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Practitioner Assisted Teaching of Vital Computational Thinking Skills for a 21st Century Society.

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Acknowledgments

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Thank you.
With all my heart, thank you.

Abstract

The leap from formal education and K-12 schools to a productive, creative and modern work environment is often surprisingly difficult. Having young people struggle in these transitional periods while entrepreneurs and businesses strive to merge new team members seemed like a worthy cause to investigate. Education often lacks the efficacy to integrate modern methods and technologies as the process of teacher education can not adequately cope with the intensity of technological progress. Especially in the field of Computational Thinking practitioners can incorporate hands-on knowledge and act as a vital interface between schools and businesses. Utilising the iterative Action Research approach this experimental study integrated practitioners in the classroom and conducted workshops to evaluate the perceived impacts. Answering the primary research question of **"What consequences has practitioner integration on Computational Thinking education?"** showed an increase in engagement and motivation in the participating students. The problem-solving approach Computational Thinking was utilised to determine the impact of practitioner involvement. Four hypotheses were evaluated by looking at the different stakeholders engaged in K-12 education. Not only the effects on learners were questioned but also the effects on in-service teachers, the participating schools as well as policymakers on a regional level. Additionally, questions about the historical context of Computational Thinking, its beginnings in 2006 and previously conducted field studies have been researched and answered. Due to the ongoing pandemic, a research question determined the impact and potential benefits of remote teaching for a post-social-distancing world.

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1 Introduction

This research project looks into the question of how practitioners from different fields can be included in the education of K-12 learners and improve the learning outcomes. To explore these goals a skillset named Computational Thinking (CT) was utilised, a problem solving approach popularized since 2006 and included in Austria's K-12 education curricula. The combination of problem solving, practitioner integration and project-based learning was researched in a number of workshop settings in K-12 education. The research design of Action Research (AR) allowed for an iterative process to gain a deeper understanding of the needs and customs of learners as well as educators. The skillset taught by the problem-solving methodology CT is an incredibly important asset for today's students (Wing, 2006). An increasingly complex and interesting world filled with a multitude of opportunities and challenges awaits young, growing up adults today. Exactly this uncertainty makes CT extremely valuable as it enables every learner to "bend computation to [their] needs". Only a very small percentage of today's students need to become master computer programmers, coders or software developers. In our digital world, it is more important to enable everybody to understand the basics of computing and the principles that allow tech-savvy experts to tackle the complex problems future generations will encounter (Bocconi et al., 2016). Carnegie Mellon University (CMU) scholar Jeannette Wing proposed that ultimately CT "is becoming the new literacy of the 21st century" (Wing, 2011). Her initial ideas led to a flood of vital case studies, exploring the ways and methods these important skills are currently taught. These case studies and experiments range broadly in age groups and specialisation, from young kids to adult lifelong learners (Grandl and Ebner, 2018; Wolf

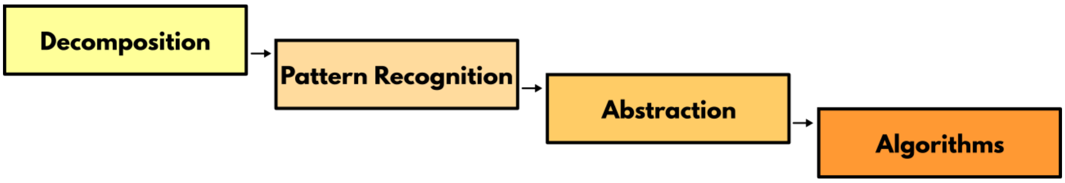


Figure 1.1: Primary Steps of Computational Thinking.

and Ebner, 2018a). These experimental settings are found in very diverse areas, from formal school environments and classrooms to makerspaces and after school events, all around the globe (Menon et al., 2019). Incredibly valuable far outside the technical community, these skills allow scholars and learners to make sense of the world that always changes around them. The problem-solving approach "draws on skills and professional practices that are fundamental to computing and computer science" (Sengupta et al., 2013, p. 3). The research at hand primarily adopts the definition of Csizmadia et al. wherein CT "is the process of recognising aspects of computation in the world that surrounds us and applying tools and techniques from computing to understand and reason about natural, social and artificial systems and processes. It allows pupils to tackle problems, to break them down into solvable chunks and to devise algorithms to solve them" (Csizmadia et al., 2015).

Based on this definition and according to Wing (2011) everybody should be able to

1. Understand which aspects of a problem can be solved with a tool,
2. Evaluate if a specific tool can solve a problem,
3. Understand the limitations of computational tools,
4. Adapt a computational tool to a new use,
5. Recognize new ways to use tools, and
6. Apply computational strategies in any domain.

For educational purposes, a shortened framework can be adapted to be practical and easily accessible in a classroom setting. This four-tier approach, illustrated in figure 1.1, is used for example by the BBCs popular MOOC "Bite-size" in the subject "Introduction to computational thinking". These steps will be analysed in detail in the later chapter entitled "What is Computational Thinking". The first goal of this study is to determine the state of the art and explore what exactly has been researched and implemented to teach CT at the K-12 educational level. The term K-12 includes primary and secondary education and signifies an age range between kindergarten and twelfth grade, ending in the Austrian education system with a examination called "Diplom- und Reifeprüfung", a form of high school diploma on the ISCED level three. An Austrian exception is granted for vocational schools where one additional year of formal education leads to an ISCED level five graduation, see figure 3.3. To form an initial baseline, a literature review resolved what elements CT consists of, according to the available definitions and what the scientific community makes of the proposed term. This led to insights and the first publication based on the research project at hand, titled "The missing link to Computational Thinking" (Pollak and Ebner, 2019). It looked at three main research questions, as this initial research presented a historical breakdown and a potential outlook into the future. To allow the historical perspective a first research question was evaluated seeking to answer: "When was CT first described and what happened since then?" The second part of this initial publication looked for literature reviews conducted in the field of CT and outlines its significance in an educational and institutional context answering "What were the most important literature review works in the field?". A third part looks more specific into how CT has been taught and evaluated in K-12 education, within institutional settings and makerspaces with a focus on European research "What has been tried to integrate CT in K-12 education?" This literature research built the basis for subsequent case studies to experiment within exemplary Austrian K-12 classroom settings with the ideas and principles present in makerspaces around the world to allow for a more practical and engaging learning experience inside established educational institutions.

A case study planned to establish a hackathon setting and challenge learners to engage in practical problem solving, with the assistance of outside experts and practitioners. The "Startup Challenge 2020" was envisioned to bring ideas from the learners to the forefront and potentially enable them to create prototypes and experience a little part of the startup and makerspace atmosphere. This challenging approach worked well for a number of published case studies in the past and the outcomes were described as favourable overall. To determine the potential of this approach for practitioner integration with a focus on CT education a pitch session was held in our partner school in Lower Austria and students showed a lot of interest to participate. This happened in March of 2020 and sadly shortly after that all educational institutions went into lockdown and were forced into a remote learning setup due to COVID-19. This case study had to be postponed indefinitely despite growing interest from the schools perspective. A paper (in German language) was written to outline the plans for the hackathon set up with the goal to publish results right afterwards. The research question posed in this publication was "How can outside practitioners support CT education?" (German original: "Wie können außerschulische Praktiker*innen im Computational Thinking Unterricht unterstützend wirken?"). Despite the unfortunate timing this paper gained some interest and will be used to inform future projects.

After a very long period of uncertainty, it was decided in December of 2020 to experiment with the effects of remote learning and build a case study around the at the time very interesting situation. Allowing practitioner integration within a virtual classroom from around the world seemed like a potential game-changer for education that can look outside its respective bubbles. To determine the feasibility a four-session workshop was envisioned and planned to be conducted within a classroom integrated subject in a secondary school in Lower Austria. This is discussed in detail in a later part where the following three research questions are answered. To determine the place of remote learning the following question was asked "What effect has remote learning on practitioner integration?". Also, a control group's performance was pitched against a test group establishing "What learning outcomes does a flipped-classroom approach lead to?". Ultimately the goal is to look to the future and determine the implications of the situation in 2020 and 2021 by asking "What lessons can be learned for a post-social-distancing world?".

1.1 Motivation for Practitioner Integration

The leap from formal education and K-12 schooling to a productive, creative and modern work environment is significant and often surprisingly difficult. Having young people struggle in this transition period while entrepreneurs and businesses strive to integrate new team members seemed like a worthy cause to inspect. With a growing software development business and a lifelong interest in education, it seemed logical to learn about, understand and ultimately improve this complex situation. Too much time, effort and excitement is lost during these transitional periods while youth loses the interest and curiosity needed to better the outlook of future generations. The main motivation for this ongoing research project is to offer new perspectives to schools, educators and learners about learning in general, Computational Thinking as a problem solving skill in particular and the entrepreneurial process.

Entrepreneurs and practitioners are very much interested in assisting young people to learn and foster their skills. It's not merely altruism that leads to this investment, obviously new talent and curious young minds are a valuable proposition to every thriving business. Here the educational system can develop new interfaces between learning inside and outside of the school building. Especially historically marginalised and diverse young people struggle to find a connection with the IT sector. Despite this fact these minds are incredibly valuable to build the tools needed for future generations. The significant digital divide has been highlighted in a number of research studies but has never been as much of a focus as other empowerment issues have been in the past. As digital infrastructure becomes more and more crucial the topics start to align and have to be addressed in unison to understand the critical issues linked to them. This research project found and still finds interfaces and potential for collaboration between different stakeholders in an effort to make education more accessible, more diverse and more current.

Computational Thinking is one of the broadly applicable skills for young professionals and thus the projects and workshops were developed around this concept. At the same time CT stands for much more, it can be a placeholder for a broad range of potential skills. As argued by Martin (2018) CT is the tissue that can connect computer science with the knowledge of every discipline. No profession today can do the work and engage in a productive discussion without the tools and methods computer science offers.

The combination of these factors can lead to improvements in formal and informal education and showcase a potential pathway in a future led by bright young and engaged adolescent. A lot of recent developments like the Fridays for Future (FFF) movement or Black Lives Matter (BLM) show the potential of this generation of thinkers, makers and influencers. Let us strive to give them the tools to build a better future.

> "Change never takes place from the top down. It always takes place from the bottom up." - Bernie Sanders

1.2 Systemic Challenges and Problems

Staple elements of formal education are slowly developed in specialised teacher education formats while the world is focused on cultural, social and technological changes. Schools exist as a mostly locked down entity in society, kids are hosted to learn an array of skills and facts to give them a shared baseline of understanding. Over the last decades the cultural context changed incredibly fast, new technologies outpace teacher education in unimaginable ways. While researchers around the world experiment with new and better approaches to education, K-12 learners rarely can benefit from current developments. The rotation of teacher education and prior research is simply too slow to make a difference in the real world. This is why practitioners from all walks of life can offer more direct pathways to school policymakers, to bridge the efficacy gap often found. The methods and interfaces with which engaged practitioners can offer their assistance and policymakers can integrate these outside experts into the Austrian schooling system are not yet established.

Resources in local businesses and striving startups often are made available to young learners and educators but the links and interfaces between these two very distinct worlds are missing. The civil society is ready to assist and host young people in their quest to gain insights into connections and networks as well as make their first steps in a sustainable future. These crucial affiliations are missing, the entrepreneurs and scientists have limited perception to find out about critical needs, to understand and learn about necessary changes and to help host fruitful workshops and interventions.

CT and the current integration in various international curricula open up a potential interface for practitioner integration, allowing for a more interdisciplinary approach in formal education. Schools benefit from the vast amount of knowledge available in the world surrounding these institutions while businesses and companies receive viable information from potential future partners, contributors and customers. These practical projects, based on real-world needs and requirements allow learners to get a glimpse into their future work environments while learning about current problem solving approaches in the field.

In today's abundance of open educational resources (OER) and the growing market for paid offers like teacherspayteachers.com and eduki.com/de, the problem for learners is not the availability of content but the lack of personal interaction. This can be seen and has been researched within online courses like the MOOCs at IMOOX.at, humans are more involved and interested in topics that they can share with other people, interact with experts and create stories together. Merely offering content is working for some pupils but hardly all of them. The project at hand tries to bridge this gap by introducing real world knowledge and outside content experts in the classroom. Gathering the didactic expertise from knowledgeable and experienced teachers while offering personal connection, the stories of practitioners and the currency of their knowledge to overcome the content focussed approach of other case studies.

1.3 Relevant Stakeholders in Formal Education

K-12 education is a complex and intricate setting to investigate. A number of institutions and stakeholders are deeply involved, some evident while others remain in the background. Within schools, teaching staff and students are the most obvious stakeholders but attached to their needs and expectations are parents, family members, local businesses, policymakers, politicians, scientists and many communities that have different expectations and requirements. Changes in the educational systems all over the world are slow, and this is by design as not to allow narrow-minded swings of focus for example by politicians or society to interfere with the fundamental development of knowledge. This slow and deliberate evolution assisted societies in the past and still is a good point of reference when the societal context shifts. Being aware of this overarching goal some developments are not short term but here to stay. Technological progress is quick and currently outpaces teacher education tenfold. At the other extreme businesses, practitioners and scientists find themselves in a position where schools are not fully equipped to educate youth for the state-of-the-art methods and approaches necessary.

A 2021 open letter from German edutech companies shows how willing and able startups and businesses are to interact with and support the formal education processes. The pandemic in 2021 illustrated how valuable a sustainable and redundant system is to overcome unexpected hardships as well as systematic problems, see iddb.school.

Who is a Practitioner

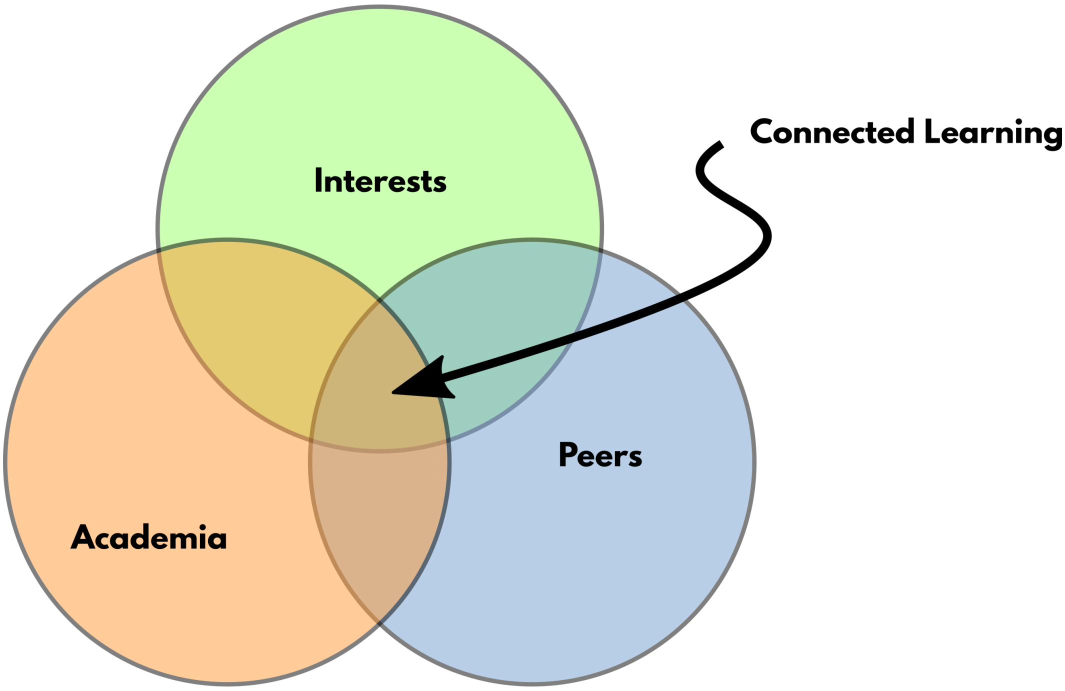


Figure 1.2: Spheres of Learning according to Ito et al. (Ito et al., 2013, p. 63).

The term practitioner envelops a broad number of subject matter experts, according to the Cambridge dictionary it literally translates as "someone involved in a skilled job or activity" (*Practitioner* 2021). In the concept of this research project practitioners spread a diverse range of interdisciplinary knowledge and experiences. Entrepreneurs, scientists, developers, craftsmen and artists can offer young people new insights into their practical problem-solving skills, outside of sterile school settings. Especially in the realm of Computational Thinking, practical projects and first-hand experience lead to a much better understanding and offer a broader perspective for future development. Authentic challenges that entail all the complexity of interdisciplinary projects found outside of formal education host a solid base for real-world Computational Thinking. Practitioners, in this frame of mind, are content specialists usually with little to no experience in classic pedagogy and didactic training. Teachers are specialists in the fields of didactics and working with young people but often are lacking the content knowledge and up-to-date skillsets many practitioners can provide to the learning environment.

1.4 Imagining Interfaces between Schools, Science and Businesses

The goal of this research project and the underlying motivation for conducting a multi-year study on practitioner integration in schools is to imagine a future that is more conducive for young people to understand the world around them. There is a big claim in the scientific literature that Computational Thinking skills allow students to better deal with complexity and the open-ended non-trivial problems posed by a world ever more uncertain and unpredictable. This research hopes to showcase one possible way that leads to a generation more adept to tackle the imminent challenges posed by the climate crisis, artificial intelligence (AI) and the societal troubles triggered by widespread automation.

A series of project-based, practical and self-motivated case studies was not only able to evaluate the already existing knowledge of participating students but also guided future use cases for practitioner integration. Solving trivial tasks is not the main skill young people - the leaders of tomorrow - need in their future work or academic environment. Creativity and so-called higher-order thinking skills are powerful - and necessary - tools within our ever-changing complex global economic and ecologic system.

> "Today's students will be confronted with a never-ending stream of unknown, uncertain, and unpredictable situations throughout their lives. Their success and happiness will depend upon their ability to think and act creatively." - Mitchel Resnick
> (Open edX, 2015)

To reach these big goals the European Union, as well as the United Nations, have created several smart and valuable frameworks that outline a future worth imagining. Two of these frameworks were especially important to understand the future this research project tries to engage with. On the one hand, the digital competence framework offers the analogy of swimming with the digital realm as a massive ocean infrastructure. This framework showcases eight levels of competence, possibly borrowed from the eight ISCED levels of education, see the illustration in figure 1.3. The first and second levels offer a solid foundation where simple tasks can be completed with different levels of interaction and assistance from the outside. These levels focus on mere remembering of approaches and lead to levels three and four that focus on understanding and independence. The guidance of others in independent problem solving is classified as an advanced skill and introduced in levels five and six. Creating new content like coding a new software application and contributing to the professional practices fall inside this level of knowledge. Sharing questions and answers on the popular network stackoverflow.com is an exemplary goal of the seventh level. To resolve complex problems and develop new approaches to problem solving the final learning level of eight is added, a goal that for a majority of people in most circumstances is not necessary to achieve. For the conducted

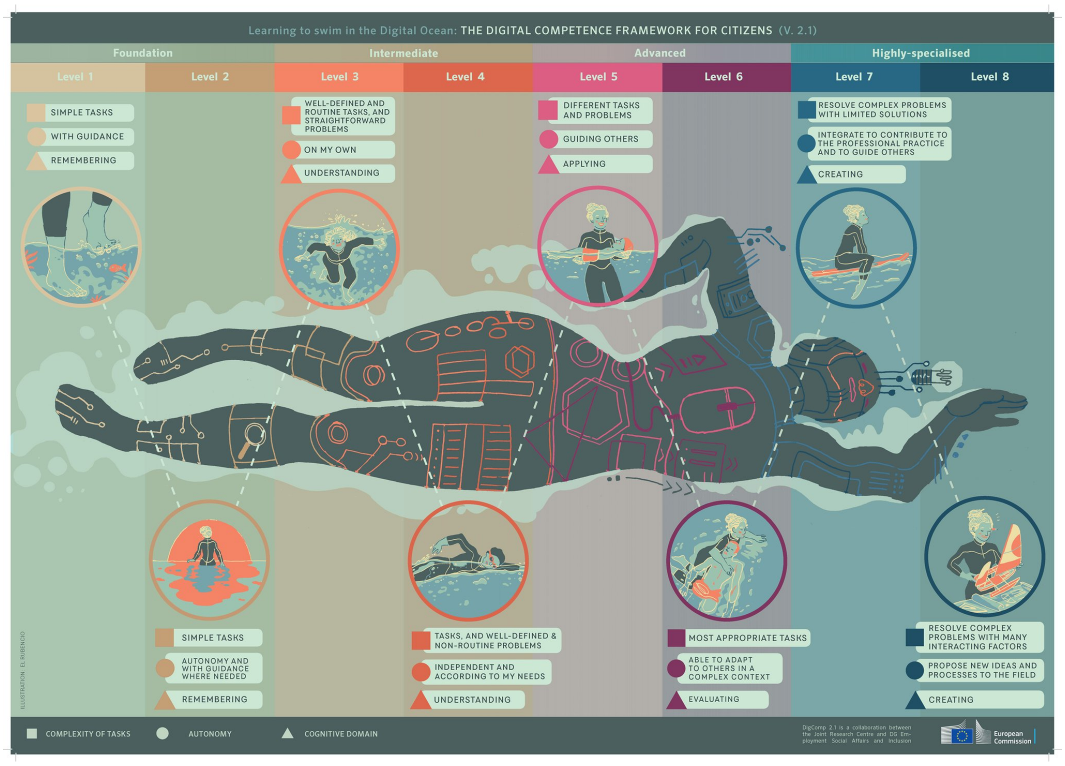


Figure 1.3: The Digital Competence Framework (European Commission. Joint Research Centre., 2017, p. 14).

case studies the goal is to generate a level of understanding and curiosity, that can in the event of further interest allow the learners to interact more with the subjects and become independent scholars.

The second important set of guidelines that inform the research at hand are the 17 Sustainable Development Goals (SDGs) that have been developed by the United Nations (UN) to understand the most needed and influential sectors of society to ensure a good life for everybody (*THE 17 GOALS | Sustainable Development* 2021), see the official illustration in figure 1.4. The fourth Sustainable Development Goal led by UNESCO is called "Quality Education" and is targeted to ensure "inclusive and equitable quality education and promote lifelong learning opportunities for all" (*Goal 4 | Department of*

Figure 1.4: The 17 SDGs as defined by the United Nations in 2015.

Economic and Social Affairs 2021).

Based on established research work currently done in the field the difficult stance of CT as a problem solving approach is obvious. As long as the ways in which teachers are educated and re-educated is not changed and institutional willingness is not fully invested in the future integration, it seems that progress can be quicker and easier made outside of the rigid school systems. Outreach programs, as shown by a number of research studies, can integrate CT in the everyday routine of invested students while engaging new and diverse students in sustainable solutions, higher-order thinking skills and ultimately in the professions linked to STEAM. This research project and the subsequent case studies presented in this dissertation proposes a different path by exploring the chance to bring experts with practical CT problem-solving skills into classrooms and the commonly found institutional settings of the world.

The problem-solving methods of maker education - often found in and referred to as constructionism - are closely related to the ultimate potential of CT. It seems prudent for all STEAM disciplines to align resources and expertise, to foster a new generation of experts. The paper at hand strives to develop immediately employable methods and a sustainable framework to bring outside subject matter experts and practitioners into the classrooms, allowing young students to make sense of the implications and develop their skills by repeatedly querying people with practical knowledge. While schools and educational institutions struggle to raise teachers' awareness and efficacy in all technological matters this massive potential remains bare and underdeveloped. Professional interactions and integrations can and should be developed to find ways of inviting outside knowledge, practical expertise and useful technologies into formal primary and secondary education.

Allowing youth to solve challenges in ways experts and engineers around the world do, by giving them the tools and constraints present in the outside world, they learn to utilise the most powerful tool they possibly can - their brain. Informal learning is surely important but to sustainably solve massively complex and interesting problems like the climate crisis, artificial intelligence and sustainable capitalism the young minds of our society need to be given the best tools and skills within the powerful structures of our public education system.

1.5 Primary and Secondary Research Questions

To enhance the knowledge in this field and establish new findings within the scientific community a number of research questions have been answered over the last few years, allowing some conclusions to be made while being conscious of the limitations of this work. Overall one primary research question stood in the centre of this project, interfacing elements of modern education, technological advances and current problem solving approaches in education. The overarching question was - and still is -

What consequences has practitioner integration on Computational Thinking education?

Obviously, this question has many distinct elements and an attempt at answering it with all its details led to this research project. Multiple secondary research questions were defined to allow useful answers as well as offer necessary background information to stakeholders. To establish the historic baseline and reasonable background knowledge, ultimately leading to the "State of the Art" chapter, the term CT was first defined and established properly in its foundations. A historical breakdown to gain an in-depth understanding of its initial meaning as well as its connotations over time was one major element of this work, answering the research question **"When was CT first described and what has happened since then?"**. To outline its significance in an educational and institutional context previous literature reviews were also analysed. During this process a meta-analysis was conducted to understand the relationship between research projects and published literature, finding **"What were the most important literature review works in the field?"**. The way in which CT has been taught and evaluated, with an intentional focus on EU research, was determined by answering the question of **"What has been tried to integrate CT in K-12 education?"**.

Due to the COVID-19 pandemic, remote learning became the norm - at least for the time being - and a case study was conducted to find its place in practitioner integration efforts. The leading research question for this case study was to determine the effectiveness of remote learning when practitioners can be integrated into the CT context. Additionally, two distinct groups were tested in two teaching modes where the utilisation of a flipped classroom environment for practitioner integration was evaluated and compared to a more classical workshop-style session. Lastly, the interaction between the currently forced remote learning environment and its potential in the future educational landscape was discussed answering **“What lessons can be learned for a post-social-distancing world?”**.

1.6 Hypotheses on Perceivable Effects

This research project led to a number of hypotheses based on the questions determined by the involved collaborators. The impact provided for every entity can be divided into four distinct perspectives.

Practitioner Integration for Schools
Schools can benefit from outside expertise and current knowledge that is commonly utilised in science, technology and engineering to develop up to date curricula.

Practitioner Integration for Policymakers
Policymakers can mitigate the lengthy process of updating teacher education by offering interfaces between practitioners and teaching staff.

Practitioner Integration for Teachers
Teachers can focus on their expertise in teaching youth while pulling subject matter experts’ knowledge into the classroom environment.

Practitioner Integration for Learners
Learners benefit immensely from interacting not only with teachers but also with a wider societal expertise by enabling hands-on, current, real-world and project-based learning.

1.7 Thesis Outline

First, this thesis builds a framework of current knowledge and understanding of the scientific community. Terms, definitions and the state of the art will be explained and gaps in the current understanding are outlined. The research methodology used to create new knowledge is emphasised and a synopsis is developed on how the research questions can be answered. The conducted case studies are explained and reviewed in detail. The results and findings are broken down and analytical steps are presented. During the discussion, crucial bits of data are compared to the currently available knowledge and their relation to the initial hypotheses is set up. Lastly, the conclusion proposes answers to the research questions and ultimately outlines a path into the future for further research.

2 State of the Art

> The initial findings of this literature review have been published in Future Internet 11.12 (Pollak and Ebner, 2019).

For a comprehensive overview of the current state of the art, a literature review was conducted, looking at published research from 2016 to 2019. The chapter Methodology will dive deeper into the specific challenges and approaches that were concluded following the state of the art. An initial search for publications on the broad topic of Computational Thinking was started, limited by the specific keywords of K-12, children and school. During this research, a vast number of publications was collected and reviewed based on a snowball approach, where, after reading one publication the most important citations were classified and also reviewed. This collection of knowledge buildt the fountaintion for the document at hand. Continuous interaction with international research groups and thought leaders in the field, facilitated by the online platforms researchgate.net, academia.edu and twitter.com offered pointers on other literature and linked research areas to bolster the foundational elements of this work. Based on all the documents and publications evaluated and reviewed the chapter State of the Art shows current knowledge, in the affected areas of expertise, that are valuable within this intercepting fields of education, problem solving, Computational Thinking and practitioner integration.

