-focused world, which is why we want them to understand the combination of making and coding. Even at university level, where the students are committed to study informatics, the project-based-learning approach can be used to foster understanding and spark passion for IT and CT concepts and make them more tangible for the students. This is especially useful for first-year students (Krajcik et al., 2005).

Similarly to our previous workshops, our workshops for university students didactically focuses on a project-based approach and on situated learning. In the university, context also means to interconnect different disciplines, such as physics and IT, since a multidisciplinary approach can facilitate understanding and will help to establish a real-life setting. IT students at university-level can profit from this approach, as it can help bridge the gap from pure IT- or coding-subjects to other supplementary subjects. For instance, the drone is a prime example of programming intertwined with electrical engineering as well as physics. The drone could be fitted with sensors for which an interface or a driver could be coded. This way, students can combine their individual areas of interest and expertise to create an inspiring project as well as learn something new or deepen their pre-existing knowledge. (Jonassen et al., 2012; Wood, 2003; Gallagher et al., 1992; Kolodner et al., 2003)

A special feature of our student workshops is "peer instructors": We train selected secondary school students to become multipliers who will then function as instructors in university level workshops.

This loosens up the learning environment and benefits the social aspect by contrasting the usual teacher-student setup.

8 RESULTS

First, we conducted an online series of three different workshops with elementary school children (age range 7-10 years old, with 12 children in every workshop, and with parental guidance). A quiz with a maximum score of 100 was held at the beginning and at the end of the workshop.

In workshop 1 and 2 the parents were urged not to help with the quiz. The points from the first and second quiz were added up and averaged out. At the end of the workshop the children were asked to rate the project, how they like it, from points ranging 1 to 5, with 5 being the best one. The overall assembly time was also conducted. One point was if the building process was accomplished successfully.

In the first workshop we had in addition to the child one parent as the assisting person to help with the project. They only received an instruction lecture on how to assemble a drone. For workshop series 2, the child and the parent were compelled to work with the shared assembly simulation in order to get familiar with the imminent task. In addition, they also received a lecture from the teacher. For workshop series 3 the kids were working alone, the parents only helped with the setup for the drone. They received the same introduction as in the second workshop. For workshop scenario 1&2 all the participants managed to assemble the drone. Three of scenario 1 and three of workshop series 2 did not manage to make the drone fly. In contrast for workshop series 3, 6 children did not manage to assemble the drone completely due to screwing difficulties. We were aware that assembling a drone at this early age will lead to difficulties but still 6 children managed to accomplish the building process without any help. We believe that parental guidance at this age is vital in order to avoid mental excessive demand.

	Building process successful	Assembly Time (in min)	Satisfactory Level (1-5)	Pre-Quizzes average score (0-100)	Post-Quizzes average score (0-100)
W1:	9	48	4.3	81	91
W2:	9	37	4.5	90	98
W3:	6	51	4.1	80	95

Figure 7: Test scenario for primary school children.

It can be observed that the average assembly time with additional pre-assembly training is the shortest for workshop series 2. This leads to our conclusion that by using the virtual drone assembly simulation the overall drone assemble process can be shortened by approximately 10%. While the satisfactory level is rather similar it can be seen that the highest score average is achieved for workshop series 2.

For high-school and university students we wanted to show that co-creational has an effect on the overall learning outcome. Therefore, we conducted workshops with 28 students for each workshop. For workshop series 1 the students could use a theory handbook at the very beginning. In addition, they did not use the shared simulation for the drone-building process. They were only given the assembly instructions at the beginning. In workshop series 2 students were creating theory documents collaboratively, training the assembly process with the shared physics simulation and were coding collaboratively. Results can be seen in Table 2.

	Building process successful	Assembly Time (in min)	Satisfactory Level (1-5)	Pre-Quizzes average score (0-100)	Post-Quizzes average score (0-100)	Final Exam
W1:	28	49	4.7	70	88	65
W2:	27	36	4.8	81	96	83

Figure 8: Test scenario for high school and university students.

It can be observed that the average assembly time with the additional pre-assembly trainings simulation is much shorter than for workshop series 1. This leads to our conclusion that by using the virtual shared drone assembly simulation the overall drone assemble process can be shortened drastically. While the satisfactory level is rather similar it can be seen that the average final exam score is much higher for workshop series 2.

9 CONCLUSION

IT is a vital component in our day-to-day routines, and it is impossible to escape it. Learning computing skills from an early age on is therefore crucial to be successful on the job market of the future. If we want to adequately prepare students for future careers in IT, we have to adapt and modernize how coding is being taught in our schools. It is necessary that we attract a wider range of students as well as teachers to this topic in order to combat the skilled labor shortage in STEM fields. This is why we believe that computational and algorithmic thinking have to be included in the curriculum so as to make the subject available to every student (Ntemngwa et al., 2018).

The current pandemic demonstrates that online education is of utmost importance and will have to be extended and developed further over the forthcoming years. The problems we are now facing when using online teaching tools show us the areas that need to be improved to create better learning experiences in the future. Learning how to efficiently use online learning tools takes time and it is an ongoing process for all those involved, if it is students, teachers, or parents. However, it is a huge advantage of these tools to help people connect and share a collaborative learning experience, especially in phases where students cannot meet in person and miss out on the social interaction in private as well as educational settings.

A vital aspect that online education is currently lacking is the possibility to collaboratively work on projects in STEM subjects such as coding and physics. However, shared experiments as well as shared goals are important for knowledge acquisition. Students who learn working in teams when they are young will also have an advantage in collaborative work environments once they get older. What future companies need are competent team players and not individualists. It is therefore important that students learn to work on projects in teams, while they are still at school (Ntemngwa et al., 2018).

The approach presented in this paper focuses on the combination of making and coding as a symbiosis as well as the collaborative aspect of online teaching through shared experiments and game-like simulations. Coding and engineering subjects are taught co-educationally with the help of drone-building and aim to create a platform for knowledge transfer. Students have the opportunity to create a real-life application with a practical purpose while going through all stages of developing a product. We believe that making and coding go together and therefore favor a holistic approach to teaching programming. This is why we chose to teach coding with the help of drones since they give us the opportunity to explain how a system combines hardware and software aspects. We believe that this approach is important because a lot of companies in the tech sector need people with practical skills as well as theoretical knowledge.

The collaborative aspect of online teaching can be found in the way students are included in the thought process and knowledge transfer. Students are not just recipients of information but play an active part as co-educating content generators. Working in teams will help students develop communication skills as well as structural and computational thinking. Collaborative methods are used to compose educational material together and flip the composing process of the educator by letting student groups create useful mathematical material in a Handbook of Knowledge (shared document). The experiments presented in this paper are a step forward in the development of innovative online teaching, yet there remains a lot to be done in this field. The following years will show how online education can be further developed and incorporated into our daily school life.

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