2.1 Literature Review

The starting point for this research endeavour was a detailed look at the currently available body of literature to determine the state of the art in the field of Computational Thinking in education. Multiple search engines were used to gain an understanding of their benefits and drawbacks with the conclusion that the well-respected search engine Web of Science (webofknowledge.com) offers a solid starting point to answer these pressing questions. First search queries were based on publications from the year 2016 up to and including the year 2019 to analyse what significant progress has been made in the field of CT. Initially, the term "Computational Thinking" was the solely targeted term, leading to a huge amount of partly irrelevant documentation. Looking for all papers including "Computational Thinking" in the subject field yielded 1.175 papers as an initial result, indicating the need to restrict the potential hit possibilities to a more manageable amount.

This study at its inception focussed on a school setting, so the word "school" needed to appear in the topic line of relevant publications. Thus the search query was amended to the following where the shorthand TS looks in the fields title, abstract and keywords of the record and the shorthand TI looks at the title separately:

TS=school AND TI=Computational Thinking

As this leads to many false positives either featuring very young kids or lifelong learning settings the term K-12 was also amended. This signifies educational settings starting at the kindergarten level up to grade 12 which makes the learners between the ages of 6 and 18 years old. Thus the search query was:

TS=(K-12 OR school) AND TI=Computational Thinking

Within our specified time range of 2016 to 2019 this leads to 151 potential publications that were added to the reading list for this research project.

Curiously the search query that looks only within the title field of potential research led to merely ten appropriate articles which were also added to the potential candidate list.

TI=("computational thinking" AND K-12)

Focussing on the subject matter that was added by the research teams the following query led to 114 results:

TS=("computational thinking" AND K-12)

Probing these same search terms without bracketing the publication dates between 2016 and 2019 led to 196 results indicating that a number of relevant research might have been published earlier. After sorting all publications by the number of citations it was determined that all papers cited more than ten times seemed relevant and were added to the candidate range. To cross-check initial findings several more complex queries were also explored, for example:

TI=("computational thinking" AND school); TS=("computational thinking" AND making); TI=("computational thinking" OR "computer programming" OR coding) AND TI=(K-12 OR school)

The precise wording is critical and different in some countries' educational contexts. To counter this fact the search terms included computational thinking, computer programming and coding interchangeably. The sole term programming is intertwined with different meanings, thus not suitable to gain an overview of computer programming or software development as the expected focus. Regional specificities are also at play as in the UK current curricula use solely the term coding. It is also important that most of this research project's work is written with a focus on younger generations and beginners, deliberately excluding university students and lifelong learners from this literature review. The specific keywords K-12, children and school were added to achieve this goal. To determine the significance of every published work, all potential papers were sorted by the number of citations, all included counts were last updated in August 2019.

A second main source for this literature review, especially with the goal to ensure that no important work was missed during the initial search process, was the database "Google Scholar" (see scholar.google.at). As a redundant search platform, most of the previously checked search queries were recreated and sampled for different results. This evaluation led to only a small number of additional potential publications validating the prior results or the initial literature review.

An example query from the Google Scholar stage is:

(computational thinking OR programming OR coding OR programmieren) AND (K-12 OR school OR schule OR makerspace OR workshop)

Some of the selected keywords are based on a data-driven analysis conducted with the visualisation tool "CiteSpace"[1] (C. Chen, 2006) that found a significant clustering between these terms: "Computational thinking, education, k12, programming, Scratch, computer science education, problem-solving, teaching, learning, secondary education" (P. Chen et al., 2018). For future reference, this thesis includes the full list of search terms linked by AND and OR statements: beginner, case study, children, coding, computational thinking, computer programming, education, K-12, kids, learning, making, makerspace, programmieren, programming, pupils, school, schule, secondary education, teacher, teaching, undergraduate, workshop.

Building upon the initial literature review a vast number of publications was collected based on a snowball sampling approach. During a snowball approach, the key questions are kept in mind but based on initially discovered publications intertwined concepts are found. The previously published literature most often entails a number of curious and important topics not easily identified by other individuals. The snowball approach allows researchers to identify associated concepts. Based on these further pointers a secondary literature review was initiated and concluded with a bigger foundation of knowledge thus improving the quality of research (Ho, 2016; Wohlin, 2014).

[1] For further information see cluster.cis.drexel.edu/ cchen/citespace/.

Category	Keywords
Target Audience	Beginner Children Education K-12 Kids Pupils School Secondary Education Teacher Undergraduate
Intervention	Coding Computational Thinking Computer Programming Learning Making Makerspace Programmieren [ger] Programming Teaching
Study Type	Case Study Workshop

Table 2.1: Search Keywords during the Initial Literature Review.

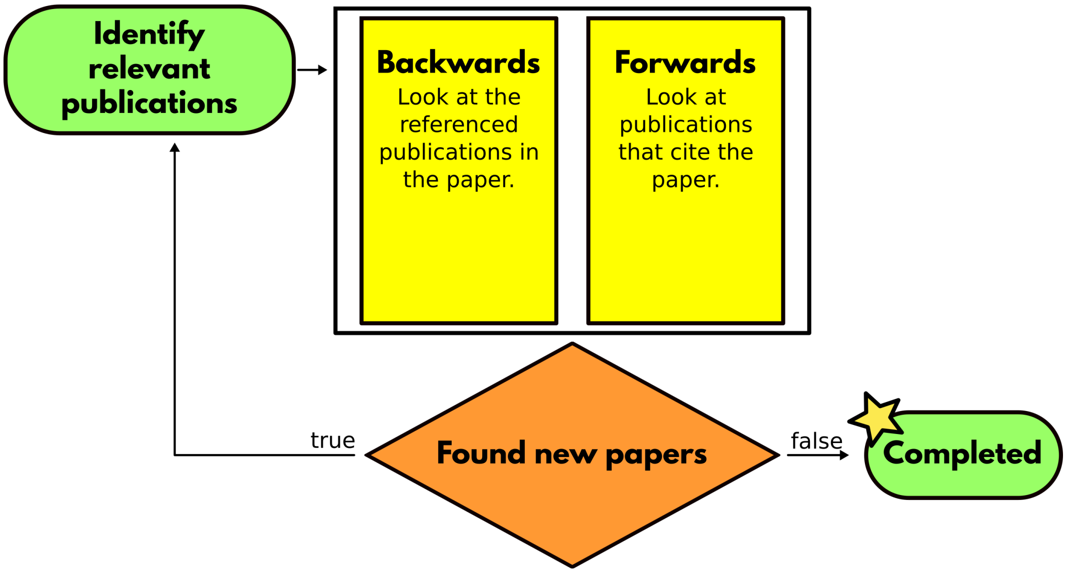


Figure 2.1: The process of a snowballing literature review (Ho, 2016; Wohlin, 2014).

Understanding concepts only loosely associated with the specific research questions allow for a holistic assessment of the situation. In the case of these publications, a lot of further reading was conducted on the key principles of modern education, the details of constructionism and the intricacies of coding education. Every interdisciplinary research team sees a different angle of any given problem thus understanding a multitude of viewpoints hopefully leads to a broader understanding of the research landscape and the associated blank spots. Thus the initial findings of this literature review have been published in the open access journal "Future Internet" (Pollak and Ebner, 2019) and built upon to conclude the research project at hand.

2.2 What is Computational Thinking

Computational thinking is a problem solving approach with the goal to allow complex problems to be solved with a predetermined process. Users can be enabled to reduce complex and intransparent problems to clear

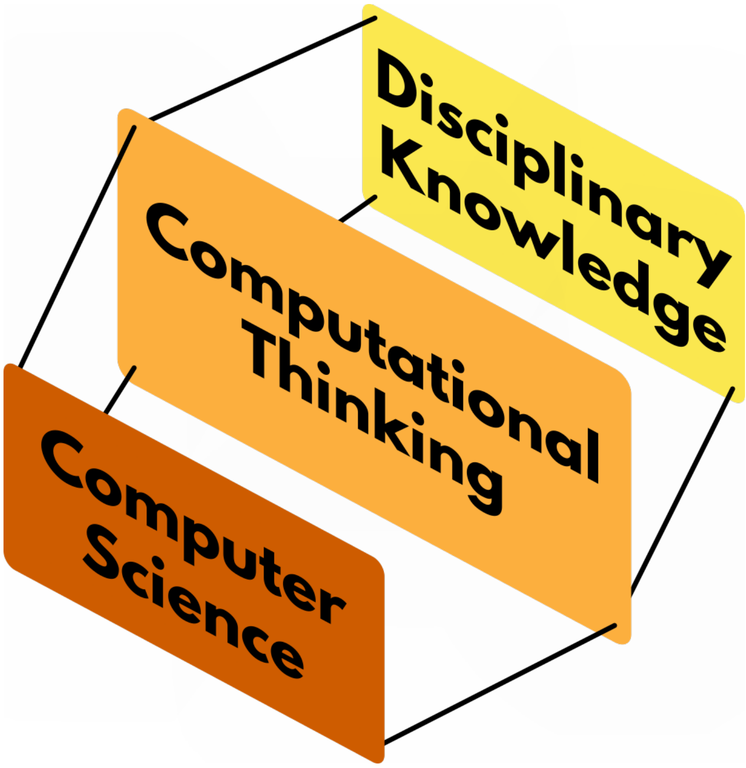


Figure 2.2: CT as the connecting tissue between CS and disciplinary knowledge based on a blog post by Dr Martin (2018).

patterns that can be analysed and ultimately worked on in a decentralised, specialised and technologically literate manner. As seen in the graphical depiction in figure 2.2, CT is the link, the "'connecting tissue' between the world of computer science/programming expertise and the world of disciplinary knowledge" (Martin, 2018)

> "Computational thinking is about connecting computing to things in the real world." - Martin

2.2.1 Historical Breakdown from 2006 to 2021

To introduce the concept of CT a historical timeline offers insight into the challenging development of this problem solving approach over time. The expression Computational Thinking was initially coined by Seymour Papert, popularised by Jeannette Wing in 2006 and better defined in a follow-up publication in 2008 (Papert, 1980; Papert, 1996; Wing, 2006; Wing, 2008). In her seminal paper, she proposed a "universally applicable attitude and skill set" to utilise "abstraction and decomposition" to tackle complex tasks with the mindset typically utilised by practising computer scientists. The introduction and detailed explanation of the approach started worldwide interest and led to a movement to integrate CT into curricula and educational institutions with the goal to "inspire the public's interest in the intellectual adventure" and "spread the joy, awe and power of computer science". These ideals were met with much enthusiasm by the scientific community, signified for example by the high number of citations, according to data retrieved from Google Scholar as many as 7098 in July 2021. Carnegie Mellon University founded, based on this initial success, the now-defunct "Center for Computational Thinking" that hosted seminars covering the topic from 2007 to 2012. As a response to some of the critiques, Wing authored subsequent papers clarifying the objectives and methods encompassed by CT.

Professor Wing posed a number of challenges to the computer science education community, one of which triggered the research project at hand. A host of scientific research has been conducted to understand and evaluate the question posed "What are effective ways of learning (teaching) computational thinking by (to) children?". In her essay, she envisioned that the fundamental approach of CT can and "will be an integral part of childhood education" thus anchoring it within K-12 or even K-9 formal education institutions. Even though the focus in her work is on the public education sector, reaching all walks of life and a majority of young minds in the US as well as internationally she explicitly argues that the potential of learning in informal, afterschool settings should also be explored to better empower young people (Wing, 2006). Certainly, the fundamental ideas of CT can be condensed into other forms of thinking and problem solving that have been argued about for a long time. Potential precursors to the ideas of CT are put forward by diSessa with the basic concepts of "computer literacy" as well as Pea and Grover who established links between current definitions of CT and the concept of "procedural literacy" coined in the 1980s (diSessa, 2000; Grover and Pea, 2013).

The term itself - Computational Thinking - was first mentioned in Seymour Papert's book "Mindstorms: Children, computers, and powerful ideas" in 1980 (Papert, 1980). It reoccurred 16 years later in his 1996 publication with the title "An exploration in the space of mathematics educations" (Papert, 1996). Papert himself proposed that the main goal of CT in education is "to forge ideas that are at least as 'explicative' as the Euclid-like constructions (and hopefully more so) but more accessible and more powerful", a thought pattern that can be seen in a lot of Papert's work after this, in a lifelong effort to establish constructionism in basic computer science education. In his quest to introduce coding to young minds he co-developed a to this day highly praised educational programming environment to teach the basic concepts of computer programming. The programming language Logo with its iconic turtle graphics is to this day used at universities to establish a basic understanding of functional and object-oriented programming. Logo as an integrated development environment specifically targeted at education and youth can be seen as a precursor to Scratch as discussed later. Seymour Papert famously also pioneered educational toys with the Danish plastic brick company LEGO, where the series of actuators, sensors and building gadgets called LEGO Mindstorm is still widely known and utilised in formal education. These brick-based robotic and software development tools are commonly regarded as the precursors to Scratch. A community of makers and the utilization of constructivist views make the tool Scratch, originally developed at MIT media labs Lifelong Kindergarten Group around Mitchel Resnick, incredibly powerful in today's educational environment. Besides the fact that it fits well within the current learning theories, it also shaped the way teachers and learners can cooperate in programming education. Within its envelope of constructivism, multiple patterns of problem solving and thinking in general can emerge and be trained, most prominently visible in today's classrooms are algorithmic thinking, design thinking and computational thinking (Resnick et al., 2009). A case for more constructionist learning at schools was also presented more recently by Dagiene and Futschek who in their publication aptly named "On the Way to Constructionist Learning of Computational Thinking in Regular School Settings" argue that the approach of CT "presents a chance to bring more constructionist learning to schools". In their shared editorial article the link between constructionist learning and educational endeavours in CT is established. Subsequently, the authors proposed the potential goal to "situate constructionism in connection to CT within the wider educational discourse". Nevertheless, it remains clear that it is challenging to create inclusive and sustainable learning materials, especially suitable for an OER environment, to foster the massive potential of CT in a stringent classroom environment with the inclusion of every student's curiosity. So Dagiene and Futschek close their argument with a plea to teachers and researchers alike to develop and publish "more examples of constructionist learning at school" (Dagienė, Futschek, and Stupurienė, 2019). There is a noticeable regional gap in CT research with the USA leading (415 publications) and the EU (351 publications) on the forefront, see figure 2.3. The focus of this research is on the EU and specifically the Austrian educational system.

Over the years and despite the initial success of CT as a problem-solving approach a growing number of critical voices in the community have been established. For example, Chenglie Hu of Carroll University (USA) considered the potential age implication of the pupils learning CT as a crucial part of cultural competencies. In his argument, he considers the teachings of CT with its big claims hard or even impossible to fully grasp at a young age. If CT "is thinking about process abstraction" he proposes "then Jean Piaget's Stages of Cognitive Development may suggest that this thinking skill cannot be effectively taught until adolescence age", making it clearly unsuitable for most of today's K-12 education. His counterargument to the growing adoption of CT in education is that the concept of CT is merely a mixture of different already established ways of thinking, composed mainly

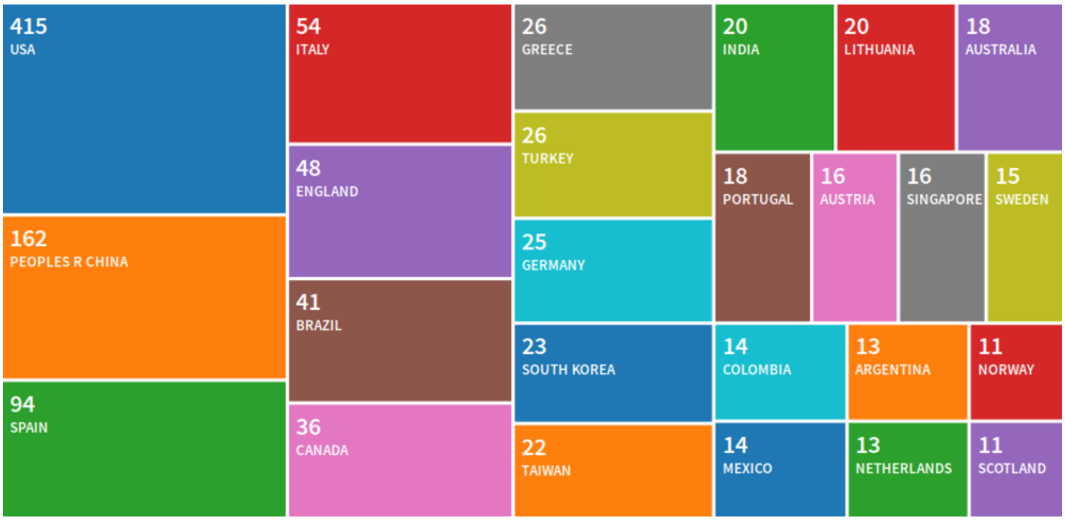


Figure 2.3: CT research papers published by country as generated on Web of Science.

from elements of mathematical thinking (Hu, 2011). Indeed higher order thinking skills have been explored in philosophy, maths and many other fields. An overview of different ways of thinking in computer science can be found in a recent study published by the HCI group at UT Vienna describing the "Ways of thinking in informatics" (Purgathofer and Frauenberger, 2019). Another prominent article proposing a stronger link to mathematical abstractions is written by Alfred Aho in 2012 who in a new definition of CT focuses on the close ties between algorithmic thinking and CT and simplifies the problem-solving approach "CT to be the thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms". The author remarks that ultimately "finding or devising appropriate models of computation to formulate problems is a central and often non-trivial part of CT" (Aho, 2012).

The growth in importance over time, especially if compared to other ways of thinking commonly found in computer science and information technology can be visualised by analysing the popularity of search terms. Google trends outputs data to reference the frequency of searchers' inputs. Parsing this data set a clear trend towards CT as a cultural technique can be established,

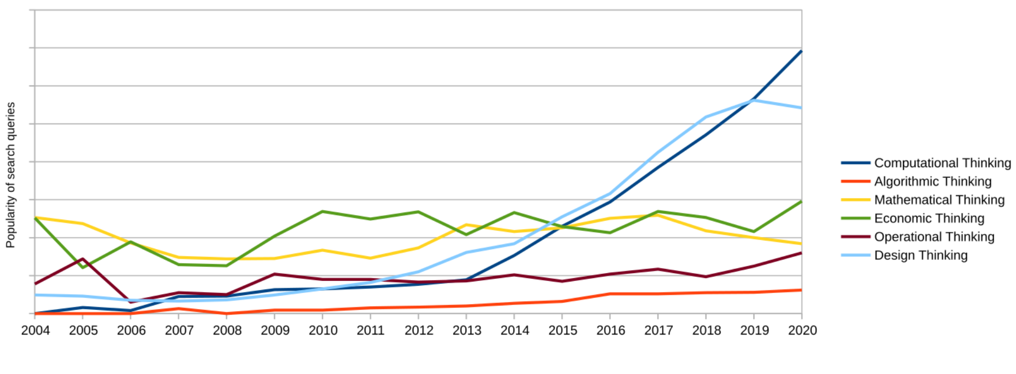


Figure 2.4: Google Trends analysis comparing ways of thinking from 2004 to 2020.

as featured in figure 2.4, showing the dominance over "Design Thinking" as well as "Economic Thinking" and "Mathematical Thinking".

2.2.2 A Closer Look at the Abundance of Definitions

Giving a solid overview of every proposed definition is challenging. These definitions are fluid and change over time, becoming solidified or disbanded. The first mention of the term stems from 2006 and Wings definition is a baseline for future developments. As discussed in the historical breakdown prior research has been conducted in other fields using additional nomenclature. This section will focus on proposed definitions for the term Computational Thinking and how they have been changed over time. The immense discrepancies of competing definitions concerning CT have by now become a meme on the internet, as depicted in figure 2.5 based on a tweet (Jean Salac, 2021).

CT definitions and especially the steps utilised to solve a problem can be grouped into 19 classifications according to a meta analysis conducted by Hsu, Chang, and Hung (2018), as seen in table 2.2. Not all steps are included and mentioned in every single definition because most research projects group multiple individual steps to develop a concise definition.

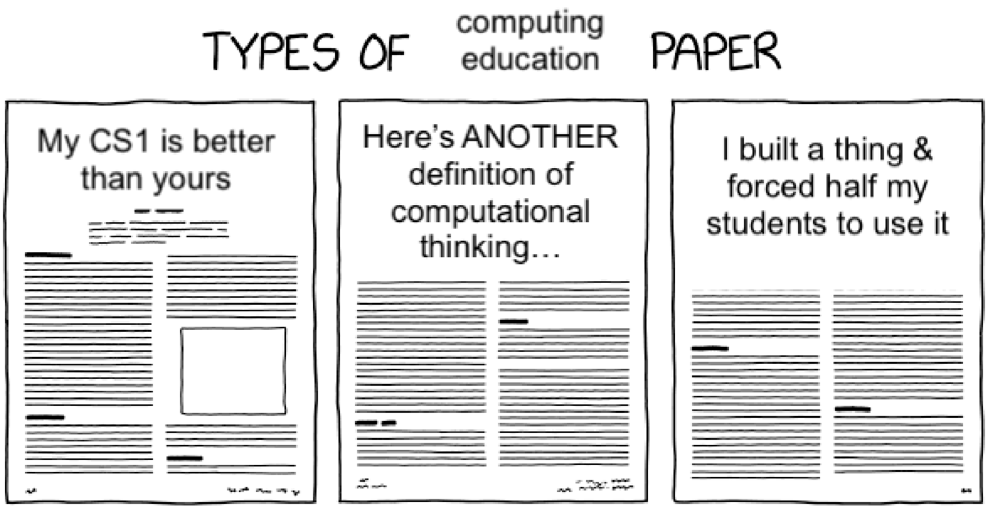


Figure 2.5: Types of computing education publications based on a meme (Jean Salac, 2021).

Nonetheless, most follow in broad terms Wing's understanding of what CT can and should be (Hsu, Chang, and Hung, 2018).

In 2011 Wing offered a seven-step definition. Based on this definition and according to Wing (Wing, 2011) everybody should be able to

- Understand which aspects of a problem are amenable to computation,
- Evaluate the match between computational [...] techniques and a problem,
- Understand the limitations and power of computational tools and techniques,
- Apply or adapt a computational tool or technique to a new use,
- Recognize an opportunity to use computation in a new way, and
- Apply computational strategies such [as] divide and conquer in any domain.
  - Wing (2011, p. 4)

In her 2011 paper, she additionally adds that the following tasks also are elements of CT, especially in an engineering or scientific context.

> "Apply new computational methods to their problems, Reformulate problems to be amenable to computational strategies, Discover new science through analysis of large data, Ask new questions that were

Step	Short Definition
Abstraction (3)	Extract relevant information from complex problem descriptions.
Algorithms (4)	Define an ordered and organised structure that can be utilised for similar problems.
Automation	Use computers to run a repetitive task (mostly) without human interaction.
Analysing Data	Process data and determine relevant elements.
Collect Data	Gathering all relevant information, closely linked to Abstraction.
Conditional Logic	Developing an understanding of dependencies.
Debugging	Determine errors in a solution and optimise ways to avoid them.
Decomposition (1)	Break a challenging problem down into smaller elements to make a solution possible.
Efficiency	Reduce steps that have to be taken to solve a problem, mostly in software development terms.
Interdisciplinarity	Involve the knowledge of other (scientific) fields to determine relevant models and patterns.
Modelling	Systematic solution development that can be utilised for similar problems.
Parallelisation	Run small tasks that are elements of a big project at the same time to speed up their runtime.
Pattern Generalisation	Create models and predictions from observed patterns that can be tested.
Pattern Recognition (2)	Observe patterns to describe a problem or a solution and model accordingly.
Simulation	Imitate and predict real-world outcomes based on models and patterns.
Transformation	Work with and extend upon collected information with mathematical and statistical methods.
Visualise Data	Organise information in a way that can be easier understood and processed, with graphs or charts.

Table 2.2: Based on Hsu, Chang, and Hung (2018, p. 299) Defined Steps of Thinking as discribed in different Proposed Definitions.

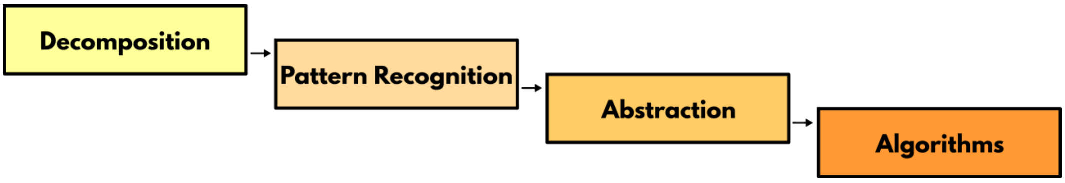


Figure 2.6: Primary Steps of Computational Thinking used in this project.

> not thought of or dared to ask because of scale, but which are easily addressed computationally, and Explain problems and solutions in computational terms." - Wing (2011, p. 5)

In 2015 Csizmadia et al. proposed that CT "is the process of recognising aspects of computation in the world that surrounds us and applying tools and techniques from computing to understand and reason about natural, social and artificial systems and processes. It allows pupils to tackle problems, to break them down into solvable chunks and to devise algorithms to solve them" (Csizmadia et al., 2015).

For educational purposes, a shortened framework can be adapted to be practical and easily accessible in a classroom setting. This consolidated four-tier approach - see figure 2.6 - is used for example by the BBCs popular MOOC "Bitesize" in the subject "Introduction to computational thinking". Decomposition of a problem is named as the first step in this framework. It enables learners to break down a complex task into more manageable, simpler chunks. These chunks also known as work packages can be worked on by smaller groups of students or individuals. After decomposition is completed the smaller chunks of a problem can be analysed and searched for known or identifiable patterns. During this pattern recognition process, computational thinkers were asked to find similarities with other problems and challenges they already encountered from their life experiences. The next step named abstraction looks to exclude unimportant sections to focus on the relevant and significant details of a solution. Often problems look complex and unmanageable from a macro perspective but after decomposition and pattern recognition the abstraction step clings to the necessary and important elements to ultimately solve the problem at hand. Finally, an algorithmic answer can be developed where simple, repeatable and concise steps or rules lead to a usable solution. In CT it does not matter if this means a policy change is implemented, a new work order tested or software code developed as CT is not merely a precursor to coding (*What Is Computational Thinking?* 2014).

Numerous literature review papers have been published, answering how the term Computational Thinking changed over time as well as what ultimately is included in the definitions. One of the more recent articles published stems from Turkey where Cansu and Cansu (Kursat Cansu and Kilicarslan Cansu, 2019) tried to give an overview of definitions and practices. The authors found that conflicting theories have been problematic to the establishment of a concise integration in formal education. They also combine and contrast definitions as well as defining components proposed to be key ingredients of CT. Ultimately the paper cautions to integrate CT in educational curricula without succumbing to populist notions and exaggerated simplifications. One publication with high impact in the scientific community evaluated "all" current definitions of CT in 2017 and added their spin to the growing field (Shute, Sun, and Asbell-Clarke, 2017). One earlier article mapped the elements CT consists of to the prior established "big ideas of computing", to disentangle and clarify the multitude of definitions (Gretter and Yadav, 2016; Grover and Pea, 2013).

2.2.3 Between CS and CT, It's Complicated

The complicated relationship between the concept of CT and the computer sciences (CS) is long-lasting and noted in most publications dealing with the intricacies of previously established definitions. This feud runs so deep that J. Wing in her initial papers felt the need to explicitly state - in the paragraph "What it is and what it isn't", that "Computer science is not computer programming" (Wing, 2008). Another prominent figure in the dispute is Mitchel Resnick, who stated clearly that in his opinion CT "is more than programming" (Council, 2010).

Historically and actually up to today, CS education was mostly and predominantly taught to program mainframe computers - today's cloud computing is an apt analogy - and this meant to write cryptic lines of textual code that can ultimately be executed. Learning a low-level programming language like BASIC - established in 1964 - meant memorising arcane commands and working in a strictly text-based environment without feedback or suitable assistance. This scarring experience is still ingrained in our culture where young learners view the profession of programmers mainly as a solitary exercise of mindfulness.

That learning to think like a software developer can be made more engaging and more playful was proven by Seymour Papert who envisioned the programming environment Logo in 1967 and levelled the ground for the ongoing success of Scratch. These tools and the constructionist methodologies they were created upon made learning to code more intuitive, with the playful LEGO-like brick user interface, more participatory with the Scratch community and ultimately more mobile with the smartphone application Pocket Code (Pollak, 2014).

A very important and thoughtful piece aimed at the CS community was written already in 2009 by Peter Denning, who first elaborated on the unhelpful close links between CT and programming, as it muddies the waters and makes the concepts hard to disentangle from an outside perspective (Denning, 2009). He cautions - justifiably so - that a mere repackaging of computer science professions as CT, only to "replace that older notion with 'CS = CT'" cuts the depth and breadth of computer science as a whole too short. The author reminds in his article that CS is a wide and diverse field and should be presented and understood as such. He reiterates that the seven great principles of CS allow for a much broader conception of our surroundings. In the words of the author "Computation is more fundamental than CT. For this reason alone, CT seems like an inadequate characterization of CS". Hemmendinger in 2010 concurred that the diverse goal of CT is not to educate more programmers but that CT "is to teach [learners] how to think like an economist, a physicist, an artist, and to understand how to use computation to solve their problems, to create, and to discover new questions that can fruitfully be explored" (Hemmendinger, 2010). The complex and often contradictory nature of the relationship between CT and the field of CS is furthermore described by Barr and Stephenson, who also tried to determine what role the CS community plays in "bringing computational thinking to K-12". Curiously researching the contradiction between on the one hand allowing CT to act as "a problem-solving methodology that can be automated and transferred and applied across subjects" to solve complex problems on a global scale, on the other hand, the very wording that entangles the fields and somehow links CT to CS and specifically programming (Barr and Stephenson, 2011). As the paper at hand in its entirety shows, this complex relationship is disputed to this day, as some showcased current articles in educational contexts still treat CT as a subfield of programming education. Finally, and also pointed out by the authors, policies and curricula are a very complex problem, the politicised nature of K-12 CS education is a challenging terrain to traverse where any "effort to achieve systemic change in this environment requires a deep understanding of the realities of the system", further arguing "embedding CT in K-12 requires a practical approach, grounded in an operational definition". Ultimately Barr and Stephenson show that the greater CS community can assist in achieving systematic change by giving "clear examples of ways it applies to and can be integrated into a range of curricular areas". Luckily, this is happening already, expedited by numerous initiatives featured in this thesis. One example of a crucial open educational resource (OER) is a freely downloadable book featuring the BBC micro:bit microprocessor (microbit.eeducation.at) and can be used without much overhead by interested educators to teach K-12 students CT skills with hands-on projects.

The field of computer science has been used as a catch-all by policymakers in the last decades, from educating computer literacy to privacy and making. It became clear that pushing more and more content in already filled curricula will result in frustration and lasting misunderstandings. The problem solving approach of CT can and should be utilised in a practical way in all educational subjects, just like reading and writing, as it slowly becomes one more cultural technique young learners can utilise.

2.2.4 Learning Through Programming

Programming or coding is merely one way to engage in CT, it represents a simplified scaffolding but should not be seen as the only possible avenue. As discussed above CT is much more, it is a way of thinking and solving problems without restrictions to a specific field or profession. The possibilities are endless and educators need to engage in a constructive and interdisciplinary dialogue to understand the value and chances CT offers. Especially in the early years of CT education, it was often discussed as a way to become better at programming and coding. The historical breakdown has shown that definitions varied widely with some proponents arguing that CT is mainly learned by writing computer code. This is still one way to introduce students to the concepts and main principles as shown in several prominent studies but not the prefered pathway towards a diverse set of skills (Tarkan et al., 2010; Touretzky et al., 2013; Kazimoglu et al., 2012).

2.2.5 A Question of Age

Computational Thinking has been taught to many age groups with different methods and rates of success. One of the earliest developed curricular frameworks finds children as young as six years old to appreciate and utilise CT as a skill (Angeli et al., 2016; Chiprianov and Gallon, 2016; Marinus et al., 2018). Of course, learning a skill has no upper age bracket, but most research has been done at universities and capped with adult participants. The author was not able to find CT courses or education in a lifelong learning setting specifically targeted towards senior citizens.

What age group benefits the most from CT skills is an open question, and has been discussed for this research project. As one of the main ideas is to introduce practitioners, project-based learning and potentially offer a pathway inside businesses and the sciences for participants, the project partners chose to work with K-12 students. More precisely between 17 and 18 years old as this age range in Austria is about to leave school and start their individual careers. Potentially other age groups benefit more from an early introduction of problem-solving skills. As shown by case studies in a maker education context the early development of CT concepts leads to a better understanding of problem solving at a small scale at first with the potential to interdisciplinary and large scale solutions with gained experience.

2.2.6 Qualifying Cultural Impact of CT

Especially in today's society the need for citizen science and digital literacy is obvious and failing to implement it in the education system at an earlier stage leads to a number of major problems. The impact of computers and smartphones on everyone's life is tremendous and game-changing. Thus the policies have been implemented to slowly allow educational institutions to teach and convey modern technologies. CT is one of many possible approaches to finding solutions to problems in an organised fashion. By definition, CT is tool and technology-centred. One valid criticism is that not all aspects of a problem can be solved or even described by a technological system. Thus it is clear that a toolset is necessary to allow for a messy and uncertain process in a messy and uncertain environment.

> "[CT] focusses [sic] on a very selective lens through which to view the world. Problems that are unlikely to have computational solutions (e.g. ethical dilemmas, value judgements, societal change, etc) are ignored."
> - Easterbrook (2014)

As part of the study initiated by the European Commission in 2015 Bocconi and his team of researchers produced an initial review of the available academic as well as grey literature. The project's title was CompuThink, intending to generate "an analysis of educational approaches to developing Computational Thinking" as can be read at the project's website ec.europa.eu/jrc/en/computational-thinking (FUCCI, 2016). Notably, the website's definition is not shared by most researchers as "thinking like a computer scientist" is not and was never the gist of CTs success. The main and foremost takeaways from this research paper are on the one side the underdeveloped and underfunded methods to assess students as well as pupils CT skills and on the other side the clear and overwhelming focus on programming and coding as the main methods used to teach CT in a classroom setting (Bocconi et al., 2016). Concrete and practical guidelines about ways to introduce and include CT in a classroom environment are crucial to the widespread implementation. While reiterating the promise of CT within an interdisciplinary context the researchers also see the paramount importance of adjusted teacher education, proposing MOOCs as a possible short term and practical solution.

Cooperation and collaboration between European agencies as well as with international actors is very important to successfully integrate CT in national curricula in a relatively short period of time. One goal of institutions aimed to sustainable shifts in the educational sectors of the European Union is to facilitate more cooperation. Teacher training institutions and research entities must encourage and understand that "the exchange of experience and lessons learned at both European and international levels will become crucial" (Bocconi et al., 2016).

In 2015 Voogt et al. highlighted the current implementation of CT in international compulsory education. The authors present the early stages of CT in a historical overview, starting with its basis in mathematical education and logic. By comparing and tracking back early definitions and including skills to their origins, the article of Voogt et al. offers one of the most in-depth overviews on research strands in the field up to the year 2015. Section four of their publication aims to showcase the different implementations of CT education and how it has been taught in an international context ending in the proposal of a draft curriculum framework for CT education. In 2015 the study calls - very prominently - for more research in the field of CT education and reminds the reader that "developing CT [...] increases students' ability to be able to deal with complex and open-ended problems" (Voogt et al., 2015). The inherent shortcomings of the concept and current research in the field of CT are reviewed in the text of Kalelioglu et al. in 2016. The authors in this report classify a big part of the reviewed papers (39 of 125) as "Idea paper" that are mostly based on personal views about the topic. The researchers propose ultimately to utilise their sound draft of a framework that incorporates findings and previous work in the field over the last ten years of CT research. This proposed framework - to unite CT research projects - applies one of the broadest possible definitions of CT to incorporate a large number of prior definitions. It is worth reiterating that this causes problems with the practicability of the structure in formal educational contexts. Kalelioglu et al. define five major columns comprising CT as a problem-solving process. Namely, these five columns are to identify the problem, gather data, plan a solution, implement and finally assess the progress made with the implemented solution (Kalelioglu, Gulbahar, and Kukul, 2016). The research conducted in CT had a profound impact on the scientific community but has not yet reached broader implementation in classroom settings.

The EU has recognised the importance of CT in education as well as teacher education. In 2020 the ERASMUS+ grant funded an initiative to bring CT education to a more practical level with the introduction of "COLETTE". Intending to "develop a learning environment which can be used to teach and learn CT independently from the socio-economic background of the students and schools" this platform has the potential to give better tools for teaching and assessment to schools (*Computational Thinking Learning Environment for Teachers in Europe* 2021).

2.2.7 Inclusion, Diversity and Interdisciplinarity

As CS still tends to be a cisgender male-dominated field more effort needs to be propagated to allow all walks of life to join and interact with computational thinking efforts. Basing education on projects and collaboration helps integrate a multitude of knowledgeable people with colourful backgrounds and abilities. Offering diverse "identity perspectives" provides "a foundation for not only broadening access but also deepening participation in computing to realize its transformative potential" (Shaw and Y. Kafai, 2020). Computational Thinking is one of the chances for STEAM and especially IT to reach out to the experts and specialists currently not seen by and engaged in technological problem solving. The apparent requirement to infuse CT into other subject areas of the curricula to "operate within the constraints of available resources" was emphasised by Yadav et al. in their 2016 report. To allow the cross-disciplinary approach of CT to be embedded in different subject areas and empower learners with this vital problem solving skill is their key goal (Yadav, Hong, and Stephenson, 2016). While only a small number of practical examples of integration are given, the authors state that ongoing teacher development opportunities are needed to enable and reinforce capabilities, reiterating the need to train in-service teachers as well as preservice teachers. In a related study featuring 134 pre-service teachers the conclusions show that participants were found to be "limited to simplified conceptions of the idea and [...] not showcase an in-depth understanding of what computational thinking involves" driving home the point that "to be successfully implemented in classrooms across the globe, preservice teacher education has to be the focus of researchers, teacher educators, and policy makers" (Yadav, Good, et al., 2017; Yadav, Gretter, et al., 2017). Prior research was also quantified in a meta-review conducted by Hsu et al. who looked at 116 research articles published between 2006 and 2017. Unsurprisingly their findings show that 75 of the 116 publications state that computer science education which includes computer programming courses was the applicable subject to conduct CT training. Within the K-12 age range, the study found a strong focus on game-based learning as well as problem-based learning. The reviewed articles showed that 74 per cent of research is inherently related to formal learning scenarios[2], highlighting the obvious push to further integrate CT skills into national curricula. Hsu et at. end their article by showing five suggestions for future research projects to focus on. One of

[2]This was confirmed by Prof. Hsu in a conversation on 29.10.19. Thank you.

these suggestions is to highlight the necessity to work interdisciplinary and adopt a "cross-domain teaching mode" (Hsu, Chang, and Hung, 2018). The common trend within all models of CT, "to introduce computing into primary education either in multiple subjects [...] or as [a] cross cutting theme" was also identified by a Swedish research project. These similar conclusions were found in this publication after first comparing and contrasting published papers by year and highlighting countries that were able to introduce CT and in small parts CS as mandatory part of their K-12 education institutions. With more and more teachers currently specialising in information and communications technology (ICT) pushed into teaching CT "there is a need to develop the digital competencies of the teachers and make school more modern and relevant". The authors observed in the duration of their project that the "common struggle among all the countries is pre-service and in-service training of teachers". The conclusion of Heinz et al. is ultimately that in primary education - from 6 to 10 years of age the focus of teaching and learning is in digital competencies, programming and CT often integrated in adjacent subject matter. Broader courses specifically teaching CS skills including software development and project management are found in secondary education in most countries (Heintz, Mannila, and Farnqvist, 2016). The link between CT, math and CS is strengthened by researchers Barcelos and Silveira, who explored the proposal that CT, as "a way of reasoning and problem solving", builds an inherent relationship between the subjects. In their effort to map the two fields' competencies the authors make the argument that it is possible to link different disciplinary traits to CT competencies, reiterating the importance of interdisciplinary education for a better future exchange. Based on the example of mathematics especially in the Brazilian and Chilean system, the authors argue that "to incorporate CT to the basic education is to analyze its relationship with other knowledge areas already present in the basic education level" (Barcelos and Silveira, 2012). One of the biggest challenges faced by integrating CT in interdisciplinary formal education is the lack of cooperation between different countries and disciplines (P. Chen et al., 2018). CT as a skill and a solid approach to problem solving can be utilised in a number of disciplines. Wing argued that it is everywhere and for everyone, so it seems logical to establish a massive network of interlinked and interdependent fields, from the social sciences (Ojha, 2021) to mathematics (Chan et al., 2021).

2.3 Practitioner Integration in Formal Education

The integration of subject matter experts into formal education is - at the moment - a niche topic without a significant body of scientific literature. While team teaching and interdisciplinary educational strategies receive a lot of interest the integration of outside experts and practitioners will need to be explored more in the future. For this literature review, many search queries tried to explore the state of the art, without finding much relevant information. To keep research current published work since 2000 was integrated into an overview. Different permutations of the terms "subject matter expert", interdisciplinary, education, k-12, school and practitioner were explored leading to a handful of fitting publications. This area of education, offering only a handful of experiments, is gravely underdeveloped at the moment. In 2010 under President Obama the US promoted "initiatives that support states in the adoption and implementation of college and career-ready standard[s]" (*The Blueprint for an America Built to Last* 2012), a standard that can only be met with the integration of real-world practitioners in the future educational space. The term practitioner in the context of this research project encapsulates a broad number of subject matter experts. The Cambridge dictionary defines a practitioner as "someone involved in a skilled job or activity" (*Practitioner* 2021). They spread a broad range of interdisciplinary knowledge and experiences in the world of entrepreneurship, scientific endeavours, artistic expression and craftspeople. By interacting with the experiences collected in these individual careers, young people gain new insights into their practical problem-solving skills, outside of sterile school settings.

Practical projects and first-hand experience can lead to a much better understanding and offer a broader perspective for future development, especially in the realm of Computational Thinking. A new interdisciplinary workflow that integrates the pedagogical and didactic expertise of teaching staff with the domain knowledge of practitioners needs to be explored and developed. While educators are specialised in the fields of didactics and working with young people they often lack the content knowledge and up-to-date skillsets many practitioners can provide to the learning environment.

For the remainder of this thesis, a model will be developed to categorise and classify learning environments. As seen in figure 2.7 the model has two axes, one exploring

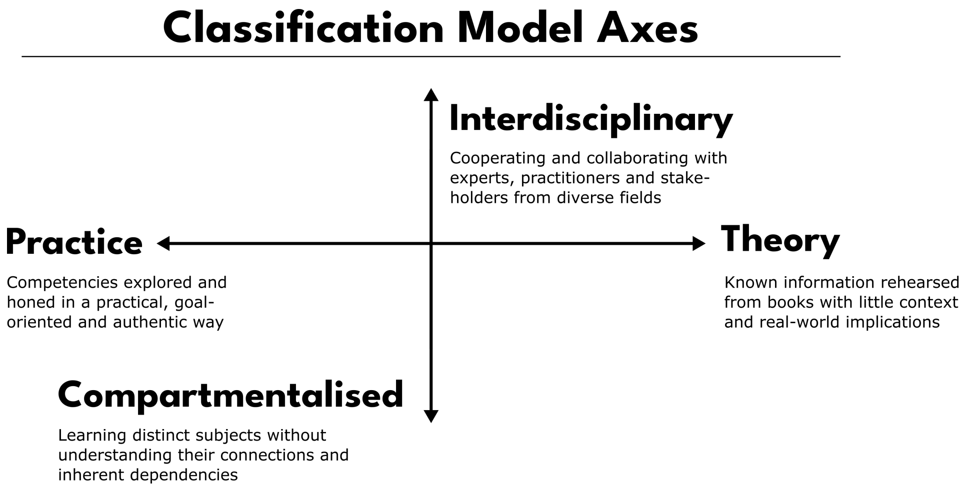


Figure 2.7: Axes on the Learning Environment Classification Model

the relation from practical to theoretical understanding and the y-axis to signify the level of interdisciplinarity of learning. On the x-axis, the path from theory-based, well-known and merely rehearsed knowledge to a practical, exploratory understanding and utilisation of content as well as competencies is marked. On the other hand, the y-axis lists the amount of compartmentalised learning through classic school subjects and increases in its level of cooperation, collaboration and interdisciplinarity to understand the complexity of real-world challenges.

2.4 Applicable Learning Theories

Purely teacher-centred, lecture-style and fact reproduction exercises are luckily seldom found in today's schools. Young educators can pull from a host of experiences and scientific knowledge on successful teaching paradigms for a future proof school setting. How to teach and assess is a complex and open-ended question that leads to a number of valuable learning theories. In the European context and in Austrian teacher education the ideals of Wilhelm von Humboldt are still thought to be the end goal of education in schools and universities. Humboldt's Ideals - coined by the Prussian advocate in 1809 - focuse not on the re-iteration and reproduction of facts alone but on personal growth, in principle uninhibited by class and social standing. The German term "Bildung" is still internationally renowned to link education with a philosophy to foster personal and cultural growth - originally in German "Wissen und Herzensbildung". It envelops maturation and lifelong learning to gain experience and personal reflection. The term "Bildung" is seen as a contrasting concept to mere on-the-job training and reproduction of known values. Humboldt's Ideals aim to the creation of a Cosmopolitan society depicted by the German word "Weltbürgertum", connecting all societies, individuals and generations.

> "Zum Weltbürger werden heißt, sich mit den großen Menschheitsfragen auseinanderzusetzen: sich um Frieden, Gerechtigkeit, um den Austausch der Kulturen, andere Geschlechterverhältnisse oder eine andere Beziehung zur Natur zu bemühen." - Jürgen Hofmann

The following paragraph offers a classification of applicable learning theories used to develop the case studies at hand, starting from the broadest - and historically oldest philosophical construct of Epistemology to more precisely defined forms of formal and informal educational approaches utilised by educators and mentors.

2.4.1 Epistemology as a Philosophical Concept

The term Epistemology stems from a philosophical need to understand learning and cognition within the human brain. The concept of formal education grew out of the desire to engage a populus capable of reading and writing as societies grew from their historic forms into networked and globalised, connected entities. First definitions of knowledge as a concept were created in ancient Greece and consequently explored in all areas of the world. One of the most impactful essays was published by John Locke in 1690 aptly named "An Essay Concerning Human Understanding". For this short overview of the historical context, it is sufficient to link the basic notions of epistemology to the Prussian philosopher Immanuel Kant. Understanding not only what we know but also how we know became a major field of inquiry in the philosophical scientific community. The teachings of Kant and his predecessors led the brothers Humboldt to their reshaping of the German formal education system and ultimately paved the way for education as we know it today - with all its innate strengths and weaknesses. Humboldt's Ideals prevail and still remain cornerstones of schools today, but his focus on the thought and still reflection seem to fall out of favour with many educators and policymakers (Carter and Kotzee, 2015).

2.4.2 About Constructivism and Constructionism

While reflecting and thinking about outcomes is vital, educational paradigms today understand the importance of artefacts for learning, of creation in the most basic sense to stimulate more areas of a learners brain. This "constructivist emphasis on discovery and inquiry" (Vossoughi et al., 2013) became key in a widely adopted learning paradigm named Constructivism. In Piaget's understanding of youth and adolescence, widely taught in teacher education today, a young mind undergoes four stages of growth (Piaget, 1976; Warren, 1972). Piaget's theory of cognitive development entails the sensorimotor stage, the preoperational stage, the concrete operational stage and finally the formal operational stage, which in itself are broken down into smaller age brackets of understanding and learning. Despite some flaws in the theory itself, uncovered over the years, the ideas brought forward by Piaget have been widely accepted and today we do understand that "knowledge is experience that is acquired through interaction with the world, people and things" (Ackermann, 2001; Matthews, 2003). As technologies became abundant and were integrated into educational settings an approach that allows lifelong learning and the adaption to new technologies forced education to embrace the importance of learning to learn. Self-guided, self-organised learning with the help of mental models and the artefacts either created by learners or by peers are key concepts found in Constructionism, a learning theory closely related to - not only in name - to Constructivism (Ackermann, 2001). The digital artefacts that are often created by CT lend themselves to the integration of Constructionism, where the construction of mental models based on prior knowledge and active discovery lends itself well to CS in general and problem-solving approaches in particular. The movement was led by the scientific enquiries of Seymour Papert, who proposed that knowledge is constructed "through their engagement with materials in the context of a personally meaningful activity" (Papert, 1980; Papert, 1996). Papert's prominent collaboration with the Danish toy company LEGO on the educational toys of Mindstorms - named after his book - cemented his standing in the formal education community as these educational toys remain one of the noticeable entries in the learning robots field. One of the more influential learning researchers today was an apt student of Papert and his theories. By adding not only robots and digital hardware toys to the classroom Mitchel Resnick and his team at MIT - the Lifelong Kindergarten Group - developed the brick-based programming language Scratch. It is squarely aimed towards learners and a target audience unfamiliar with common programming languages but adept in the use of bricks - much like LEGO bricks. Building on powerful predecessors like the programming language Logo with its famous turtle, the concepts are to easily understand and extend upon well-known ideas. Simple blocks with minimal functionality can be linked together and are utilised to create scenes and control figures on a screen. These simple elements allow newcomers to engage with the fundamentals of programming on a playful and innovative level. Many current development and learning tools stem from these concepts introduced by Scratch. A development environment (IDE) targeted towards a more mature and potent audience has been introduced with Snap! and the mobile integration of brick-based programming interfaces was developed at UT Graz with the Catrobat smartphone application.

Lately, the educational paradigm of Constructionism came under criticism as kids today need to learn a lot of different skills in a lot of distinct fields. Constructionism is a widely validated but at the same time highly expensive approach - in terms of time as well as money and learners attention. This led to a trend towards Social Constructionism, where the formal rules and strict borders of Constructionism get dissolved by a more collaborative approach. The research led by Vygotsky rejects the notion that learning is a purely individual task and focuses on the socioeconomic context in which learning happens. As with most topics in academia, the benefits of Social Constructionism is a battled over topic and the author acknowledges this fact.

2.5 Maker Education

A critique that is repeatedly levelled against CT in the context of education is its recurring failure to engage diverse student bodies. In this field, the movements of the maker and DIY cultures excel and enable learners of different backgrounds, genders and age brackets to interact with and learn from each other (Shute, Sun, and Asbell-Clarke, 2017).

Rode and the team around him authored an article in 2015 that makes a solid case to move from the baseline of CT to a computational making approach. The argument is that a budding goal can be to "consider the potential of tangible interfaces to support learning". This way evaluating the learning experience of primary school children, that in the project were working with e-textiles in Germany, may be easier as an integral part of the process. By introducing DIY-Labs - effectively makerspaces in K-12 schools with a meaningful and sustainable outlook a Spanish team of researchers focussed their effort on the socio-economic changes driven by maker education. The authors identified, next to a number of findings that will be discussed in other chapters, that students that found their comfort zones "in highly regulated educational contexts, teacher, and factual knowledge and test-centred, had a hard time when asked to think and act by themselves". This outcome foreshadows the problematic and challenging goal of change management in an educational environment (Sancho-Gil and Rivera-Vargas, 2016).

The concept of computational making is proposed as a transformation from CT in the realm of making education by Rode et al. The researchers propose five key factors that can enable CT to be more representative of the maker movement's goal as well as the educational aims it represents. These five factors are namely aesthetics, creativity, constructing, representations and materials. While it is clear that CT "is a core skill to making in that it speaks to individual creativity, collaboration and problem solving" the collaborating authors believe that there is significantly more to it. To deeply incorporate the values and integrate them into STEAM education CT needs to broaden the understanding of tools from merely computational tools to all tools available to young learners. The authors argue that this can enable a deeper understanding of problem solving potentials in the real world while educators as well as learners "benefit from the diversity that making allows" (Rode et al., 2015). Communities of practice, DIY-Labs, hackerspaces and makerspaces clearly focus on and benefit from this current trend that aims "to create programmable objects as art projects" (Knochel and Patton, 2015, p. 13). While a big portion of these learning spaces have been and are developed in informal learning contexts, distanced from schools, classrooms and formal educational institutions researchers propose to keep this crucial form of education inside the classrooms, with the goal to allow inclusion and to avoid the exclusion of certain groups. They argue that “code should be embraced as a form of critical digital making” (Knochel and Patton, 2015). Still, the scientific literature confirms time and time again that the concepts of tinkering, creating, debugging, persevering and collaborating are not yet fully explored in an educational context, as Zaharin et al. state so elegantly, “due to constraints of time, misconceptions and over-emphasis on examination” (Zaharin, Sharif, and Mariappan, 2018).

The three-stage progression - from usage to modification to finally creation - is a valuable concept in education. It is often inadvertently utilised in teaching and assists learning in more comprehensible steps while emphasising the fact that every new invention is based on the prior efforts of countless female and male engineers, artists, thinkers and makers. CT often can be applied in K-12 education using this methodology and the study from Lee et al. highlights this fact by showcasing after school programs. This research publication concludes that more efforts are required by policymakers and school administrators to allow teaching staff the necessary time and resources to extend their teaching beyond current capabilities dictated by a significant lack of time (Lee et al., 2011). The same progression is utilised by Giovanni Serafini, who in his research project explored the possibility to teach coding and CT skills to K-8 children. His argument is that CT “can be introduced and taught on an appropriate and adequate level of abstraction at all school stages”. During the experimental phase the well-known programming environment Logo, with its iconic turtle interface, was used at workshop events. The relatively simplified interface, which still requires learners to write lines of source code, was found to be valuable to keep the cognitive load of younger students down and the feedback received confirmed the success of this approach (Serafini, 2011; Tsarava et al., 2017). It seems important to note that today significantly better programming environments, specifically tailored to young students exist. With the advent of Snap!, Scratch and Pocket Code students can learn in a more playful and intuitive way how blocks of code interact and react. These possibilities will be discussed in more detail. This is especially important when considering the inclusion of historically underrepresented groups in CT and CS education. Teachers need to work with a relatively diverse set of students, as for example an Austrian study notes. This successful interaction - the publication concludes - is one highly underestimated factor in solving CT challenges and problems (Standl, 2016). This focus, more on the social aspects of maker education, was also described by Kafai

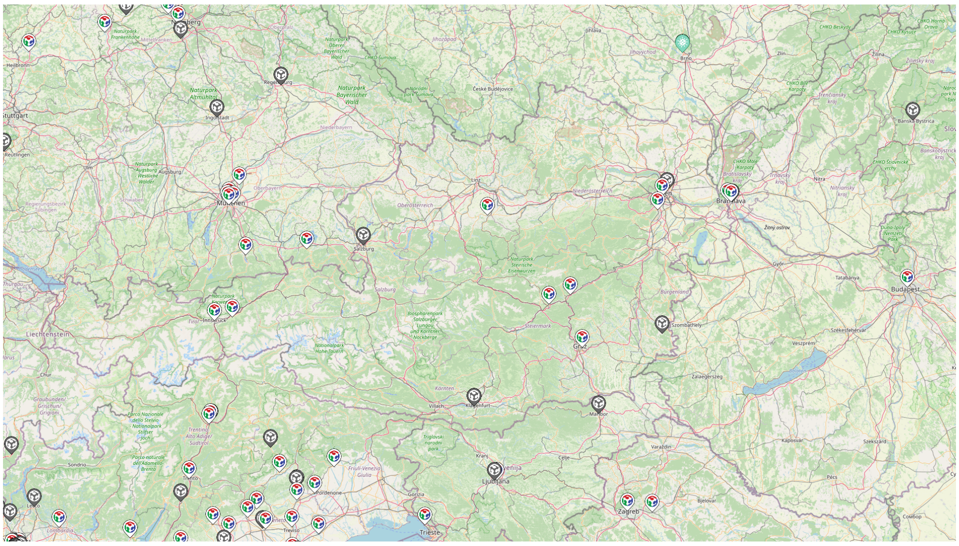


Figure 2.8: Fablabs and Makerspaces in and around Austria on a map.

and Burke, who documented the noticeable impact they experienced when using the participatory programming environment Scratch as a tool to develop CT skills in K-12 education. Teaching by allowing students to "create authentic applications" and remix the work of their peers on the well-received Scratch platform has been described as a constructionist way to develop new skills (Yasmin Kafai and Burke, 2013).

Luckily there were a number of research projects that particularly focussed on maker education and its impact on CT learning. Makerspaces are centralised locations with a hands-on and collaborative approach to learning (Sagbauer, Stocker, et al., 2021). With the advent of the DIY movement maker communities sprung up all over the world. These communities developed shared workspaces for creation and collaboration, and aptly named them makerspaces. A incomplete overview of active makerspaces can be found at fablabs.io/labs/map, a curated list of active makerspaces in Austria in 2021 follows, see also figure 2.8.

The terminology here sometimes gets confusing and unclear. Fablabs (short for Fabrication Lab), Makerspaces, Open Workshops, Hackerspaces, Co-Working, Open Learning Spaces etc. often are utilised interchangeably. Within its basic structures and for all intents and purposes during this project it is the same idea with other

Name	City (Country)	URL
clever-together	Hollabrunn (AT)	makerspace.htl-hl.ac.at
GrandGarage	Linz (AT)	grandgarage.eu
HAND.WERK.STADT	Mödling (AT)	handwerkstadt.org
HappyLab	Wien (AT)	happylab.at
MakerAustria	Wien (AT)	makeraustria.at
Makerdays (Popup)	Graz (AT)	learninglab.tugraz.at
Makerspace[A]	Amstetten (AT)	makerspace-amstetten.at
Otelo	Multiple Locations	otelo.or.at
SpielraumFabLab	Innsbruck (AT)	fablab.spielraumfueralle.at
Steyr-Werke	Steyr (AT)	steyr-werke.at

Table 2.3: A Curated List of Active Makerspaces in 2021.

focussed elements.

Diversity and Inclusion in the Context of Making
A number of capable and successful outreach programs show that inclusion is possible and absolutely necessary for a solid and fruitful future. For example the Vienna Museum of Science and Technology (German original: "Technisches Museum Wien") has a special exhibition on women in technology and the Danish toy manufacturer LEGO has a series devoted to strong women in technology - named "Women of NASA", featured often in this project. The German outreach program called "Innotruck" boasts a complete science exhibition huddled inside a semi-trailer truck to allow young minds outside of larger cities to experience current technological trends. This approach has been adopted by the technical museum Vienna, with a similar mobile makerspace program, see technischesmuseum.at/roadlab.

Technical fields are often dominated by male actors. Despite the benefits of interdisciplinary and diverse work, high paying technical jobs are mostly filled with the Caucasian or Asian cis male stereotype. In the early years, computer science had the chance to revolutionise this with a start mainly in female-dominated clerical work, but for the most part, did not reach its potential. Today for example computer science majors are predominantly (85 % in 2011) awarded to male students (Sax et al., 2017). Despite some visible female staff at major tech companies, the underlying problems remain as underrepresentation of diverse groups leads to a clear gender pay gap and further problems for a society reliant and often dependent on technologies.

From an early age, stereotypical job outlooks are repeated to pupils. The discourse is pretty similar internationally, where young girls become hairdressers, receptionists and veterinarians while boys tend to be taught to become policemen, engineers and software developers. In the school setting these stereotypes are involuntarily reinforced as girls statistically are graded worse in math and boys are graded worse in the languages. Teachers are humans and fall for the same inequalities inherent in the culture they exist in and it is very hard work to try and recognise these patterns. The same goes for inherent prejudice against a non-conformal group of people, people with a migration background, refugees, and members of the LGBTQ+ community. All young girls and boys struggle to find their identities, but the ones identifying as members of any non-conformal community might find even less connection to like-minded peers (Wolf and Ebner, 2018b).

Of course, this list can go on and on, people are luckily very diverse, society strives because we are, and recognising these benefits can lead to incredible progress (BMVIT, 2021; Grasenick, Kupsa, and Warthun, 2011). Knowing this the fourth United Nations Sustainable Development Goal named "Quality Education" is targeted to ensure "inclusive and equitable quality education and promote lifelong learning opportunities for all" (*THE 17 GOALS | Sustainable Development* 2021). In the context of makerspaces research shows a massive overhead in male participants and users. These spaces, with their technophile approach mainly appeal to male audiences, because they mostly are funded and created by male actors. This of course is no accidental development, it is a continuation of the current situation, a reiteration of the status quo.

Recent research showed the decline of girls' interest in STEAM subjects correlates with increasing age. Where girls up to 12 years old are eager to interact with technologies and show enthusiasm for creative problem solving older girls are more often reserved towards this male-dominated field (*MAKER DAYS for kids – Informatische Grundbildung* 2021; Grandl, Ebner, et al., 2021; Sagbauer, Stocker, et al., 2021). Makerspaces, schools and universities recognised the importance of a more diverse audience, as diversified groups can lead to much better and sustainable projects (*FIT - Wir Gestalten Die Zukunft* 2021; *Unternehmen Für Mädchen 2.0* 2021). Making inherently is a skill in earlier times predominantly linked to women and girls, working on projects, building things for home use or sale. In the sciences, in general as well as in computer science in particular there are a number of historic and current role models for girls and young women to look up to. Stories of early scientists like Marie Curie are pushed in the spotlight recently with movies being published about their incredible feats. Social media channels like Instagram are currently used very successfully to translate historical figures in a medium that youth today can relate to. But these historic role models should be boasted with more current influencers on the social networks young people interact with. One sucessful german speaking implementation is the podcast series titled "TECH SHE LIKES - technology is feminine" (techshelikes.co) hosted by my colleague Daniela Wolf. This is one of the major outcomes generated in a workshop on diversity management hosted by Prof. Karin Grasenick. Giving young females visible and outspoken role models to look up to and interact with allows for a mentorship role and an easier introduction to the STEAM fields. Awarding these role models a very visible spot in the social networks and presenting their work and achievements in public relations is vital to allow them proper participation.

To host a more diverse audience, giving these underrepresented groups their individual spaces and timeslot creates a safe environment for an initial approach. Events like "Girls Days" and "Girls Nights" offer tailored activities and a safe space for interaction, relationship building and interdisciplinary learning. The early inclusion of women and girls in the creative process allows for a more diverse, interdisciplinary group of people to design and develop the look and feel of the provided space as well as the possibilities offered. This is important to prevent the I-Methodology and understand that - despite their best intentions - people do have prejudices. It is incredibly difficult to find diverse answers within one's own mind, influenced by different environments, education and experiences (Akrich, 1995; Oudshoorn, Rommes, and Stienstra, 2004).

> "Listening is not a skill; it's a discipline.
> Anybody can do it. All you have to do is keep your mouth shut." -
> Peter Drucker

The way makerspaces, hackerspaces and fablabs are marketed often include heavily technophile language and imagery. Robots, computer code and soldered breadboards might be intriguing to some participants but it is unintentionally excluding a huge spectrum of diverse young (and even older) thinkers, tinkerers and makers. Despite the knowledge that "the more diverse the team, the greater the potential for innovation" (*Multicultural Teamwork* 2014) often is not implemented that way. It is pointless to make overarching statements, but attention to a more inclusive marketing approach and outreach programs is important to attract new audiences. Young people often are limited in their mobility, some people can reach the location by bike or public transport but still a number are brought by their parents. Giving the parents something to do offers a host of new opportunities for the space and a new audience. To involve and engage local parents and neighbours in the making progress a regular repair cafe is interesting, to allow for more interaction and instil the "Reduce, Reuse, Recycle" ethos in the participating youth. Another special offering for mature audiences - not particularly interested in making themselves - is a small library and a comfortable reading corner. Having the kids play for a few hours while reading a good book, flipping through magazines and drinking good coffee is a smart combination of treats that can lead to further intergenerational networking effects. Thinking creative spaces inherently in an inclusive way is key with the goal of furthering a class- and age-independent setting (Sagbauer, Pollak, and Ebner, 2022).

In conclusion, it is impossible to create anything without falling into some pitfalls and initially excluding some people unintentionally. This is okay. Keeping in mind that everybody struggles with these issues is the most important step, the key is to ask questions, to intentionally listen and inquire with peers as well as people far outside our individual comfort zones.

> "Coming together is a beginning. Keeping together is progress. Working together is success." - Henry Ford

2.6 Communication Technologies in Education

In 2020 new learning technologies were forced upon all education systems to expediently enable remote learning. This showed the potential and downfalls on a previously unimaginable scale. This unexpected pandemic led to an incredible spread of modern collaboration and communication technologies and the world in 2021 still struggles to hang on. For the improvement of formal education, a number of technological advancements were made in the last years and should be added to the roster of teachers and policymakers. Concerning this research project, a number of tools and processes were used to gain interest and spark joy in the participating students. Some kind of video conferencing tool has become vital in the year 2020. Most schools in Austria use Microsoft Teams as their collaboration suite. In Germany, the Free and Open Software Tool Big Blue Button (in short BBB) is also commonly used due to privacy concerns. Other widely available alternatives are Zoom, Jitsi and Webex.

A number of messaging apps are available and consequently used for learning and teaching. In the educational system of Austria - and in Europe in general - the question of data protection and privacy is asked often. In Europe, the General Data Protection Regulation (GDPR) has been in effect since 2018 and caused a massive rise in awareness for the privacy issues faced by today's society. Not only the companies behind a service are important but also where the service is hosted and the physical server infrastructure is situated. To protect the privacy of young learners this has to be taken into account and should be reflected upon when utilised in an educational setting. In Austrias schools the group work tool Microsoft Teams has become the de facto standard, as the regional authorities (German original: "Bildungsdirektionen") rolled out Microsoft Teams to consolidate efforts in K-12 education during the second COVID-19 lockdown.

2.7 Teaching the Teachers

The integration of CT in national and international curricula is only one part of the challenging introduction of a new concept. A specific look at the hurdles and challenges faced by teachers in everyday classroom environments show that practical implementation is lacking behind. An inadequate focus on teacher education and re-education paired with content contributions mostly based on computer science make it impossible for most practising teachers to integrate the new concepts fully.

Research studies conducted with in-service teaching staff finds that a lack of confidence linked with low levels of self-efficacy in the subject matter in some teachers might cause a problematic correlation. The authors find that this potentially could be remedied by a focus primarily on educating teachers. During this study, the researchers ran full-day workshops geared towards Australian K-8 teachers and a total of 75 educators participated in the post-workshop survey. Two major factors were held culpable for the lack of integration and teaching of CT practices at school. On the one hand, the lack of knowledge was remarked as one leading factor, on the other hand, the lack of time spent with students which can be attributed to a full schedule and complex curricular requirements. As one practical solution, the authors propose that "schools could organise support groups that include peer learning and teaching buddies" and also point out the role of academia and industry to fill this obvious gap. After attending the single-day workshop teachers reportedly gained a better understanding and the authors argue "it is possible for teachers to build up their confidence level [...] in quite a short period of time" (Bower et al., 2017).

It has been established that CT training and the introduction of CT concepts should start in early childhood education, to cement the understanding of the importance it has in schools. Research shows that this is a key factor in fully understanding and appreciating the basic concepts of CT with the ability to transfer the skills in everyday problem resolutions (Qualls and Sherrell, 2010). One solid starting point for policymakers and educators is provided by Lockwood and Mooney who answered the question "Where does [CT] fit?" by conducting a thorough review of the literature body. They showed testing possibilities, the importance for institutional adoption and the interdisciplinary implementation of CT in formal educational contexts (Lockwood and Mooney, 2017).

> "Teacher trainers must not forget the age-old pedagogical dictum that 'teachers teach as they were taught, not as they were taught to teach'."
> - Howard B. Altman

To conclude the state of the art section of this thesis it is already viable to answer one of the initial research questions asking: **What were the most important literature review works in the field?**

All evaluated publications are important contributions to the state of the art in CT education, where Grover and Pea, Lye and Koh, Sengupta, Kalelioglu, Denning and Yadav became the most prominently cited researchers.

3 Methodology

3.1 Research Design

This research project employs a number of methodological approaches utilised in an iterative and transparent manner. An initial literature review showed a number of complex problems and challenges in educational institutions.

> "The world cannot be understood without numbers. But the world cannot be understood with numbers alone." - Hans H. Rosling, Rönnlund, and O. Rosling (2018)

3.2 Action Research

To answer the research questions the iterative process of action research (AR) was chosen. The AR approach, first introduced by Kurt Lewin (1946) at MIT, allows participative and collaborative exploration of a known problem space. It is especially useful to gain an understanding of the students' perspective, where engagement is understood as a two-way interaction between learners and educators (Gibbs et al., 2017). Four main characteristics should be considered before AR is implemented, namely the practical nature of the research, the focus on change, the need for multiple cyclical iterations and the active participation of practitioners (Denscombe, 2014, p. 73). To work on observable problems in combination with stakeholders a challenge is defined and an experiment planned.

After the first phase of planning action is taken and, in this case study, expert integration for a project-based CT skills training is tested. The workload is split

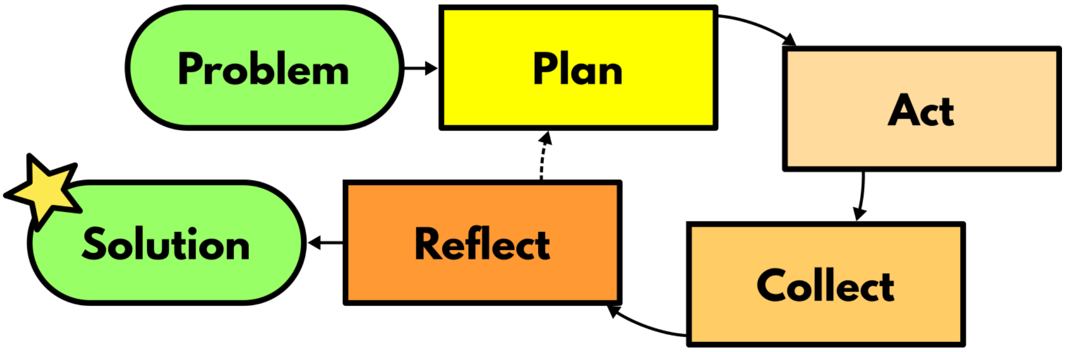


Figure 3.1: Illustrating Action Research as an Iterative Process.

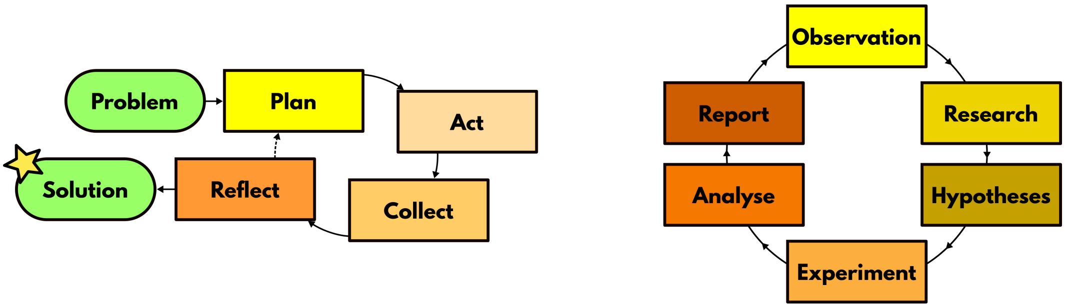


Figure 3.2: Comparing Action Research to the Elements of Scientific Methodology.

between five workshop sessions. After this experimental setting is concluded, feedback, data points and evidence are collected and reflected upon by all involved entities, to determine lessons learned and define better solutions to identified problems. These findings are shared with the academic community and finally, an improved iteration is planned. Compare these iterative steps with the Illustration provided in figure 3.1.

AR very stringently holds to the baseline structure of a scientific methodology, that is basically mirrored in most scientific fields but iterated upon in its procedures and structures. The close resemblance of the two approaches can be seen when placing the relevant elements next to each other as can be seen in figure 3.2.

This process of defining research questions initially, mostly based on a curious observation within the world, and finding a robust and resilient conclusion has been criticised in the last decade for its minimalistic and constraining nature and idealisation of a messy process. Its homogeneity in approach has been mostly replaced with a specific and specialised methodology that differs between fields. Action Research is mostly holding to and applying the principles of scientific methodology but ultimately retains control of the messy inner workings of humans and human-led institutions. In its idealised state, the scientific method allows researchers to analyse and understand the non-trivial problems society is surrounded by. Designed with a clear focus on natural sciences it often underestimates the complex, messy and unpredictable ways humans interact and communicate - or in this specific instance: learn.

An initial observation in this idealised view of the scientific method leads to a number of clear and answerable questions. These questions in turn specify a clearly delimited area for a research topic that can be studied before a hypothesis is generated by the research team involved. After that, the researchers strive to develop experiments strictly designed to test a hypothesis, aware of the numerous complex subsystems that can alter a result. The collected information and data is then analysed to determine causal relationships and notable event structures. This presumed correct data and all the assumptions underlying the conclusions is reported to the scientific community and scrutinized in the peer-review process. It is obvious to the reader that the whole gamut of human knowledge can't be structured in this idealised way, necessitating most every field altering this clear cut structure and developing its own specific and specialised set of rules. Action Research - sometimes named "Action Based Research" - has evolved in the social sciences and since been adopted in a wide range of scientific fields like pedagogy, humanitarian work, inclusive research and management studies. In the learning sciences one research approach is very similar to action based research and is named design based research. The premise here is based on the learner and the very complex and intricate systems learners find themselves in. First introduced in 1990 its goal is to develop and implement "interventions" to problems in an educational context with the same iterative structure found in action research.

3.3 Meta Analysis

To qualify the findings of the literature review and get a broader understanding of past developments a meta analysis was conducted during the project's creation. In itself, meta analysis is a well known quantitative method established in the social sciences to create a countermeasure to mostly qualitative research. The author has previously studied in the department of Science Technology and Society (STS) at the University of Vienna where meta-analysis of previous research studies is one of the key approaches to a solid literature review. The goal is to analyse in a statistical and empirical manner the data collected during other individual studies, to understand the connection between data points and integrate the findings in the intended research framework (Hedges and Olkin, 1985). In the case of practitioner integration at the K-12 level, a number of detailed quantitative and qualitative literature is outside the primary scope, for example, conducted in universities or lifelong learning settings. A number of these studies were read, tagged and summarised for the purpose of understanding overarching themes. The findings were then reintroduced into the research design of the project at hand, leading to a strong interaction with the main action research framework.

3.4 Pedagogical Approach

Schools and teaching, in general, have improved incredibly over the past few years. Younger and more aware teachers graduate from "University College of Teacher Education", in Austria the "Pädagogische Hochschulen" and bring the most up to date knowledge of student-centred lesson design into the classroom. The days of instructing students in front of a chalkboard, of a clear knowledge divide and teacher-centred lesson plans are almost over and luckily today's learners experience concurs during the case studies conducted. Working in diverse groups, project-based teaching and alternative assessment methods are commonly found in Austrian schools and especially after the experiences due to the phase of distace learning caused by the COVID-19 pandemic modern, remote and digital tools are employed on a large scale.

During the design phase, a number of research projects provide useful guidelines to enable learner-based project design.

- Provide scaffolding by offering easy places to start like pre-programmed code blocks.
- Allow different difficulty levels to be chosen by the students initial efficacy.
- Offer relevant and significant choices to the participants.
- Make things complex, not complicated.
- Draw from students' desires.

These guidelines are based on the research conducted by Lytle et al. in the use of Scaffolding in CT education projects (Lytle et al., 2019).

3.5 Research Framework

This research study explores the feasibility to introduce practitioners Computational Thinking knowledge to learners aged 16 to 18 in a formal education context. One workshop was conducted within school hours in a classroom setting and a second workshop as an after school event. All evaluated learners were about to graduate ISCED level five with a final examination called "Diplom- und Reifeprüfung", a form of high school diploma as seen in figure 3.3. Internationally this is akin to ISCED level three but in the Austrian educational system, an exception is granted for vocational schools, where one additional year of formal education leads to an ISCED level five graduation. Figure 3.3 shows the different steps of the countries education system laid out by Austria's Agency for Education and Internationalisation (*Das Österreichische Bildungssystem* 2021).

The experimental workshops were conducted in Austrian secondary schools, where each case study was planned for a classroom size of 15 to 30 young people. Based on the Austrian school system, the research author assumes that a number of these findings can be extrapolated to other countries and regions. Especially in Europe class sizes in this age bracket are consistent over all countries, with Austria having an average of 21.1 in 2018. On the extremes of the OECD statistic there is Costa Rica with 35 pupils per class and within the EU France with 25 young learners. On the lower extreme, suggesting better funding of public secondary schools is the EU

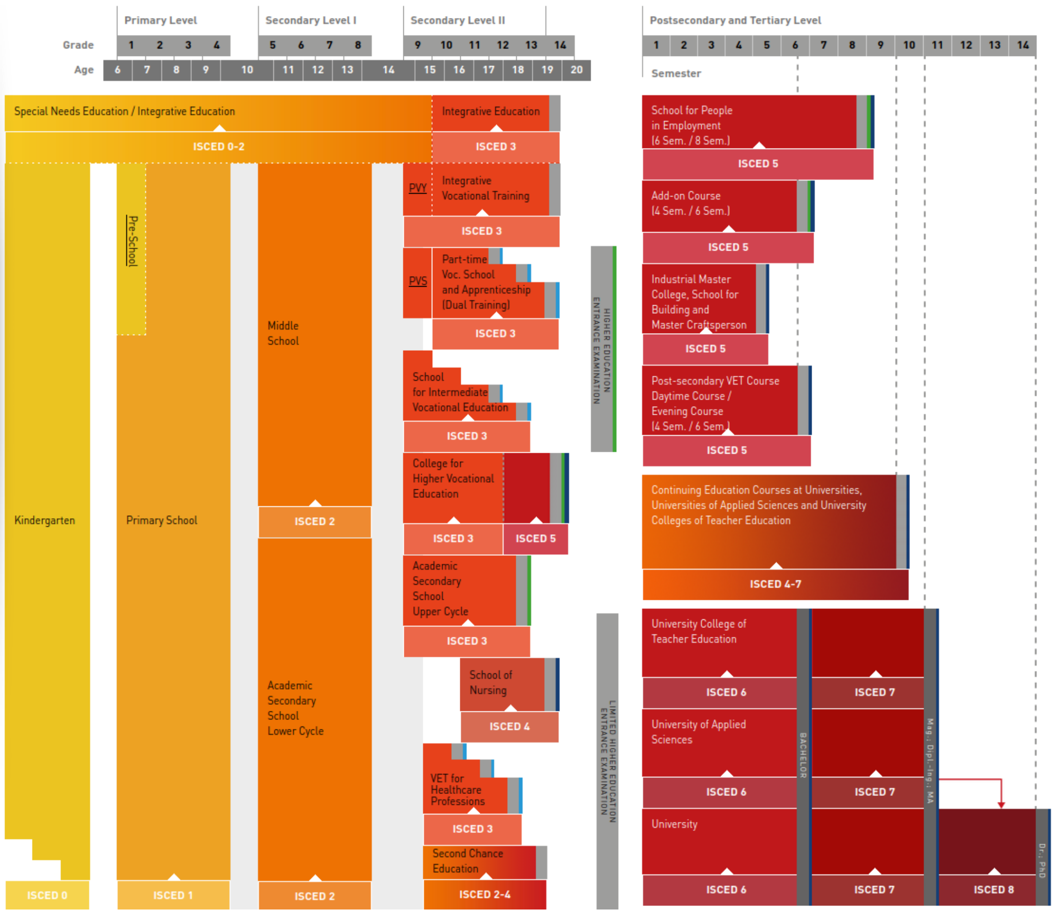


Figure 3.3: The successive layers of Austria's Formal Education System.

country Latvia with 15.9, followed by Luxembourg with 18.2 and Switzerland with 18.6. The map featured in figure 3.4 offers a more detailed but not as current look at the educational landscape surrounding Austria (*Education at a Glance - OECD* 2021; *Student-Teacher Ratio and Average Class Size : Average Class Size* 2021). Merely looking at classroom size is of course not the only indicator of a well balanced educational landscape. Another key figure is the financial situation of educational institutions where Austria in 2017 spent 5.4 per cent of the country's GDP on education compared to the EU median of 4.7 per cent (*Government Expenditure on Education, Total (% of GDP) - Austria, Germany, France, European Union | Data* 2021). Based on these comparisons and the data gathered internationally, findings from this study likely can be utilised and implemented in other settings.

This research study is limited to a small number of specific schools in Austria. Thus broader applicability needs to be assessed and evaluated on a case to case basis. According to the college for higher vocational education with a technical focus' data, only 81 (7 %) of the 1.104 students in 2020 were female. This fact corresponds to the data collected in this research, where only three of the 28 participants were young women (11 %). That constitutes a prominent limitation of the project at hand and is in stark contrast to the partner school in Waidhofen an der Thaya (HAKWT) with an economical focus, where workshop participants were split almost evenly and the schools 224 learners are predominantly female (152 / 72). This is another clear reminder for more female learners to push into STEAM areas and for educators to tap this massive unused potential (Moote et al., 2020; Schön et al., 2020).

The partner schools can be marked on the Learning Environment Classification Model in figure 3.5. They were chosen because vocational schools have a significant focus on practical learning as well as an appropriate age bracket. In the formal education system of Austria, Polytechnical Schools offer a more practical but narrower curriculum. Following this level learners can graduate to higher levels of formal education where Universities depending on the subject matter often provide a more interdisciplinary and practical education. An exemplary outlier can be found in maker education, where the majority of learning is inherently practical.

As a quick geographical introduction, the country of Austria is in the centre of Europe, part of the EU and home to almost nine million people in 2021 (*Austria* 2021). For geographical context see figures 3.6 and 3.7.

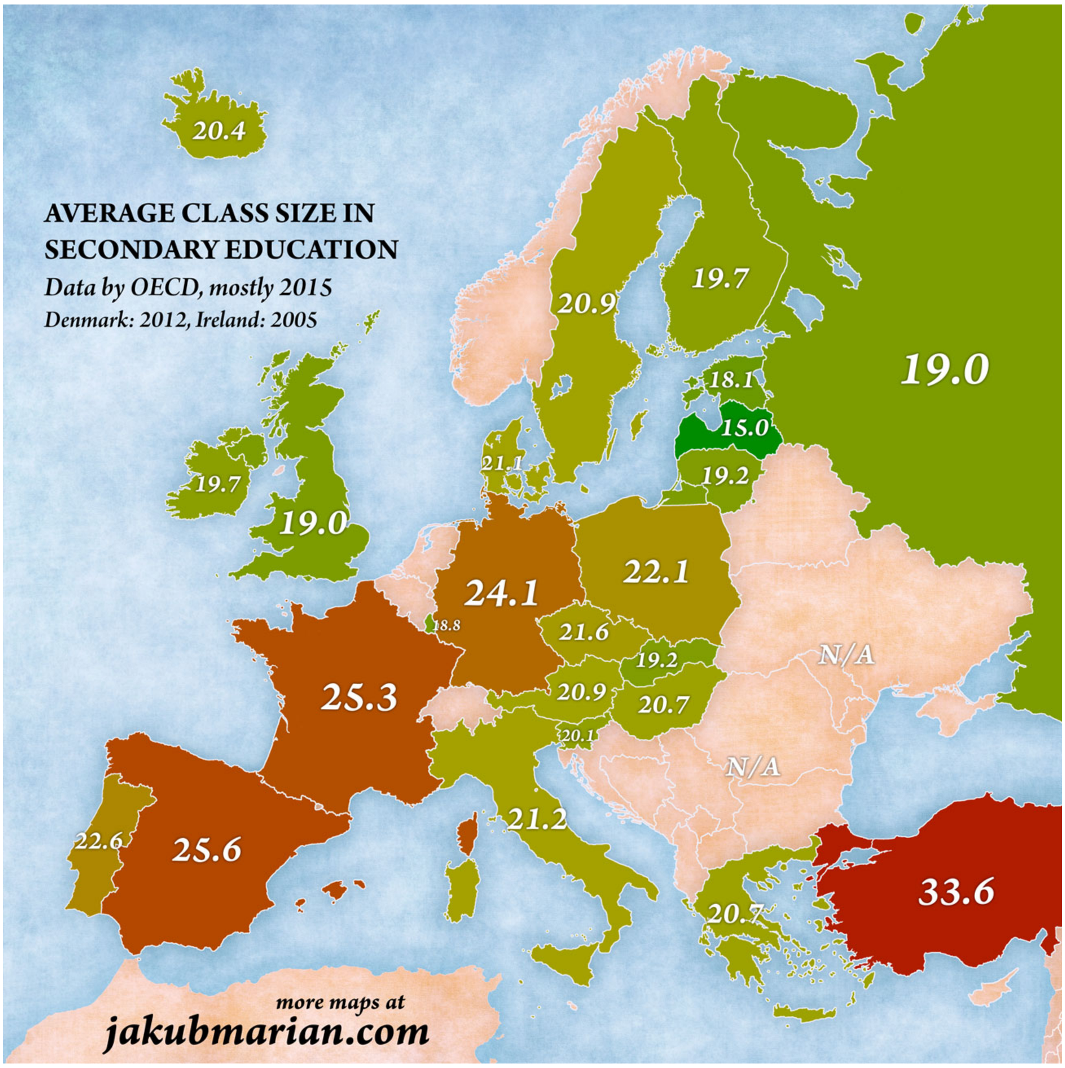


Figure 3.4: Map of Europe with average classroom sizes in secondary education created by Jakub *Average Class Size by Country in Europe* (2017).

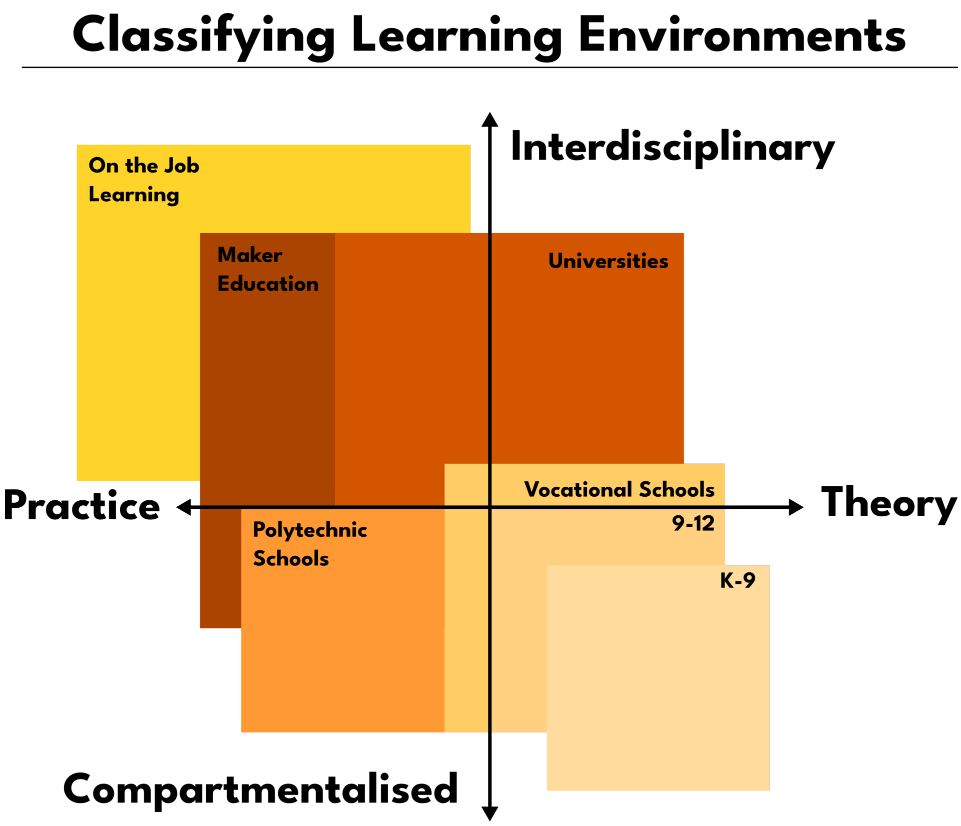


Figure 3.5: Classification of Learning Environments in Austria.

Figure 3.6: Austria is situated in the centre of Europe.

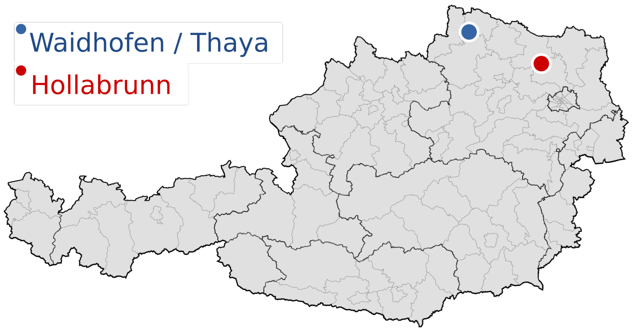


Figure 3.7: Locations of our partner schools in Austria.

3.6 Evaluation of Learning Outcomes

One primary challenge of this project was the evaluation of learning outcomes over such a short period of time and with a complex topic like CT. By analysing student's learning diaries, conducting questionnaires and in-person interviews learner's reflection was captured. Despite these efforts, a conclusive understanding of the long term learning outcomes is not trivial. To combat the limitations of short project terms, limited budgets, and the lack of a control group not only the quantifiable results were integrated. One major effect of practitioner integration was the motivation of learners, evaluated by interviews, researcher's notes and informal discussions.

3.6.1 Learning Diaries

To gather participants' feedback the students were tasked to write a short learning diary after every session. To ensure completion the learning diaries were uploaded and mandatory for the students and contributed to their grading in this curricular course. For the students, an optional template including the following coarse headlines was prepared for download as seen in figure 3.8.

- What did I learn today?
- What did I not understand?
- What will I ask in the next session?

Lerntagebuch Datum:

Was habe ich heute gelernt?

Was habe ich noch nicht verstanden?

Was Frage ich bei der nächsten Einheit?

Not zen, Ideen, Skizzen?

Figure 3.8: Template for the Student's Learning Diaries.

The explicit goal of these learning diaries was to foster the students ability to reflect on their experiences and review the interactions of this particular day. This can and did start an interesting discussion between the learners and the educators about the concept of CT, the knowledge these young students bring from previous life experiences and the path of understanding and competencies in general. Of the 28 students that participated in the workshop 26 handed in their learning diaries and allowed the researchers to analyse their notes anonymously.

During this review process, the questions posed by the participating students revealed the broad scope of interests and curiosities these young minds bring to a workshop. This topic is elaborated in the results as well as the discussion part of this dissertation, but the desire to learn more about a multitude of topics introduced, the tools the teams worked with and the capabilities and potentials these tools can offer were discussed often by the participants.

On a more technical note, the students were required to post their learning diaries a few days after every workshop session. It became obvious that most learners were comfortable writing down their questions and ideas in their documents but hesitated to speak up in the workshop setting with the pressure of all their peers listening in. To facilitate a discussion, learning diaries should be checked regularly and parsed into the upcoming session by the educator, to honour the fact that most students took significant time and invested effort in their learning diaries. The pride put into these notes can boost the workshop setting and establish the baseline for a solid, interactive discussion.

3.6.2 Questionnaires

After the second workshop concluded a simple open ended questionnaire was given to the participating students. The aim was to establish quantitative data points and evaluate students' perspectives on practitioner integration, elaborating on interviews and qualitative data points. The questionnaire was in German language, but the topics translate as follows, see figure 3.9.

- Which elements of the workshop would you add to regular lessons?
- What do you think of adding practitioners to regular lessons?
- What topics would you like to be covered in the future?

- What else would you like to say?

3.6.3 Failure is an Option

The assessment of CT skills has been discussed vividly in recent years with various clear cut answers present in the publicised research. During this stage in the project, the grading and evaluation of CT skills and knowledge was difficult, especially at the portion where competitive challenges demanded a winning team to be chosen. To develop a fair and comprehensive grading scheme based on the rubrics evaluation template options and priorities were discussed with teaching staff. For the Startup Challenge, a jury was envisioned consisting of practitioners based in a business context and educators from the school. The inclusion of peers from outside the participants pool also makes sense to understand the full spectrum of work done.

A catalogue of grading options would have been established while participating teams received a grade in every category from one to five stars as well as a long-form text comment. The jury was tasked to create short and positive speeches to further the appreciative feedback culture. Assessment is not only based on final success but importantly includes the process as a vital element of ultimate success. Solid teamwork and a sustainable failure culture to experience struggle and overcome challenging problems as a team while growing in the process distinguish successful ventures. This idea was included in the grading scheme as the category "bravest mistake" allows for a positive connotation despite the potential throwback.

This is one of the potential ways how schools and formal educational institutions can and should change in the coming years, as envisioned by researchers and educators alike. Scientific literature shows potential in new forms of assessment, struggle and challenging tasks and projects are important in today's ever-changing world, too much caution can snuff out ingenious ideas and brave concepts. The controversial founder of the space exploration company SpaceX, Elon Musk is credited with the following quote, underpinning the fact that failure is a vital part of successful innovation in businesses and startups.

> "Failure is an option here. If things are not failing, you are not innovating enough." - Elon Musk

Fragebogen HTL HL G1

Welche Elemente des Workshops würdest du in den normalen Unterricht übernehmen?

Was denkst du über die regelmäßige Integrat on von Prakt kerInnen im Unterricht?

Welche Themengebiete würdest du in zukünf igen Workshops gerne anschneiden?

Was möchtest du sonst noch los werden?

Danke für deine Hilfe! Alle Antworten werden natürlich anonymisiert behandelt.

Falls du noch Fragen hast gerne an
workshops@michaelpollak.org bzw. ht ps://t.me/michaelpollak

Figure 3.9: Template for the Questionnaire the Students Worked on after the Workshop.

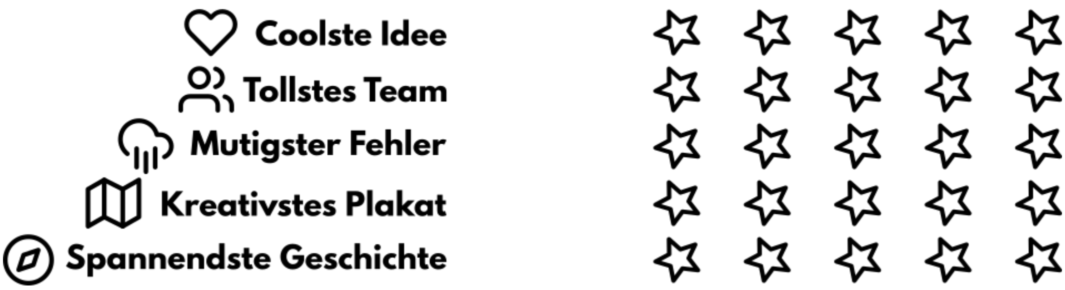


Figure 3.10: Proposed Grading Scheme for the Startup Challenge 2020.

Impressive leaps are possible today, much has to be credited to brave and independent teaching staff keen on furthering their learners' possibilities. Good grades to appreciate failed but innovative trials and experiments would be a societal value that a number of adults would benefit from as well.

4 Case Studies with Practitioner Integration

Multiple case studies were planned and conducted during this project. The action research approach dictates multiple iterations on an idea to find the best solution to a complex problem. In the case of the aforementioned research questions and the broader topic, this meant to work with young people and evaluate their needs as well as their comfort level with practitioner integration. At first, a face to face workshop was developed, to understand the baseline and get to interact in person and informally with the participating students. This culminated in a finalised project and the publication of the website of "HEROES.HAKWT" (heroes.hakwt.at), providing a platform that connects current students with alumni. A second iteration was planned to conduct a hackathon-style workshop to introduce the gamification elements and challenges to learning. This case study was postponed due to the pandemic restrictions and will be held at a later date, as learners, as well as educators, were curious about the outcome of such a project.

During the distance learning phase in Austrias schools, a remote workshop was conducted with the help of a second partner school to act as another case study. As described in more detail later, students were tasked with the development of a simple website that can help teachers navigate the real-world problems of remote learning. The second element of this case study was the comparison of a flipped classroom group with their peers that were taught in a lecture-style setting.

Figure 4.1: Collaborative Grouping of the Developed Ideas and Concepts.

4.1 Face to Face Workshops in Secondary Business School

The findings of this workshop have been published at the 2020 EdMedia+ Innovate Learning conference (Pollak and Ebner, 2020).

The first partner school is a rural secondary school with an economic focus (German original: "Handelsakademie", HAK) in Waidhofen an der Thaya, situated in a rural region of Lower Austria named "Waldviertel" or Woodquarter, see figure 3.7. A signifier for this is the population per square kilometre of 158 with an absolute population of 5.365 people in the community. The whole district boasted 25.682 inhabitants in 2020 (*Statistik Austria - Waidhofen* 2021). Our partner school in Waidhofen an der Thaya is located in a small city with around 5.000 residents. The town offers six different school types to its youth. The school, from now on referred to as HAKWT (see www.hakwt.at) has students usually from 14 to 18 years old and graduates at ISCED level five. According to recent Statistik Austria data, the school in 2021 has 208 active students, 138 female and 70 male. This rural economical school is primarily visited by female students (66 %).

For the first iteration, the team chose - in coordination with the teaching staff and the schools directorate - an after school workshop setting. Students of the secondary school with a commercial focus in Waidhofen an der Thaya were asked to voluntarily participate in these workshops to work alongside practitioners and

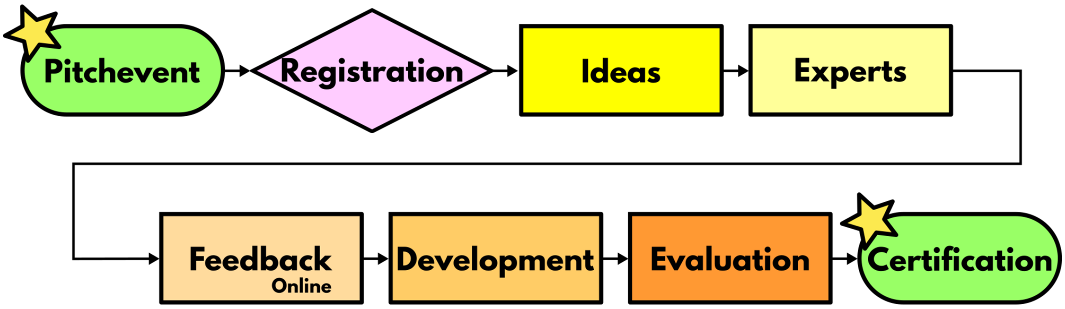


Figure 4.2: Flowchart of the Evolution of the First Workshop Iteration.

gain an insight into real-world project development patterns and practices. Initially, the sessions were pitched to two 3rd and two 4th grade high school classes together adding up to 62 students, between the ages of 16 and 18. The findings of this workshop were published at the 2020 EdMedia+ Innovate Learning conference (Pollak and Ebner, 2020).

Five workshop sessions were agreed upon, led by a pitch event held in all four classes viable to participate in this project. One workshop session was also held online, utilising the tools available at the time, rather new to the students in the age before the COVID-19 pandemic hit. The flowchart in figure 4.2 illustrates the sequence and the dates can be seen in table 4.1.

	Workshop Date
Pitch Session	January 29th 2019
Develop Initial Ideas	February 21st 2019
Subject Matter Experts	March 20th 2019
Collaboration and Online Feedback	April 4th 2019
Solving Challenges and Presenting Solutions	April 19th 2019
Evaluation and Feedback	June 7th 2019

Table 4.1: Dates of Sessions Conducted during the First Case Study.

4.1.1 Pitch Session

The first and initial workshop of this series of projects was pitched in January 2019. In four classrooms a cohort of 62 young people was presented with the opportunity to take part in this upcoming workshop. To allow the participating students to showcase their individual capabilities and realise their potential an open, participatory and creative workshop structure was proposed with the argument that a playful, entertaining environment leads to intrinsic motivation and casual interaction (Grandl and Ebner, 2018). The innovative setting aimed to reproduce the equitable structures of modern companies, offering the chance to get real-life work experience.

A promised certification at the end of the project to thank them for their participation and offer them long term benefits for their future career was met with much engagement and enthusiasm from the group. For some, the possibility of interaction even after this course program and the collaborative establishment of a compulsory graduation project was a key argument. The pitch event promised three different teams with individual focuses, namely design, marketing and one team dedicated to technologies. The explicit goal of this determination was to establish areas of expertise in all fields and not deter young people initially disinterested in or prejudiced against classic computer science topics like programming. It was made clear from the start that each and every role was an important cornerstone and equally valuable to the successful project completion.

Students were given the opportunity to post their questions online as well as in person after the pitch event concluded. The students were asked to respond within two weeks of this initial event by registering to the workshop if they are interested in participating. A special web interface was set up to receive registration data and store it in a secure database. This simple form received 38 responses initially which correlates to a 62 per cent reply rate after the pitch event. The 21 students that registered to participate in the workshop were asked to collaboratively schedule the first session of the ideation workshop. Using a schedule finding tool similar to the ubiquitous "Doodle" tool but with better data protection hosted by the Austrian government called "Termino", the 21st of February 2019 was chosen to be the date of the first workshop. This information enabled the teaching team to formulate the scope of the project as well as the concepts to be explored with this group of students.

In-person pitch events are of vital importance based on the learnings of previous experiences with blended courses and massive open online courses (MOOCs). Young learners especially need in-person time to bond and engage with the people and faces offering educational resources. This is key to creating and sustaining a sense of urgency and importance as well as connection and teamwork. This chance to ask first questions immediately initiates a strong feeling of project ownership and shared responsibility among the team's members. Blended education should strive to engage on these informal levels as well as on the pure intellectual facts.

4.1.2 Develop Initial Ideas

Two goals were the focus of the first session in this case study. On the one hand, establishing a group feeling and on the other hand, developing a set of ideas and possible use cases for the project. A gamified approach was chosen to build trust within the group and establish expectations and a rapport between the practitioner and the participants. Sorting students and teachers first by height and then by name got communication and free movement within the classroom environment established. Neighbouring students were asked to find three surprising similarities, culminating in the following challenge to find three positive character threats for every participant. During a 15 minute break, the curious participants were given the opportunity to ask questions as well as share their stories and expectations.

Participating students were made aware of their qualifications as subject matter experts already at the start of the ideation process. These young learners, soon to be alumni of the school had precisely the knowledge required to estimate how alumni and currently enrolled students could use the proposed platform. The intention behind that initial presentation was to establish a more relaxed and egalitarian environment that offers creative problem solving beyond the classical hierarchy usually found between teachers and students. The transfer of knowledge was explicitly presented as a two way street between different curious participants. It quickly became clear that learners in a formal classroom setting are rarely used to these two-way interactions which made it challenging to establish an open and creative environment. The ideation process itself grouped learners into teams of four students after offering only a minimal amount of guidelines. LEGO sculptures were successfully used to heighten the sense of creativity and fun in the workshop setting, where the recently released set "Women of NASA" became the obvious choice. Every team also was handed a stack of ten colourful pieces of blank cardstock. All teams were given the task to think of useful and meaningful functionality that would improve their experience in school as well as outside of the formal education setting, in their roles as learners as well as graduates. The participating students were asked to discuss freely, pose open questions and utilise their smartphones for the duration of 30 minutes during this process. By introducing creativity tasks learning outcomes can be improved remarkably with a Croatian team of researchers for example arguing that "creativity-supporting activities provides students with new perspectives [...] exposure to different attitudes, assists students when overcoming barriers, and prepares students for complex and multifaceted employment environments" (Žižić, Granić, and Lukie, 2017).

All cards were collected after the allotted time. In a collaborative effort, the whole group was asked to cluster their findings, recognise apparent patterns and identify shared hotspots. To do so one wall of the classroom hosted all of the students cards and grouping was done collaboratively during a discussion. During this episode also the basic knowledge of CT was established and discussed, mainly what aspects of a problem can and cannot be solved with a computational tool and if a new online platform can solve a specific set of problems. This of course highlighted the potential as well as the limitations of computational tools as described by Wing (2011).

The students documented the ideation wall after patterns were successfully established using their smartphones and posted to the shared chat group. This channel of communication was established and managed by the participants and led to significant engagement after the workshop ended. It later became a vital platform for announcements, communication and learning over time.

It has to be noted and acknowledged that the popular and widely used messaging application "WhatsApp" as a legal part of Facebook is problematic in terms of the GDPR (general data protection regulation, or in German DSGVO). In the section Useful Tools for Practitioner Integration alternatives are discussed and should be utilised in future iterations. In real-world classroom settings, it is often important to

Figure 4.3: Students Recognising Patterns in the Required Functionality.

find a balance between an optimal setting and a realistic solution - teachers have to establish this border routinely - and with practitioners entering this field it becomes even more difficult to find a shared tool without introducing significant overhead. All 21 students participating in this initial case study were very motivated and engaged in discussing their ideas as well as learning about new and creative ways of thinking. Collectively they explored their intuitive understanding and established knowledge to solve authentic problems that can be engaged with computational tools.

4.1.3 Invite Subject Matter Experts and Stakeholders

Potential guests - subject matter experts from their respective fields - were discussed at the end of the first session as well as in the chat group afterwards. The possibility to invite relevant stakeholders was openly discussed and agreed upon by the group's participants. Usually, self-contained educational environments do not invite outside guests regularly so the group was excited about the chance to invite

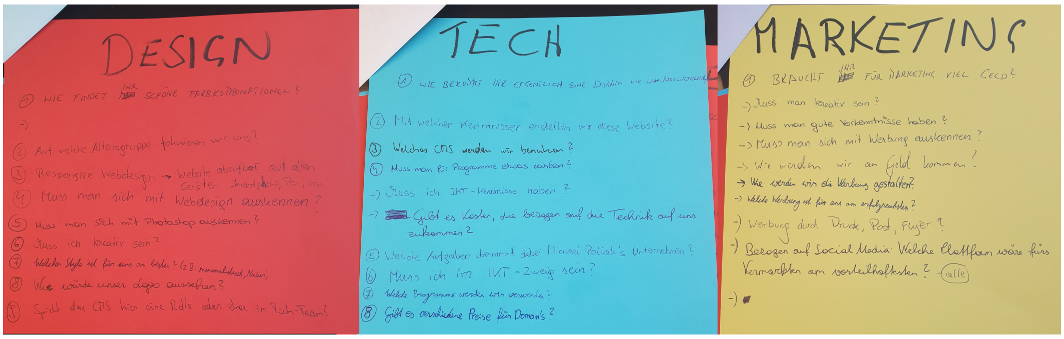


Figure 4.4: Students' Questions for Each of the Teams.

experts from different fields to discuss their ideas and give feedback on their proposals. This seemed important to show the value of their own work as well as the outside players that should be involved from the start. Identifying relevant entities was brought forth by prior CT research as a vital competence, which was integrated by discussing different stakeholders during this project (Basu et al., 2016, p. 22). Due to time restrictions only eight of the 21 participating students were present while meeting with three experts explaining the needs of businesses, graduates and the school respectively.

Prior to the invitees' arrival, the three distinct teams were established - design, marketing as well as technology. To gain an understanding of the students initial considerations a gamified version of a world cafe was experimented with. Three tables were positioned in the room, each table signifying one of the teams, where the students were asked to write one question for every group on a sheet of colourful paper on these tables. The precise question posed was "Think of tasks and responsibilities of every team, what questions do you think should this team work on?". The students gave interesting answers and provided some curious insights into their needs and expectations doing so. For example, the design desk got questions about responsive web design, showing an already well-defined knowledge by some students. A question about the choice of CMS for this project also strengthens this observation. At the same time, a lot of insecurities can be observed in questions like "Do I need to be creative?" and "Do I have to know Web Design or Photoshop?".

During this stage of the workshop, a major amount of discussion and movement within the classroom is created. This led to a lot of unexpected and very important conversations within the group of this experimental setting. The main takeaway discovered during this stage was the insecurities projected by learners about the new setting and the doubt they openly expressed in this stage. Most of the questions were concerning their perceived lack of knowledge and funding for a real project, which realistically inhibits their ability to experience the proposed freedoms to be creative and experimental with new learning paradigms. At the end of this exercise, all participants were asked to align with the tables they feel most comfortable with, be it the design team, tech team or marketing team, to establish a natural team structure. To alleviate openly shared fears and anxieties a big portion of the session was used to discuss these topics with the group, see figure 4.4.

After a break, the invited outside experts joined the group's discussion. These three practitioners - all alumni of the school - were happy to lend their time and knowledge to the curious students. During the first stage and to initiate a positive interaction a short presentation of the three subject matter experts was given. During this introduction, the three teams received an envelope with fourteen colourful paper snippets and were situated around their respective tables. To guide individual discussions and provide a framework for grouping and structuring the snippets contained all the ideas the group developed in the first session of the experimental workshop. Every stakeholder was explicitly asked to sort these ideas by significance and during a conversation with the group's members, explaining their mindset and decision while collaborating with the teams. Every 15 minutes the students were asked to move to another table and initiate a conversation focusing on their experiences and expertise. This was designed to ensure every participant had the chance to talk to every stakeholder and understand the represented group's needs and reasoning process.

These discussions and the developed significant features led the students to realise that different entities may and in fact usually have diverse sets of priorities that should be taken into consideration for every successful project, honing their CT skills in the process as shown in figure 4.5

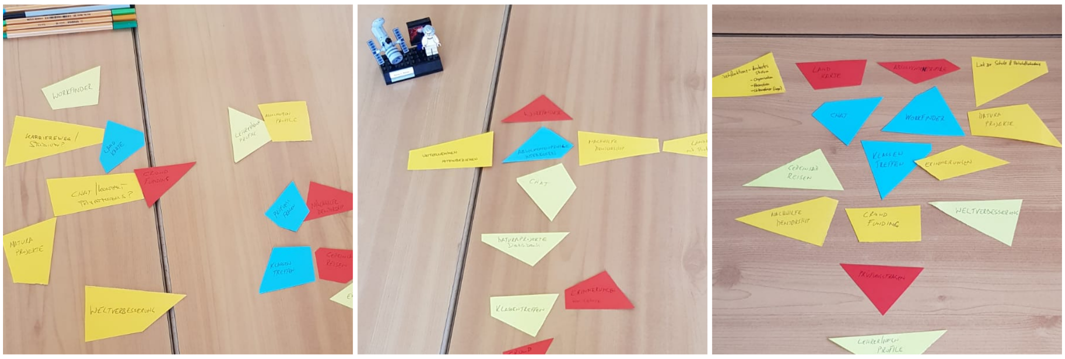


Figure 4.5: Different Priorities shown by Businesses, Graduates and the Schools Administration.

4.1.4 Collaborative Writing and Online Feedback

To facilitate online cooperation the well known collaborative document editor "Google Docs" (see docs.google.com) was introduced to the students. Participants were asked to explore the possibilities after a brief explanation and met online for the third session. As a starting point for the participants, they were asked to enter all the questions posed to the teams in the online tool. Following that the teams independently tried to answer all questions with the use of the internet, online documentation, provided manuals and all available resources. All entered information and remarks were collected, organised and edited by the team members, to allow all members of the team to access the groups combined progress. The chat functionality in combination with collaborative online writing and commenting was experimented with and received very positive feedback from the learners. This fully remote online session established one vital component of CT education, the adoption of new tools and the recognition of what tools can be utilised for. The students were introduced to editing and structuring texts for far more than just writing, they were allowed to explore the possibilities and find the boundaries. From a research perspective, the goal was to evaluate the usage, understanding and integration of online cooperation tools during this fully remote part of the workshop. Participating students were initially not familiar with this methodology and obviously seemed overwhelmed by the possibilities at first. The learners lacked self-motivation and organisational skills vitally important for a successful online blended learning experience. These obvious downsides could have been mitigated by taking additional time to introduce and experiment with the software during previous sessions where the workshop was still in a face to face setting. This may well have changed after years of remote learning due to the pandemic and needs to be re-evaluated in the future.

4.1.5 Solving Challenges and Presenting Solutions

Following the online session on April 19th 2019, the fourth workshop iteration was coordinated with the participants. The date has some significance as Friday the 19th was a holiday in Austrian schools and despite this, the students determined that date in a poll and were eager to participate. Working in teams on their respective challenges and independently looking for solutions was the goal of this iteration. The students were asked beforehand to bring their own devices (BYOD) to school to simplify the process. The instructions for this workshop session were outlined in a casual group meeting after which the interference was kept to a minimum and the assistance from practitioners was actively asked for by the teams. As the explicit aim of this iteration was to have learners look up and learn about the required techniques either before the session or independently as a team during the workshop it was a success to observe them working. The task descriptions and relevant documentation was sent out two days before the face to face session via chat for the learners to explore on their own schedule. The students themselves observed how computational strategies were applicable to them in different domains, a fact that was later in this session reiterated as the final important element of the problem-solving approach of CT. This successful workshop session was concluded with an informal round of show-and-tell at the end of the session, which made interdisciplinary feedback possible. The participating students were highly motivated to share the results of their group's work and discuss the knowledge they had collectively discovered.

4.1.6 Evaluation and Feedback

Students have been asked to keep working on their respective problems over the course of the two-week break. During the last session, a number of challenges

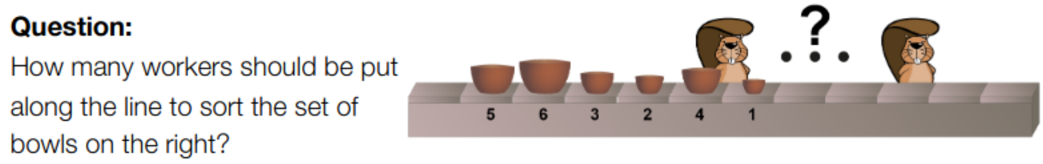


Figure 4.6: Screenshot from the Bebras Bubble Sort Question titled Bowl Factory.

were established for each team and communicated to the team members via group messaging. If applicable links to ideas and solutions based on open educational resources (OER) were distributed. At the time it seemed vital to offer a broad range of authentic, real-world problems for the teams to choose from, with the aim to allow for diverse and targeted choices. Also, the participants were offered low-level access to additional guidance via multiple social media platforms prominently used by the students.

The final workshop session was dedicated mainly to celebrating the successful conclusion of the tasks and presenting the knowledge created by all the involved team members. During the course of five sessions, all relevant CT strategies were learned, explored and internalised. The acquired knowledge was utilised in different domains to gain more information about coding, documentation, finances, graphic design, marketing, project management, software development and web hosting. To test their new capabilities learners took part in the competition "Biber der Informatik", a German version of the well-known bebras testing suite bebras.org. Of the seven contestants, four had a score of 100 % and three students had a score of 75 %. The only problematic task was called "Bowl Factory", see figure 4.6, which determines the understanding of a sorting algorithm named bubble sort, common in computer science education. This leads to the conclusion that the utilised practice-based teaching approach was successful in making learners aware of the basic steps of CT problem solving.

At the end of this workshop, the participating students were presented with signed certificates for their future job market portfolio, see figure 4.7. The headmaster of the school as well as the involved practitioner signed the documents to commemorate the work accomplished. This final social event with the participating student celebrated a successful project and an interesting case study for research purposes.

Zertifikat

Frau **Erika Mustermann**

hat beim Workshop "**HAK Startups**"

im Schuljahr 2018/19 mit seinem Wissen und seiner eigenverantwortlichen Arbeit maßgeblich zum Erfolg der AbsolventInnenplattform der HAK Waidhofen and der Thaya beigetragen.

hak has waidhofen an der thaya

OStR Mag. Rudolf Mayer
Direktor

Michael Pollak, MSc
Founder

Figure 4.7: Certificate Presented to the Participants after the Workshop's Completion.

Figure 4.8: A Group of the Students Collaborating on a Shared Document.

4.1.7 Initial Timeline and Final Project Support

Resources, especially the finite resource of time at educational institutions are always scarce, to say the least. The workshops were scheduled in five afternoon sessions in anticipation of limited time resources with each session lasting about four hours. The participating students were queried in a termino questionnaire about preferences and available dates to establish a sense of ownership, self-motivation and control. Workshops were held on February 21st, March 20th, April fourth, April 19th and June the seventh of 2019, following a pitch event held for every cohort. Online communication was a critical element between sessions with a number of slack channels and a collaborative document.

> "Finding the right balance between freedom and structure is the key to creating a fertile environment for creative learning." - Mitchel Resnick (Resnick, 2017, p. 80)

Based on the first workshop the learners were tasked to finish the proposed website during their final school project. In secondary education in Austria young people need to complete and present a final project as a team. Most often the students develop some kind of practical project with the skills learned in their education at a vocational school over the last five years. As a bonus, the author and his team of professionals offered support over the time between the ideation phase up to the release of a final website project. The goal of the ongoing support was to understand the knowledge levels shared within a team of four young students that were supported and assisted by content level experts in the final development phase of the web platform heroes.hakwt.at, culminating in the successful presentation of the project, see figure 4.9.

4.2 Hackathon in Secondary Education Business School

The concept for this workshop was published in "Medienimpulse 58" (Pollak, 2020).

For the second iteration, a hackathon was planned and prepared. Shortly after the pitch event the worldwide COVID-19 pandemic shut down the schools and kept outside personnel barred from educational institutions.

4.2.1 Pitch Session

The students were very engaged during the pitch event and asked a number of questions. To establish a plan and communicate the goals to the participating students all four potential classes were presented with the idea of a project day on March 24th, to work on their own projects and ideas for eight hours with the help and guidance of content specialists. The goal was to create something fun from the students' environment, to have a challenging competition and the potential to extend the idea to become their final project. The four areas were pitched to the students and created noticeable interest in this group of young minds. To allow for teamwork and the CT element of decomposition the groups were determined to be composed of four to six participants. After the pitch presentation, the students were asking questions and got time to document their initial ideas on a worksheet, as seen in figure 4.11.

Figure 4.9: Final Presentation with Local Politicians, Businesswomen and Policymakers.

Figure 4.10: Proposed Flowchart for Shortened Hackathon Iteration.

For the partner school, it was necessary to correlate all the possible hackathon topics with school subjects to assign the right teaching staff as well as grade accordingly, see table 4.2.

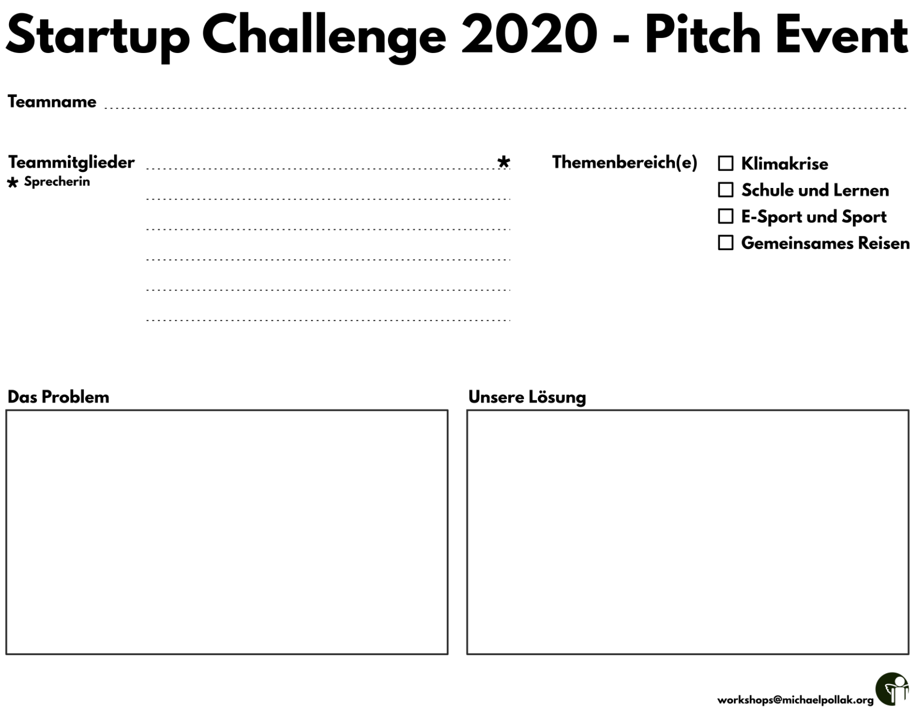
Topic	Curricular Subject
Climate Crisis	Natural Science, History
Learning and Schools	Political Education
Sports and ESports	Sports, Multimedia
Travel Together	Geography, Law

Table 4.2: Possible Topics and their Correlating School Subjects.

Sadly this was the last time the research team was able to visit the school and work with this group of young students. By now they have graduated and left the school. Still, it was an interesting experience and in the future some sort of hackathon, potentially the "Startup Challenge 2023" will be held to finally conclude this part of the project. The initial concept was published in 2020 in Medienimpulse 58 (Pollak, 2020).

4.2.2 Cancellation due to COVID-19 Restrictions

In 2020 all non-essential staff was barred from entering and teaching classes at school property due to growing health concerns. Ever greater COVID-19 case numbers eventually led to lockdowns and complete school closures mitigated by quickly implemented remote learning opportunities. After the conceptualisation and its publication in the journal Medienimpulse, the proposed Hackathon "Startup Challenge 2020" was made impossible by the increasingly strict rules regarding pupils' health and COVID-19 prevention. The author intends to conclude this



Startup Challenge 2020 - Pitch Event

Teamname ....

Teammitglieder .... ★
★ Sprecherin
....
....
....
....
....

Themenbereich(e)
☐ Klimakrise
☐ Schule und Lernen
☐ E-Sport und Sport
☐ Gemeinsames Reisen

Das Problem

Unsere Lösung

workshops@michaelpollak.org

Figure 4.11: The Worksheet used for the Hackathon's Pitch Session.

project phase at a later point in time but at the moment the necessary postponement led to a slight shift in the focus of this research and an expansion to include distance distance and remote education. After a few months of hopefulness and postponements, it became clear that the circumstances will only change with a vaccine and a fully vaccinated student body. At the end of 2021 only around 63 per cent of 15 to 24-year-olds are at least partially vaccinated while the crucial incidence value is rising dramatically in Austria (317 at 28.10.2021).

So the inevitable conclusion has to be made that in the near future face to face workshops with outside practitioners and experts are not viable, sadly. Future research needs to clarify the impact of in-class sessions especially compared to remote learning interventions.

Figure 4.12: Distance Learning with Microsoft Teams from the Practitioner's Perspective.

4.3 Distance Learning in Secondary Education Technical School

The findings of this workshop have been published published at the 2021 EdMedia+ Innovate Learning conference (Pollak, Sagbauer, and Ebner, 2021).

For the later iteration participating students were between 17 and 18 years old and at the time attending a college for higher vocational education (German original: "Höhere Technische Lehranstalt", HTL) graduating with ISCED level five, with a focus on electrical engineering in Lower Austria (see www.htl-hl.ac.at). The school, from now on referred to as HTLHL (www.htl-hl.ac.at), is located in Hollabrunn, a town north of Vienna in an area named Weinviertel (*Statistik Austria - Hollabrunn* 2021).

In 2020 most institutions were forced to implement programs for teaching and learning in a remote setting overnight. Everything went online and looked similar to figure 4.12. Some elements of learning are well suited to remote learning and decentralised learning, but teachers as well as implementing software developers were racing to get a grip on the ever-evolving situations. Policies were implemented, software licenses bought, trials explored and an incredible amount of knowledge developed in this rush. One way communication formats like big university lectures were easily translated and transformed into the newfound digital realm. This can be illustrated for example by the usage patterns from UT Graz (Austria), that document

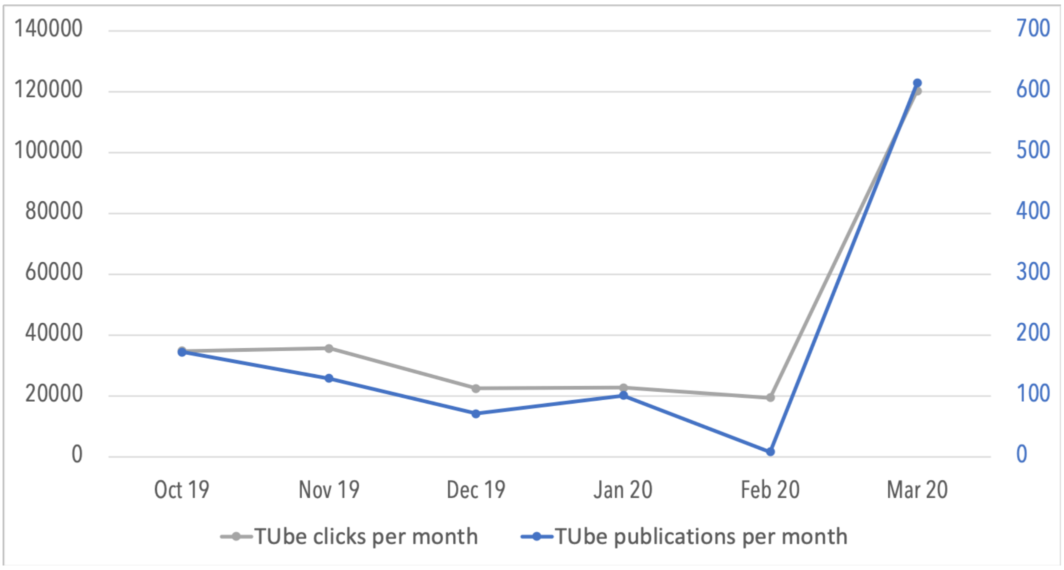


Figure 4.13: Usage patterns (clicks and publications) at TU Graz.

the immense popularity of audiovisual teaching materials in higher education, see figure 4.13. At the same time primary and secondary schools struggled immensely to make the necessary transition to some form of viable remote teaching (Ebner et al., 2020). All this work was done while offering guidance, personal connections and practical help to struggling students in this unprecedented situation.

In the educational system of today the public expects high efficiency and efficacy of educators, despite funding levels below the European average (4,9 % of Austrias GDP for education in 2018 (Canova, 2018; Gavurova et al., 2017). The health crisis that started 2020 uncovered and magnified structural as well as organisational pitfalls baked in the current formal school system. To create a future proof and sustainable educational system motivated educators and policymakers should be unburdened by an interdisciplinary effort to strengthen their resolve and incorporate them in a broader societal context (Ingram, Wolfe, and Lieberman, 2007; Lam et al., 2014; Wentzel, 1998). Based on previous experiments and their positive effects, the need to introduce experts from an economical, industrial and scientific perspective into classroom settings can be illustrated (Pollak, 2020; Pollak and Ebner, 2019; Pollak and Ebner, 2020). The search for better ways to invite practitioner based training in CT education was deflected because schools are not allowed to host on site workshops due to the ongoing COVID-19 pandemic situation. This constraint forced practitioner integration into a remote setting and offers teaching staff the chance to include and host subject matter experts in remote learning environments. This case study aims to reflect on potential and downsides of these virtual spaces and outlines a framework for future instalments of resilient remote learning.

For this case study a workshop was designed that fostered CT skills and abilities in a K-12 classroom based on a practical project. To test the effectiveness of a flipped classroom environment two groups of students were working on a shared project. Group one (G1) was taught in a lecture style setting without prior preparation while group two (G2) got their tasks in advance and was engaged in a more interactive, flipped classroom style. Group 1 started with their workshop sessions at 07:50 and they lasted till 09:30 while the second group started the synchronous section of the workshop at 08:30 and also ended at 09:30. The idea was for group 2 to prepare their work independently before entering the synchronous part of the workshop.

	Lecture Style (m/f)	**Flipped Classroom (m/f)**
Idea Collection	Dec. 2nd 2020 (10/3)	Dec. 9th 2020 (13/0)
Breakout Sessions	Dec. 16th 2020 (9/3)	Dec. 23rd 2020 (12/0)
Evaluation	Jan. 13th 2021 (11/3)	Jan. 20th 2021 (14/0)

Table 4.3: Date of Sessions as well as the Number of Male and Female Participants.

The students that were participating in this iteration were between the ages of 17 and 18. They were attending a college for higher vocational education (ISCED level five) with a focus on electrical engineering in Lower Austria's district of Hollabrunn. As this case study was inevitably limited to a specific school, broader applicability needs to be assessed and evaluated on a case to case basis. According to the schools internal information, only 81 (7 %) of the 1.104 students in 2020 were young women. This corresponds with data collected during the workshop, where only three of the 28 participants were female (11 %).

That constitutes one of the more prominent limitations of the study at hand and is in stark contrast to the partner school in Waidhofen an der Thaya with an economical focus. Participants of the first iteration workshop were split almost evenly, mirroring the schools predominantly female learners. In 2020 the school's

208 students were split 138 young women to 70 young men. This serves as yet another clear reminder that more female learners should be engaged in STEAM areas and schools need to deliberately tap into this massive unused potential (Moote et al., 2020; Schön et al., 2020). The utilised group work tool was Microsoft's teamwork suite called Teams, provided and hosted by the school in Hollabrunn. In Austria, this collaboration suite has become the de facto standard as the regional authorities (German original: "Bildungsdirektionen") rolled out Microsoft Teams to consolidate efforts in K-12 education during the second COVID-19 lockdown.

Comparing this workshop's schedule with the prior conducted case studies shows that a much more condensed and shorter approach was utilised. Instead of seven sessions, only three sessions were scheduled in this evolution, to meet the practical needs and restrictions of the research partners. The flowchart in figure 4.14 illustrates the abbreviated schedule. This shorter time allowance of three sessions was agreed upon, where students were asked to quickly and efficiently use the learned skills in a practical and project-based way. Every participating group had three scheduled workshop slots to come up with a suitable solution for a given problem, embedded in the curricular subject of computer-aided project development (CPE). Prior iterations utilised the chance to talk to more outside experts and develop ideas independently of predetermined scaffolding. This iteration's restrictions forced a concise methodology for engagement and learning.

Based on time restrictions and the known complexities of a virtual setting a condensed format was decided on by the school, teachers and participating researchers. With only six workshops - three workshops per group - a strict scaffolding was prepared and elements of the projects were completed beforehand. Notably, the setup process of accounts, search for web hosting platforms, and other preparatory tasks were conducted prior to the workshop's start.

A first session was mainly used to get to know the students and the groups participating in this iteration. The goal was to present the problem, the area of expertise and collect initial ideas from the group itself. During the second date, the main goal was to split the participants into smaller breakout rooms and develop three distinct fields independently. The areas of interest were namely the technologies used, the graphical representation of individual issues and the textual content describing the problematic areas. During the third and final session, the

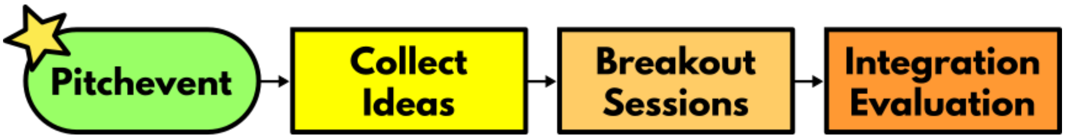


Figure 4.14: Evolution between the first workshop iteration and its current state.

knowledge gained within the breakout sessions was combined and the three teams integrated their results in a final product while evaluating the process itself.

4.3.1 Comparing Two Teaching Styles

The idea of researching the effects of a flipped classroom came up in discussions with teaching staff. The two distinct groups within this class seemed like an interesting candidate to determine the pros and cons of different approaches so it was decided to host one of the two groups with a special twist. While group one was taught in a participatory teacher-centred style and acted as a control group the other participants in group two were asked to prepare their work independently whenever they felt like it and had spare time. As a benefit, their workshop sessions started later in the day. Handouts describing the tasks were prepared and uploaded to the collaboration software. Students were given the chance to ask questions outside the scheduled workshop sessions.

4.3.2 Collect Ideas

The initial session to collect ideas and get to know each other was held on December 2nd for group one and December 9th 2020 for group two to introduce the project to the participating students. To generate a positive rapport with the learners, participating students were presented with a little personal background as well as a professional curriculum vitae. After that both groups were given the opportunity to ask questions of the practitioner and input the broader fields they wanted to know more about in an online tool.

From these results it becomes very clear that young people are very curious to interact with outside practitioners, to learn about their personality, about their

Figure 4.15: Topics that the students wanted to learn more about.

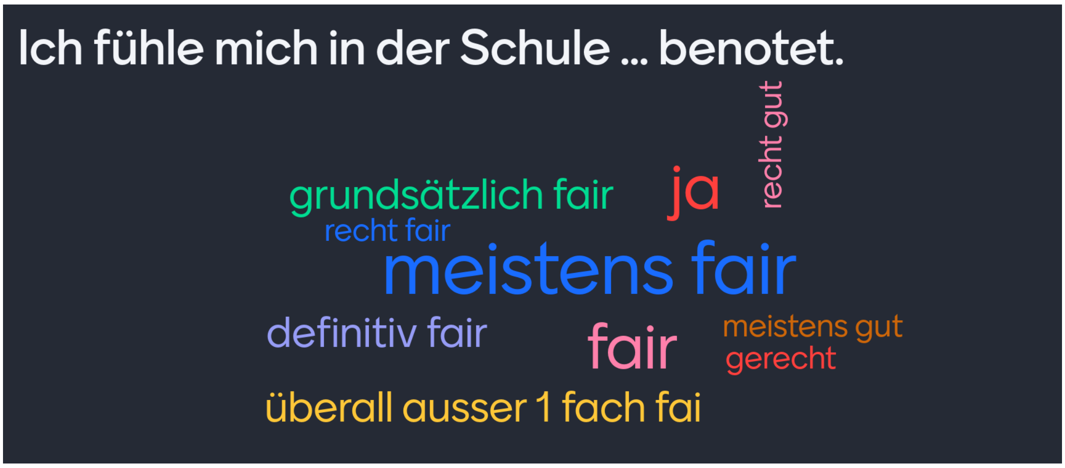


Figure 4.16: How fair do the students feel their grading is.

efforts to create a stable work-life-balances and the possible pathways chosen where their own decisions still need to be made. For this workshop the available time was very limited so not all inquired topics were talked about. For future iterations it might be a good idea to offer more time for discussions, to allow for a deeper exchange between the generations and worlds we share, as can be seen in figure 4.15

Out of curiosity and to test the capabilities of the questionnaire tool the students were asked about their grading schemes and how fair they feel their grades are compared to their performance, see figure 4.16. This successful test of the capabilities showed the engagement created by utilising modern tools and technologies. Students were curious about the options of this questionnaire tool and were con-

Figure 4.17: Prefered media to be used for the project, results of group one and group two with a clear preference for a website.

sequently asked to think about their medium of choice for an upcoming project. The researchers presented a list of options for ideas, like a website, a smartphone application or a poster. Both groups showed similar interests in technologies where a website became the obvious choice. Posters, videos and TikToks were also mentioned with some students clearly less curious about website development, see figure 4.17. It seemed reasonable to assume that learners had previous experience with some media formats practiced in their spare time. This was confirmed during subsequent discussions with the group and shows the necessity of asking learners themselves to become experts in their fields and engage their knowledge deliberately. It was decided with the groups to create a simple website with multimedia elements to engage as much of their curiosities as possible.

Additionally, the participating students were asked to read and try to solve CT challenges on their own to acquire a baseline. With five minutes of lead time the Bebras task named "Mutation of an Alien" was shown and discussed - see figure 4.18. This particular question from the wide range of Bebras questions is an interesting CT evaluation as it challenges models and forces participants to de- and reconstruct their thought process. After the last answers showed up in the Mentimeter platform - see figure 4.18 for details - the participating students discussed their solutions and the way they solved this particular challenge. It was obvious at that point that the practices engrained in CT are part of learners' everyday problem-solving process. The students were very interested and curious to understand the elements it entails and the potential it has for their future, when faced with complex problems to solve. It was interesting to discuss solutions and approaches, despite their varying "correctness" in this case. For example, the group in figure 4.19 is not uniformly certain what the correct answer is. In the subsequent discussion, the learners shared their solutions and collaborated on correcting their answers and the mental pathways the participants took, consequently collaborating on the final solution to this challenge.

A second challenge named "BikeFun" from the Bebras catalogue was introduced to and subsequently answered by students, see figures 4.20 and 4.21. This sparked a discussion that compared different approaches and conflicting outcomes, strengthening the aforementioned point. At this stage students developed an understanding of the importance of concise and clear problem solving approaches as well as communicating their methodologies.

After establishing a shared baseline the practical tasks for this workshop iteration were introduced. The given problem of remote teaching and learning, the students role as subject matter experts and a path to support their teachers was showcased. The final task of this interactive session was to identify problematic elements of their remote learning experience over the previous months. What challenges and problems the students faced while working with their teachers in a virtual classroom environment. All topics mentioned during the discussions were marked down, grouped and categorised by the participating students. This session ended with a final roster of eight main problems that were established from the learners perspective, as can be seen in figure 4.22.

4.3.3 Breakout Sessions

Prior to the breakout session the major areas of common problems and practical issues were determined. After this identification process with the learners, the issues were reiterated quickly and the eight problematic areas were ranked most pressing to least important by every student leading to this outlook as presented in figure 4.22.

The first and second most significant problems are the technical issues of "Is the sound quality good?" and "Is the internet connection good?". Trivial technical problems still seem to be the main challenge after six months of remote learning. Also, issues concerning virtual teaching style and the specific needs of online learning have a focus. The questions "Do I ask enough questions", "Is my writing

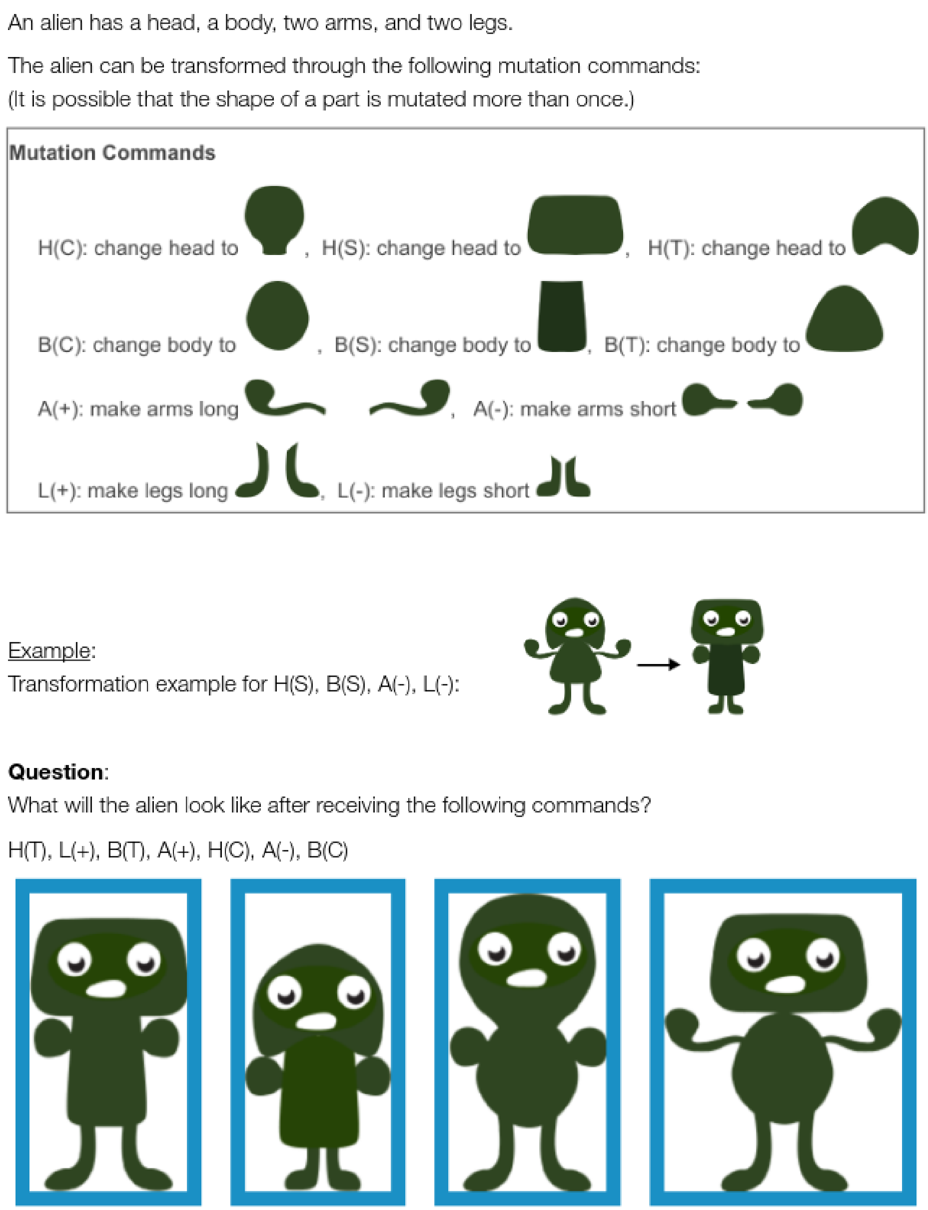


Figure 4.18: The Bebras challenge named Mutation of an Alien.

Figure 4.19: Not all Answers to Mutation of an Alien were correct initially.

Figure 4.20: The Bebras Challenge named BikeFun.

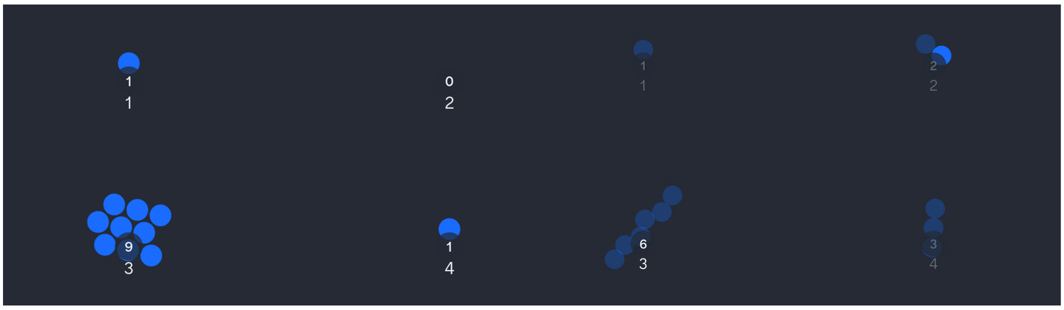


Figure 4.21: Conflicting Answers to BikeFun by Group 1 and Group 2.

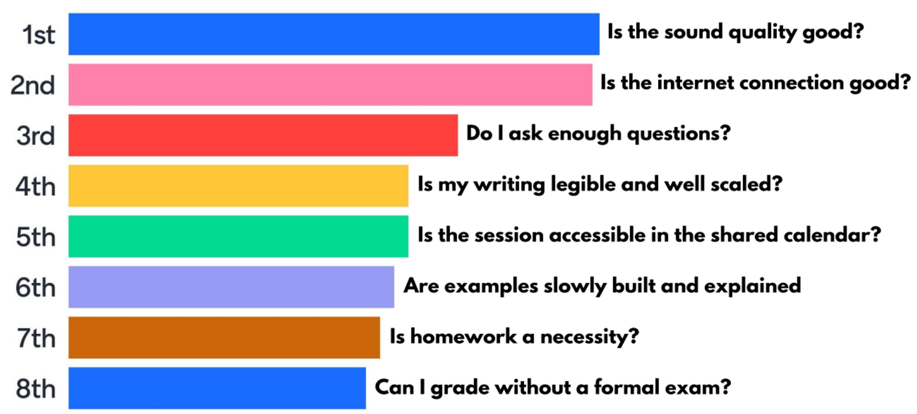


Figure 4.22: Problems with distance learning ranked by students.

legible and well-scaled?" and "Are examples slowly built and explained?" came up in this research project. The technical need of entering lectures and appointments in a shared calendar was explained where else homework and exams seem to have lower-ranked importance.

Three teams were established with a focus on technology, graphics as well as texts to tackle problems in separate breakout sessions before combining their efforts. The tasks for the flipped classroom group - G2 - were handed out with prepared worksheets. Room for questions was offered but not used by the students. Given tasks were split up to facilitate teamwork and collaboration. The technology team was asked to research software tools to build a simple and free website. Three possible solutions were given with sites.google.com, webnode.at and wix.com. The graphics team was tasked to find one animation or image for each of the eight main problems. Lastly, the team working on textual content collaboratively wrote a paragraph for every issue to explain their need in detail and to a broader audience. The teams were given 30 minutes to work on their work packages and prepare a short presentation for the whole group, which ended the second session.

4.3.4 Integration and Evaluation

Integrating the different elements of the project groups into a final product and implementing a website to conclude the project were the goals during the final session.

To start off, the groups were asked to reflect on their work and reiterate what CT means for them and what they understood and remember about the approach. After that the team tasked with technological implementation presented the drag and drop interface of their chosen editor to the participating students. The first group started with the implementation of four guidelines collaboratively, with students from the text team adding prepared paragraphs as well as the graphics team pushing fun animations and graphics to the website editor. With these preparations finished the second group was tasked with reviewing the work of their peers and building upon it by adding the mission key statements teaching staff should focus their preparation work on. The finished product (see screenshot figure 4.23) was then published with students permission and can be found here 1028164.wixsite.com/gutevirtuellelehre.

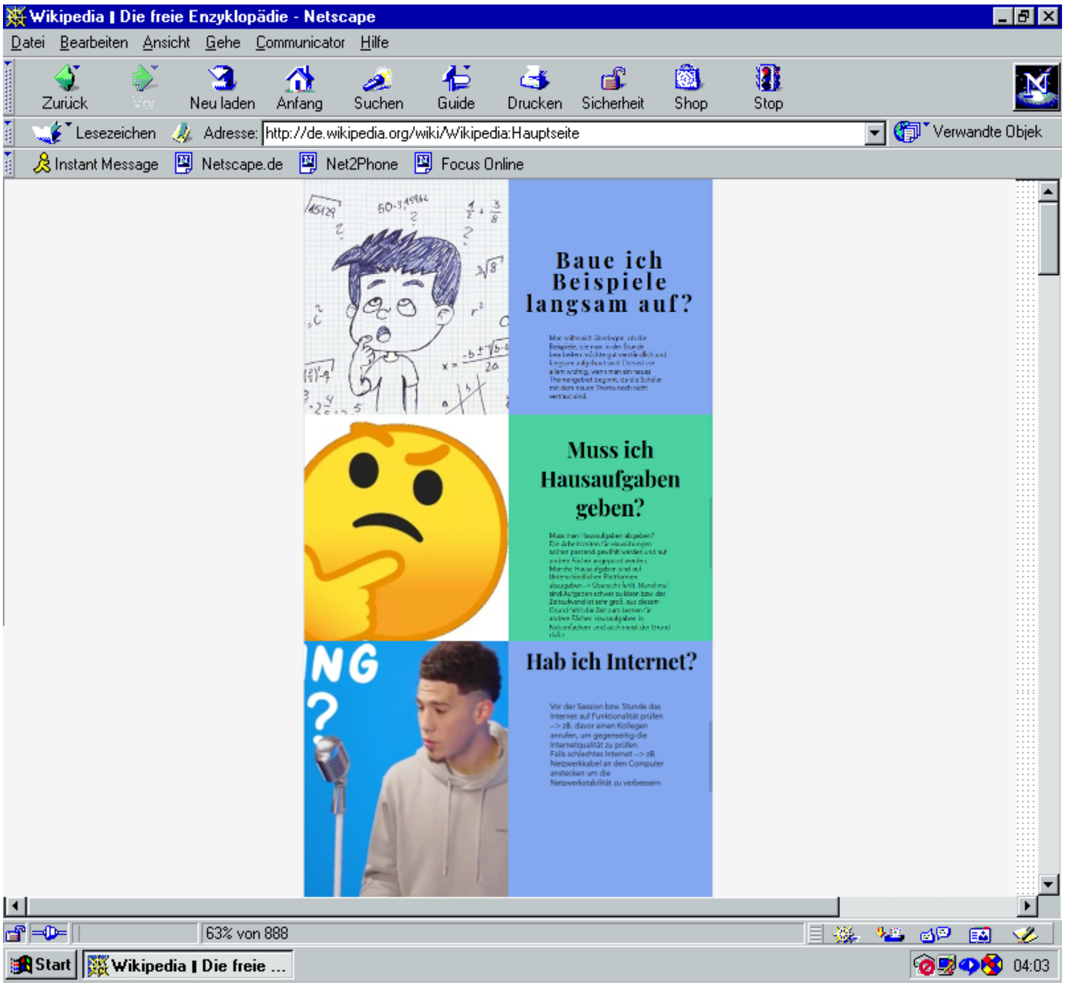


Figure 4.23: Screenshot of the checklist for better remote teaching.

5 Findings

The main takeways found during this projects runtime are as follows:

- Adding practitioners to in-class and informal learning settings is beneficial.
- Students enjoy the practical knowledge and variety provided by practitioners.
- Computational Thinking can be learned in a practical, project-based way.
- It is complex to integrate outside expertise in an already bursting schedule.
- The assistance of in-service teachers is key to successful learning environments.
- Current interfaces between schools and practitioners are underdeveloped.

5.1 Collected Data from Face to Face Workshops

During the face to face workshop a host of data was collected, from questionnaires to quotes to short interviews as well as the students notes. The primary idea behind this initial workshop was to evaluate the status quo and students' ability to cope with new, uncommon and surprising methods of learning and teaching. The integration of outside experts was established by a project-based workshop where the group was tasked with the bold outlook of creating a startup-like, open and innovative infrastructure for a platform that should be interesting for former graduates, current students at the school as well as future prospects at the economic school.

The notes from interacting with and talking to the students show that - in hindsight - the scale of the project was challenging for learners to grasp. Envisioning a project that can be created in this condensed environment but at the same time is interesting for the students as well as being impressive to the larger environment is a nontrivial task. During discussions with the teaching staff it became clear that closer collaboration between the practitioners and teachers is necessary to allow feedback on the scale as well as the prior knowledge of learners. This leads to the generation of feasible projects in the span of the allotted sessions as well as manages expectations of all stakeholders realistically.

Students got a sense of value and size of the proposed undertaking. Working in close proximity to subject matter experts the challenges of modern, scalable social media platforms as proposed by the participants were discussed. The technological, logistical and organisational scope of the project was talked about and decided in a collaborative fashion, culminating in the development and testing of a simple prototype. A team of four students was ultimately tasked to implement the project envisioned during the workshop as their final school project.

The practical use of CT and this way of learning a new problem solving approach was well received by the learners. During the first presentation phases, a number of questions were asked about the usefulness of this approach and especially if it can only be utilised with a computer. In the sessions, the learners explored the elements of CT and enjoyed the benefits of a clearly structured approach. This was often communicated during group work sessions. The teachers interviewed were not fully aware of the concept and did not include it in their teaching. During the preparations for this project, the author interviewed a part-time teacher at the school who is also working as a software engineer. In his CS classes he explicitly teaches CT with the help of the Java IDE called "greenfoot"[1] and the associated textbook, implying a clear link between CS and CT. The interview with this career changer (German original: "Quereinsteiger") clearly shows the interest of entrepreneurs as well as scientists to engage with and assist the schools in their local communities. But despite the often existing curiosity and willingness to engage in formal education, the interviewees often pointed to current policies and decision-makers that make it challenging to integrate outside practitioners in formal education.

During discussions with the students it became obvious that the value of authentic,

[1]For further information see greenfoot.org

real-world problems can not be overstated. The participating young creators were eager to engage in a productive and self-motivated project with the outlook of presenting it to their environment. This chance to engage with other people from outside the environments they are used to has clearly been one of the main motivators für the participating students and the path to a successful implementation lies within this collaborative engagement of ideas, people and worlds. Students are aware that institutional teaching is - at least to a significant degree - outdated, especially in a technological sense, and outside experts can introduce current methods and problem solving approaches to the classroom. Keeping the goal impressive but manageable will lead to more satisfaction and success among the learners.

From the notes, it appears that a lot of students were not taking place because of their other obligations. It is obvious that a face to face after school workshop can never reach every pupil within a cohort.

The aspect of time in combination with socioeconomic constraints hides the problems of disadvantaged students from this research project. These often more diverse and heterogeneous groups can not be reached by this intervention, missing the main goal to show all young people the power of CT for their benefit. During discussions with teaching staff as well as the students themself this point was often reiterated and an in-class workshop within a public secondary school would be more beneficial - despite the more challenges to establish this setting.

5.2 Collected Data from Distance Learning Workshops

In 2020 the world changed and schools were forced to close and implement remote learning in an effort to slow the spread of COVID-19. Different evaluation methods were used to determine the students' engagements and interests as well as their learning outcomes. To analyse the CT efficacy of learners, a number of challenges from the test suite "Bebras", or in German "Biber der Informatik" were used. The students individually worked on the tasks after each session and posted their answers on mentimeter. The students in the distance learning cohort were asked to write a learning diary after every workshop session was concluded. In addition to these data points a subsequent questionnaire offered more insight after the workshop was concluded.

The engagement, probably due to the remote learning environment and the condensed timeline, was notably less and informal discussions and exchanges happened rarely. The setting within school hours and a formal in-class environment constrained the engagement of the students. Distance learning holds a lot of challenges for educators and practitioners alike, with its removed feeling and missing interpersonal interaction. Nonetheless, the learners were interacting and working on their project as expected, they seemed curious and interested in the topics at hand. Of course, some students were more engaged and coped better with the remote learning environment than others who seemed distracted. From the notes and subsequent interviews with the teaching staff the after school event fostered a smaller but more interested and tight-knit group due to a number of human factors. The next paragraphs will try to compare the collected findings in more detail.

5.3 Comparisons

5.3.1 Students Feedback

Overall students feedback was positive and engaged for the face to face settings as well as virtual learning environments. During the face to face workshops, engagement was noticeably more involved with a smaller group of students working for a longer period of time on a shared project. The shorter and more remote interactions during virtual learning had the effect of some students rarely interacting with the topics and the project itself. This is reflected in the students feedback throughout where the difference between forced in-class sessions and volunteers working on an afterschool project became exceptionally prominent.

Understanding the very limited time resources of students and their commitment to formal learning and especially the assessment and regular grading in school was one key result from learners' feedback. Participating students struggled to integrate more content into their day to day lives, often juggling multiple responsibilities in the little spare time they have after a full day at school. Certainly more involved and

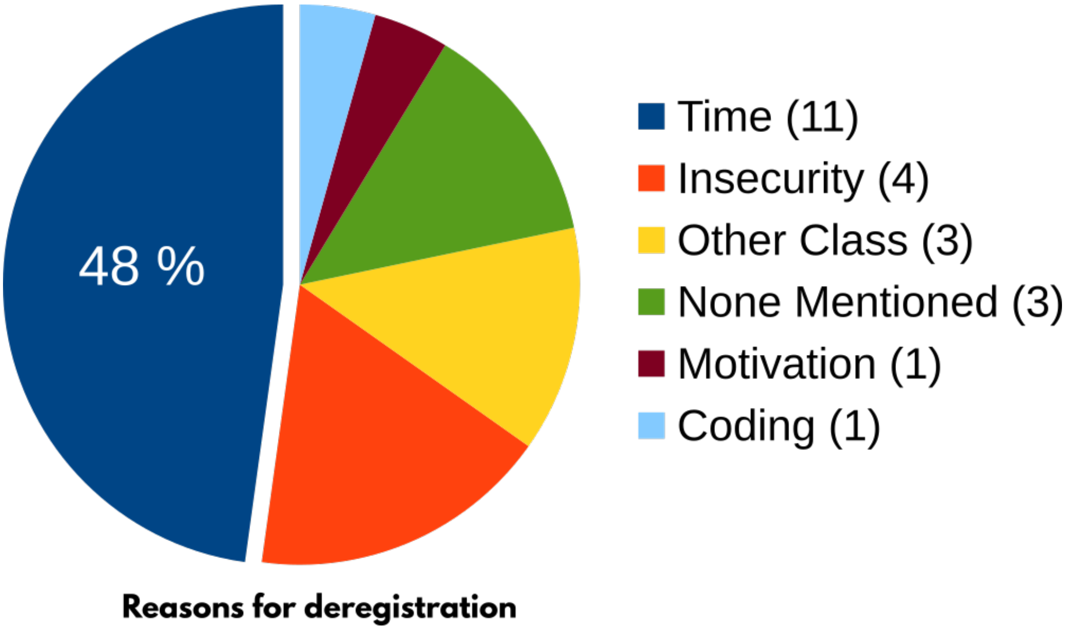


Figure 5.1: Stated reasons why some participants left the workshop.

long term programs need to account for the very limited availability of students, allowing for a hassle-free and flexible learning environment. Sadly - it seems like - todays youth often can not simply work on the projects they love and learn about the concepts they crave, see figure 5.1. Often the fight for time and its associated struggles start at a very young age and continue during their careers, a vicious cycle of perpetuating focus on outside grading.

Giving students the opportunity to interact and engage in their own projects within the realm of formal education may offer one pathway to get out of this struggle for time and combine engaging projects with the boundaries established by institutionalised education. Students feedback was very positive with a focus on outside experts offering new points of view to young learners.

The lack of time resources plagued especially the initial workshop as well as most other experiments that try to squeeze more content into students' lives. Luckily this project worked with a very interested and motivated group of young people, but even then it became clear that time is a rare and valuable commodity. Learners at the age of around 17 have apx. 38 hours of classes every week and in rural Austria

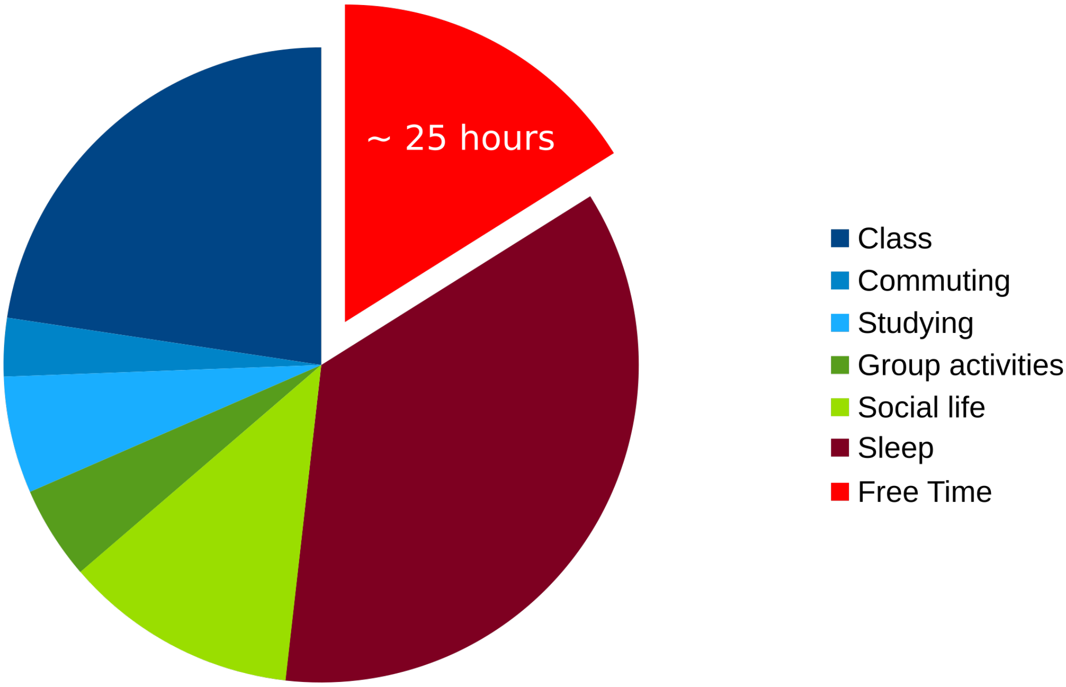


Figure 5.2: Allotted time of secondary school students.

need to drive apx. five hours a week from and to the school building. Add to this the approximately ten hours of work preparing for exams and doing homework this ends up being a very full schedule. Most students interviewed attend group activities like football, basketball or volleyball, do voluntary work at their local firefighting group or practice Esports regularly, which on average added 8 hours to their weekly workload. Attach an active social life and the need to sleep an average of 60 hours a week, to get a feeling for how little time informal learning environments compete for. School is hard work for youth, the time available to learn outside of it is minimal, see the pie chart of alloted time of a secondary school student in figure 5.2.

Extracurricular workshop settings are viable to engage learners with prior interest and the ability to self motivate, but fail to integrate disadvantaged students and entire cohorts. The goal for expert driven CT education should be to reach all learners, to become an inclusive, sustainable movement. Workshops integrated in curricula, as shown during this project, are a viable option to reach this goal.

Figure 5.3: The diverse interests of participating students.

Offering more possibilities outside schools and formal education is vital for the growth of capabilities but initial engagement and the promotion of ideas needs to happen in public schools and reach all young learners equally.

During the distance learning workshop students were pitched the idea of the project and the research questions behind it. After discussing the main pillars of the work and the people involved the students were allowed to ask questions and post topics they would like to know more about in the questionnaire. This became a very interesting exercise - despite the fact that it was only included last minute - because it vividly shows how diverse the groups and the young people within this classroom think and what their fields of interests are. In one group the experiences outside of work and formal education became the focus, asking about hobbies and leisure time activities. Also experiences at university were a focus as obviously some of the participants were thinking about career and education paths along their future ways. The other group's focus was on the scientific project itself, the research goals and the career choices in the past, see figure 4.15. Within this very limited sample of young learners an incredible spread of knowledge and interests becomes strikingly obvious. And this is exactly what makes education in a formal setting as challenging as it is.

5.3.2 Teachers Reactions

One main concern of this research project is the motivation and increased efficacy of teachers, with a very varied range of personal involvement. Certainly teaching staff is a diverse and heterogeneous group but some facts remain similar in all school types. In interviews and discussions, the workload for educators was evaluated. In-class time, in general, is a scarce good as curricula have become denser over the last decades. New content is added, new technologies get adopted while the time allocated mostly remains unaltered. So educators are forced to integrate more content in less time, often having problems attending to the needs of every learner involved. Trendsetting technologies and current knowledge often are adopted very late by formal education. According to the participating teachers, it is often a struggle to fit all curricular content and state-of-the-art developments into the scheduled time frame and educators need to choose the focus and the depth of their lessons wisely. Their abilities to offer technological up-to-date knowledge and profound expertise demand constant on-the-job training and professional development in addition to their regular teaching duties. The Austrian school system permits a teacher three days of absence from classes to participate in training sessions without financial loss. The attendance of specialized technical courses outside the teacher training programmes of University Colleges of Teacher Education (German original: "Pädagogische Hochschule") is not stipulated.

These facts illustrate the need for external professionals and experts to provide students and teachers with glimpses of real-world problems and solutions, and enthralling state-of-the-art topics. Together with one educator the main obstacles for teachers, when inviting experts, were analysed as follows in the publicated results of this research endeavour (Pollak, Sagbauer, and Ebner, 2021).

Finding experts that are willing to share their knowledge and real-world experiences, without financial incentives is not a trivial task. Practicioners with real-world expertise that do have the knowledge to break a complex problem down to a level that the students can understand and prepare a concise and engaging workshop are challenging to contact and engage. There is no platform available or program that is able to disseminate that information to schools and teachers currently.

The second topic that is challenging to educators is integrating practitioners workshops in the formal classroom setting. Every teacher in Austria is obligated to provide a timetable, where the content of the curriculum is assigned to a class schedule in the beginning of each school year (German original: "Lehrfächerverteilung"). Intermediate events that take up time that has originally been scheduled for curricular content can cause problems, especially if understanding the content is a prerequirement for the following topic.

Teachers additionally are obligated to grade students based on their classroom engagement and achievements. There are spot tests like written exams and oral examinations as well as the continuous observation of class participation to grade learners. When an expert workshop like the one at hand takes up a couple of weeks assessment of participating students and grading is necessary.

Despite the expected reduction in tasks and invested time the involved teachers were required to put in some organizational effort by inviting the practitioner to the group meeting. Technical challenges also took up valuable learning time and caused disruption in the process. Overall the teachers feedback showed an increase in preparation requirements for the workshop in comparison to usual lessons for this class. During the workshop the teacher in the remote learning environment was observing the participating learners as well as keeping records of students involvement and absence. The pedagogical support was also a very valuable input of the teaching staff. From a teacher's point of view, the intensity of labour was significantly lower for assisting the expert workshop than for teaching a regular class. In summary the experimental practitioner workshop consumed more of the class teacher's time due to additional organizational issues regarding online remote access of the expert, which was countered by a lower intensity and attention level during the conducted workshops.

The stressful and often unsolvable challenges experienced by teaching staff are well documented in scientific literature. One recent article intensely explains the dichotomy of a technologically savvy and well-trained student body and one teacher unsure about the applicable rules. As regulations are brought into existence, teachers need to be enabled to utilise the skills and tools available outside of the classroom. The dilemma is best summarised in her own words "Where is the line between my responsibility for students' education as a teacher and stepping outside my remit drawn?" (Mrazek, 2021)

5.4 Useful Tools for Practitioner Integration

Interesting and new tools and techniques can be a very strong motivator for young learners. Allowing students to interact and play with exciting technical software tools was one of the major selling points of the first workshop setting.

The sustainable integration of open source tools especially is invariably useful when integrated in a scholarly environment, as students can hone their skills outside of the classroom, which is a stark contrast to the often seen click by click guides commonly seen in office software, which are worlds behind current teaching methods. The power to potentially see, play, dissect and comprehend new and uncommon tools will be an invaluable skill for the future industrial and academic workplaces a big number of young people will spend their careers in. Understanding of the low-level functionality is only possible with access to the source code. The underlying algorithmic structure of the utilised tools is open to read, evaluate, change and execute. The incredible tools the international FLOSS community offers to institutions and policymakers implement the constructionist targets and goals of MIT media labs Lifelong Kindergarten Group's paradigm - a vision for a future proof education (Resnick et al., 2009). Offering a low barrier of entry with a simple install process and a neat, easy user interface, but at the same time giving virtually indefinite access to modify, change and experiment with the software computer code presents a wide gamut of interactions with the tools used. For the workshop and this project, a number of tools were crucial and can be highly recommended to teachers and educators going into open source software.

Atom	Specialised software development IDE
Geany	Text editor to work with software source code
Gimp	Software to work with and create pixel graphics
Hedy	Gradual programming language designed for learning
Inkscape	Tool to create and edit vector graphics
Pocket Code	Smartphone App for coding exercises on the go
Scratch	Visual programming environment for education
Signal	Secure messaging application
Snap!	Extended block-based coding language
Termino	Scheduling tool
Wordpress	Content management system to deploy websites

Table 5.1: Free and Open Source Software Tools for Education.

Many tools have been evaluated and can be recommended to make the integration of outside practitioners easier. Often schools rely on already existing platforms, so especially with online communication tools and collaboration suits the formal education sector is locked into proprietary solutions. Using Microsoft Teams or other collaboration tools, practitioners have to comply with these given structures to allow students to focus on the content rather than the tools themselves. Nonetheless in some areas powerful (mostly) open-source tools can be used to create more effective interfaces between stakeholders, allowing for a more fun and interactive learning environment. Here is a list of tools that have been used in this project, as a starting point for the reader and a hint for policymakers and teaching staff alike.

Atom

If Geany has not enough features the Atom text editor / IDE is a suitable alternative for bigger project development, integrating the git version control system and a host of other useful features. atom.io

Geany

Simple open-source text editor to view and edit software source code, be it HTML/PHP/JS or Python this editor offers code highlighting and is extendable if additional special features are required. geany.org

Gimp

Open-source tool to work with pixel graphics, comparable in feature set with Adobe Photoshop. www.gimp.org

Hedy

Teaching and learning Python, a functional programming language widely used in education is made easier by this browser-based tool. It gives an interface and a clear lesson plan to gradually introduce new concepts in a hands-on fashion. hedycode.com

Inkscape

Tool to view, edit and create scalable vector graphic files comparable to Adobe Indesign. inkscape.org

Pocket Code, formerly known as Catrobat

A Smartphone App that allows simple, block-based coding exercises on the go. The interface is inspired by Scratch and Snap! and can be used independently as well as in connection to the aforementioned tools. It is perfectly usable for an impromptu BYOD coding exercise with groups of students or in an informal learning environment. catrob.at

Scratch

A very playful programming language based on a block styled interface specifically tailored to young learners and kids. scratch.mit.edu

Signal

A secure messaging application that can replace WhatsApp if no other service is provided by the school. signal.org

Snap!

Another playful programming language based on the block interface of Scratch and specifically tailored to advanced kids, offering additional blocks and functionality that is not available in the original Scratch interface. snap.berkeley.edu

Termino

A GDPR conforming scheduling tool much like the ubiquitous "Doodle" tool developed and hosted by the Austrian government. It is free to use, does not store personal data, protects users privacy and is a drop-in replacement for other scheduling tools. termino.gv.at

Wordpress

Powerful content management system to build feature-rich websites.
wordpress.org

6 Discussion

6.1 Evaluating Effects of Practitioner Integration

Collecting and hoarding results is not the point of this exercise. A structured reflection of the work accomplished and the lessons learned over a few years and many fruitful exchanges is crucial to retain the knowledge and make it possible to share findings with the community. So - arguably - this part of the document is the most important. At the same time, it was the most challenging to write as often documentation focussed on one point of view or one specific incident that can never fully explain a complex, unstructured setting like a classroom. Despite that limitation, a number of clear and obvious results can be seen and based on these factors. This thesis strives to lay out what can be done to improve the situation.

Learning and engagement in students is a complex and multidimensional challenge. During this research project elements of Learning Experience Design have been utilised and confirmed, see figure 6.1, where the interconnection between technologies, learners interaction with practitioners and the pedagogical skillset resultet in the most promising reactions. From the collected data we have developed an understanding of the role outside experts can play in a formal educational setting. Learning Experience Design can provide an understanding that learners need more than pedagogical inputs but a complex entanglement that integrates cooperation and technological efficacy in the mix. This results in a sustainable environment that on the one hand can unburden educators from excessive expectations and on the other hand allows learners to cooperate with real world problems and adequate technologies.

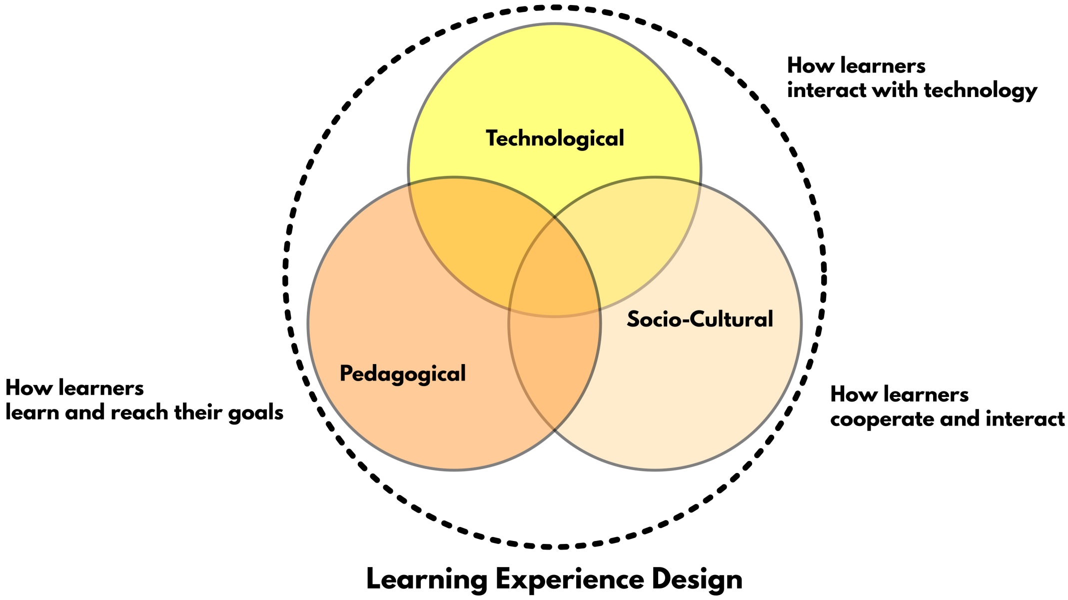


Figure 6.1: Learning Experience Design according to Schmidt (2021).

6.2 Why these Results Matter

Education is one of the most challenging topics the world we live in today faces. The young minds around us need to be supported in developing new pathways to a sustainable future for themselves and their peers. The 17 Sustainable Development Goals (SDGS) - see figure 6.2 - have been developed by the United Nations (UN) to understand the most needed and influential sectors of society to ensure a good life for everybody (*THE 17 GOALS | Sustainable Development* 2021). The fourth SDG is called "Quality Education" and is targeted to ensure "inclusive and equitable quality education and promote lifelong learning opportunities for all" (*Goal 4 | Department of Economic and Social Affairs* 2021). The steering committee for this particular SDG is led by the UNESCO (*| Education within the 2030 Agenda for Sustainable Development* 2021).

> "Education is a human right and a force for sustainable development and peace." - Education 2030

Based on these results new interfaces between classic educational settings and

Figure 6.2: The 17 Sustainable Development Goals as defined by the United Nations.

the entrepreneurial and scientific landscape need to be created. Using current, virtual and remote environments established at schools and universities a blended learning environment can enable almost seamless integration of practitioners. Subject matter experts in close coordination with teaching staff can use a virtual setting to drastically enhance students' computational thinking skills.

6.3 Proposing Improvements

6.3.1 Teaching the Teachers

In-service teacher education is a generally slow and cumbersome task. Learners often are a lot more engaged in the intricacies of current technological development, especially in fast-paced fields like IT and CS. This leads to a problematic intertwining of educator and learner, where the classical hierarchical structure is broken down and friction appears. In the Austrian school system, an only marginal effort is made to keep practising teachers up to date on new developments (Andreitz and Müller, 2015). To allow for collaboration and sharing it seems vital to make especially engaged and motivated teachers aware of the possibilities of OER and creative commons licensing (*Understanding Free Cultural Works* 2021). And while educational resources are available and it certainly is possible to learn new skills independently, it is necessary to pay teachers for their effort to keep up with the curricular expectations and their students' curiosity to learn. A scale has been developed and is still in review to establish the efficacy of teachers in a technological as well as pedagogical context. Current research proposes a solid groundwork and can lead to future improvements in teacher education and lifelong learning efforts. Teachers should be able to utilise this framework for gaining an understanding of their individual knowledge and potentially decrease known deficiencies. Future research should look into teacher education with the goal to integrate all levels of the TPACK framework - see figure 6.3. Still, teacher education is slow and requires a big concerted effort to fulfil its potential. In a perfect world it would be one of the key elements to modernise formal education but realistically speaking outside practitioners can introduce the needed knowledge a lot quicker and without additional overhead.

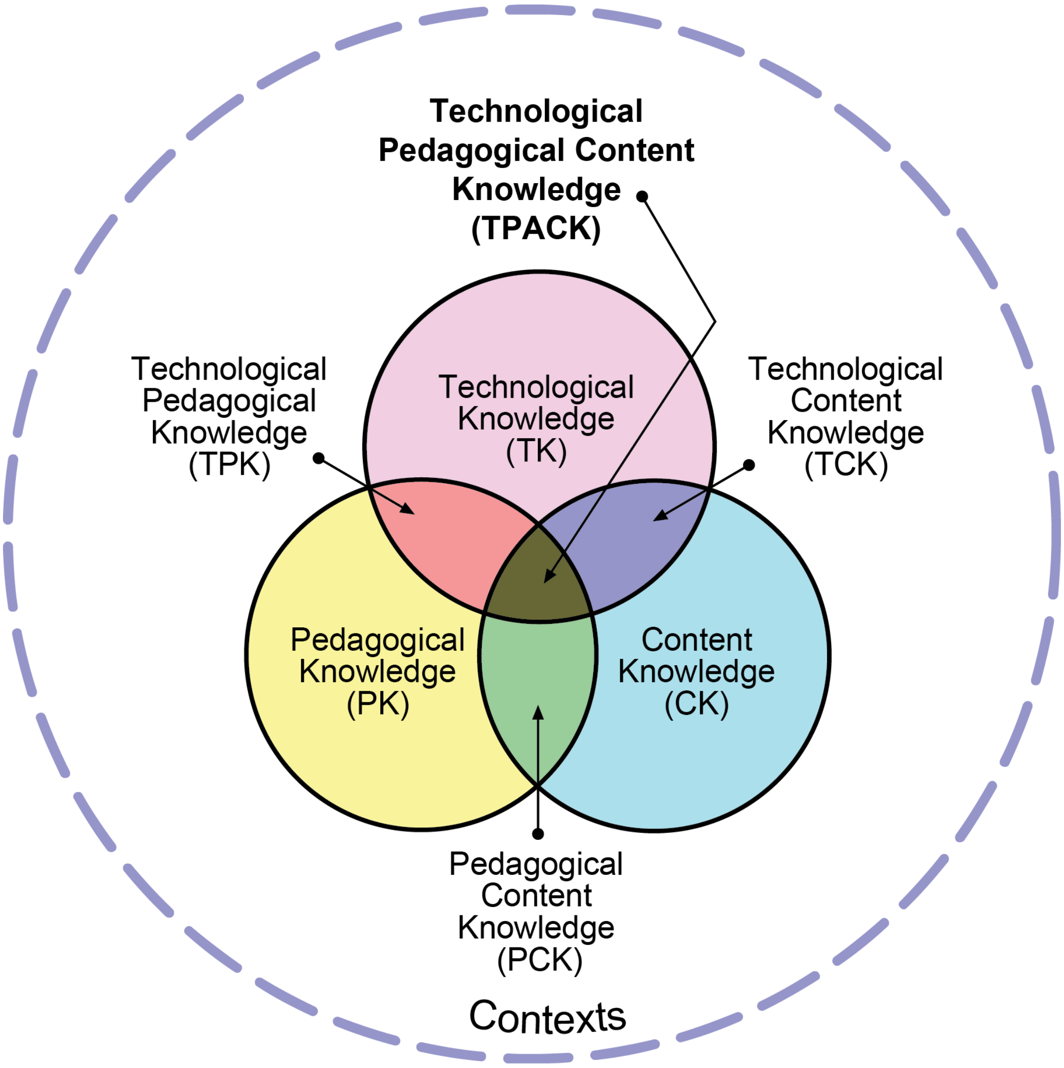


Figure 6.3: Technological Pedagogical Content Knowledge according to Erdoğmuş et al. (2021, p. 261).

Figure 6.4: UNESCO Campaign to invest in teachers (*Invest in Teachers Campaign* Fri, 05/28/2021 - 14:38).

Teaching current and future teachers needs to be one of the elements requiring additional attention, be it financial or scientific. Training future teachers and in-service staff repeatedly and with current knowledge provides the tools needed for up to date education. This can be realized by continuous integration of practitioners in classroom settings, both boosting the efficacy of teachers as well as students, effectively serving a combined purpose in their role.

6.3.2 Virtual Learning

Even after the global COVID-19 outbreak that started in 2020 will be finally overcome, virtual and remote learning is here to stay. This form of education and communication reasonably will remain a significant learning environment for formal as well as informal education. This leads to a number of effects for practitioner integration in the classroom because geographical borders slowly are reduced to intellectual entities. In theory any German or English speaking expert is able to host and conduct a workshop or seminar from wherever in the world and interact with students in a very natural and already established fashion.

Of course, the downside of virtual learning is clear, less interaction, little parallel communication and the missing interpersonal links are hindering the effort. Still if used in a reasonable form virtual learning can connect communities of practice with learners and students engaging in a long term fruitful relationship. Not only in times of a worldwide pandemic is it hard to establish rapport with policymakers and schools administrators, the overhead can be overburdening. For these instances a virtual setting with short inputs from practitioners and experts can offer the possibility of establishing a lighthouse project and show the immediate effects of outreach programs.

6.3.3 School-Based Makerspaces

Some educational institutions like schools and universities have developed in-house makerspaces to engage students. Learners are enabled and encouraged to work on physical artefacts and develop ideas at school. Often the libraries within the school or specialised buildings or areas close to the school proper are ideal spaces to work and develop new ideas. The resonse of policies and a legal framework often is a justifiedly strict approach to risk management. This prioritising is not especially conducive for free movement and new ideas. Most school administrators and policymakers are not willing to compromise to allow for a more hands on and DIY approach. So the solution can be to recreuit outside actors like local companies and entrepreneurs for the challenge. As soon as an outside actor bears the responsibility schools usually are more willing to open their spaces and allow for controlled but curious play (Sagbauer, Stocker, et al., 2021).

6.3.4 Rural Makerspaces Special Challenges

In cities and universities, makerspaces grow and become a common sight for students, parents and educators. Having a large number of well-educated hosts and peers offers massive advantages for groups that are in fact already privileged. Collaborative learning and making has the potential to allow disadvantaged students in rural communities to gain knowledge and skills vital to their future environments. In the countryside a lot of low key grassroots elements can be envisioned, a lot of private citizens open their personal workshops and spaces for curious neighborhood kids. The name is different, mostly too small to be noticed by the outside community, but the goal is the same. By creating and learning from each other. Often this leads to first introductions into technical topics and the world of STEAM.

In rural Austria every farm has a workshop, almost everybody has some sort of room to fix, build and repair, with a broad assortment of tools and specialities. This leads to special challenges, as hand tools are often used by youth and accessible already while the delta between the young people concerning tool usage and accessibility is broad. This difference leads to opportunities of small scale interactive learning but at the same time needs moderation and mindful planning to succeed and not leave a number of curious and interested youth behind. The discrepancy between classic hand tools and state of the art technologies seems problematic but in practice can be an incredible asset to the users. Being able to fix issues on every scale imaginable with a broad range of tools and expertise is one of the key promises of CT education.

A rural makerspace needs to focus more on community building and less on the tools used. Often technophiles demand that the tools are the key components, place the available toolkits and gadgets in front of solution driven marketing approaches. As discussed beforehand this limits the potential participants interest and excludes a number of otherwise important diverse people. When developing an inclusive and outspoken makerspace these informal communities of practice are vital to success, as no idea exists in a vacuum but inside an already well formed societal web.

There are incredible role models in maker education, that led the way in creating makerspaces as well as documenting and researching the experiences of running them (Vossoughi et al., 2013).

6.3.5 Approaching Learners with Project Based Education

One significant aspect is the way researchers and in the future other institutions can approach interested teachers and students. During this project, students were asked - within a scholarly environment - to participate in a workshop setting. So the contact has been initiated by the school and teaching staff. This approach limits participants to a specific educational setting and can be detrimental to diversity within the group. Nonetheless, schools as a setting offer a cross-section of this specific age bracket. After school programs often target the parents of participating students which leads to a strong bias towards societal groups with higher formal education, leaving promising young minds out of the draft. So one of the most interesting questions for future research is how to best approach young curious minds for after school programs. There is no simple answer, but the ratios and promising effects can be studied in several research publications from different continents. People are very diverse and it is interesting to see how outreach programs have tackled these issues over time and in different contexts.

6.3.6 Expanding Assessment Methodology

Assessing and grading skills and competencies is challenging in every aspect of educational institutions. Based on a vast amount of literature reviewed the assessment of long term skill sets like CT is not yet fully understood and developed. There are a number of ideas and research projects currently in explored but none is fully matured. The two main assessment tools used to gain an understanding of pupils learning outcomes are the Computational Thinking Scales (CTS) of Korkmaz et al. as well as the Computational Thinking Test CTT introduced by Román-González et al. (Korkmaz, Çakir, and Ozden, 2017; Román-González, Pérez-González, and Jiménez-Fernández, 2016). Both research projects establish assessment scales to determine the efficacy of students CT skills on multiple distinct levels. Korkmaz for example defines five factors - namely "creative thinking, algorithmic thinking, critical thinking, problem solving and cooperation skills" - to be crucial ingredients of CT skills. Still, it is very challenging to include these five factors in real-world assessment tools, so the authors defined 29 items that learners are supposed to answer independently and truthfully to grade their CT skills. See figure 6.5 for some exemplary items within the Computational Thinking Scale.

On the other hand, the self-assessment tool of Gonzales et al. is especially targeted to young learners (12 to 14 years of age) and reminiscent of the Bebras testing suite, see figure 6.6. Bebras is a well-known challenge for international students to learn and compete in a computing challenge. Test cases are based on the understanding of models, concepts, logical thinking and algorithmic thinking.

AlgoritmicThinking	I26	I can immediately establish the equity that will give the solution of a problem
	I25	I think that I have a special interest in the mathematical processes
	I28	I think that I learn better the instructions made with the help of mathematical symbols and concepts
	I27	I believe that I can easily catch the relation between the figures
	I22	I can mathematically express the solution ways of the problems I face in the daily life.
	I9	I can digitize a mathematical problem expressed verbally.
Cooperativity	I42	I like experiencing cooperative learning together with my group friends.
	I46	In the cooperative learning, I think that I attain/will attain more successful results because I am working in a group.
	I41	I like solving problems related to group project together with my friends in cooperative learning.
	I45	More ideas occur in cooperative learning.

Figure 6.5: Excerpt of CTS items according to Korkmaz et al. Korkmaz, Çakir, and Ozden (2017)

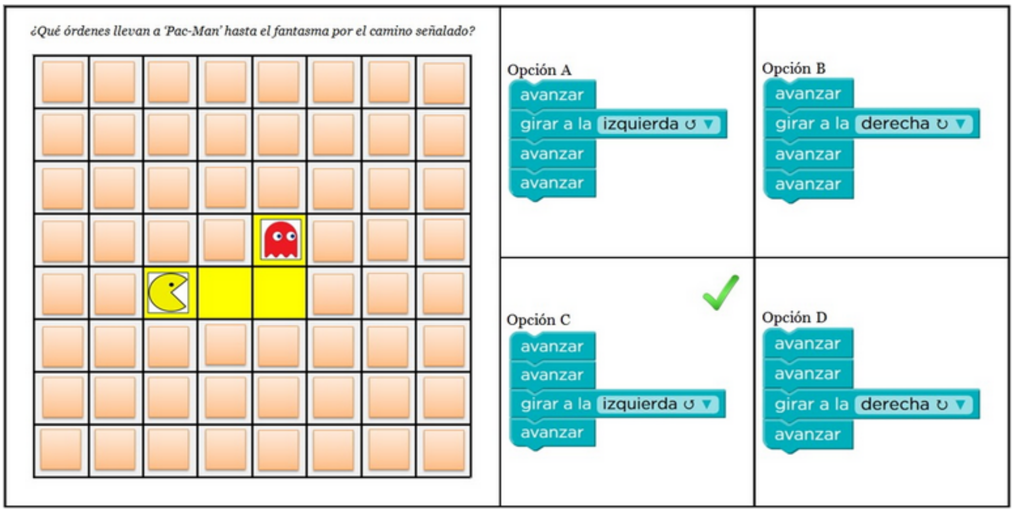


Figure 6.6: Example Assignment from the CTt according to Gonzales et al. Román-González, Pérez-González, and Jiménez-Fernández (2016).

For the purpose of the research project at hand, a combination of assessment methods was chosen. Self-assessment of learning outcomes with learning diaries combined with challenges based on the CTt and outside observations were a viable way to grade engagement as well as efficacy.

6.4 Limitations

Two partner schools in Lower Austria were chosen to create a set of case studies that introduced practitioners in the learning environment to teach about Computational Thinking as a problem solving skill. To get a deeper understanding of the effects of location, age bracket and setting more schools need to be analysed and researched as well as a broader breakdown of geographical and economical spread. As it stands the research outcome is limited to a small sample of case studies and needs reproduction and testing by other researchers in the field. With limited manpower and funding comes a challenge of prioritising and extrapolation, to shine a light on a niche that is currently underrepresented and underdeveloped in the community.

6.4.1 Long Term Learning Effects

The research at hand can only cover a three-year span of gathering and analysing information. The literature shows that long term effects can be seen in students participating within special programs and computational thinking skills are often sustainable. It also seems clear that participating students that have been interacting and curious to collaborate with practitioners will have a better outlook in the field and an initial understanding of the modern work environment. More research needs to be done to evaluate the specific long term learning effects a single workshop environment can have on a young mind and the capabilities of learners.

6.4.2 The Human Condition

This intersecting area of education, sociology and technology is particularly tough to evaluate. Sociological research is messy, people are impossible to fully describe and pressure in clear cut and quantifiable groups. Borrowing heavily from sociological research methodology this thesis tries to span the gap between classical natural sciences and the quantitative ways to evaluate human behaviour. Interviewing a small number of teachers and learners can never tell the whole story of learning at a school, but the author hopes to approximate and show similarities between stakeholders. It can not always succeed, but this paper is keenly aware of the limitations it comes up against.

7 Conclusions

To answer the initial research question a lot of data has been collected and evaluated in this experimental setting. Utilising the Action Research approach it is possible to look into answering:

What consequences has practitioner integration on Computational Thinking education?

Practitioner integration has positive learning effects as more diverse learning strategies are enabled and modelled during these workshops. The effects for teachers are negligible as the apparent effort to set up a practitioner integrated workshop outweighs the time-saving element. The learners showed very positive resonance and the created projects were successful. The efficacy of learners as well as teachers in the use and utilisation of computational thinking strategies were improved slightly. Long term effects need to be proven by future research.

Subquestion one, trying to understand the history of CT as a concept was specifically: **When was CT first described and what has happened since then?** Within the literature review chapter it was determined that Jeanette Wing coined the term in her 2006 seminal paper. A long history of divergent definitions followed during which the first integrations in national curricula originated. Ultimately Wing's definition from her extended 2011 publication remained the standard and triggered an immense uptake in research wherein Grover and Pea, Lye and Koh, Sengupta, Kalelioglu, Denning and Yadav became the most prominently cited researchers.

The second subquestion looked at prior experimental setups to determine: **What has been tried to integrate CT in K-12 education?** A lot of effort has been corroborated to link coding and computer science directly to the concepts of CT. So most case studies and experiments have been conducted in coding classes and technical subjects. The age range of previous implementations is astounding, starting from young children as early as six years old and turning up in lifelong learning curricular and university courses. Removing CT from its namesake of computing and computer science has rarely been tested despite the multitude of pleas that the two topics are not necessarily linked.

Lastly, a third subquestion was added to reflect the struggles posed due to the COVID-19 pandemic asking: **What lessons can be learned for a post-social-distancing world?** It can be shown that the effects of a remote classroom are negligible, as the student body of today is used to virtual and remote learning environments. The space in which teaching, as well as learning, is conducted appears not as important as the human connections shared in these learning environments. Even though during the face to face workshop engagement was noticeably increased several other factors were more relevant to all participating stakeholders and the allotted time, presented topics and socio-cultural elements played a much bigger role. This can lead to more utilisation of these technologies now broadly tested and understood in formal K-12 education globally.

7.1 Rethinking the Role of Practitioners

Schools offer a lot of opportunities for young learners and thinkers, with immense potential but a lack of time and efficacy stifling their progress. To allow the full spectrum of entrepreneurial businesses and science to interact and be integrated into schools, big steps need to be taken. Teacher education ought to be modernised and the lifelong learning approach should be strongly ingrained in public school staff. In this day and age, where new technologies outpace teacher education, outside expertise can successfully bridge the current gap between state of the art work environments and the knowledge brought to the table by capable and well-trained teachers. The basis of today's formal education still are curricula and - in large percentages - the textbook issued to the teaching staff by their respective schools. This broadens the gap by adding a multitude of political and societal barriers to updates and upgrades in schools tasked with educating the youth.

While the rooms we share and learn in, in reality, have only minimal impact, be it virtual or face to face, the people interacting in these rooms can bring a multitude of new emotions to the table. Practitioners, based and operating in the world students are trying to understand, people with a grasp on current developments in the workplaces and research spaces so crucial to our society can offer new stories, share new points of view and engage in an incredibly important exchange. The technologies we have developed in recent years can offer new rooms that are more easily accessible for some practitioners, that can be quicker to set up for schools and institutions while the key element remains to share ideas and concepts as broadly as feasible. By introducing practitioners and outside experts more often and more open in these institutions, by embracing technologies and diversity new spaces can be offered. Practitioner integration won't change the world overnight, but offering learners different and diverse impulses, giving them the chance to act as subject matter experts, listening more and openly sharing are substantial keys to a more sustainable educational system.

7.2 Time as a limiting factor

As it currently stands a lot of energy is lost by pushing more content into less time, thus stifling the efforts of teaching staff as well as engaged practitioners. Humans, especially young and curious humans have a limited capacity and the human condition dictates that often life works in intriguing ways. Especially during the current situation where face to face time is very limited and important this project suggests that adding more is counterproductive. Even blatantly stating that CT is a life-changing skill to have for young learners, it is ill-advised to simply add it into already packed curricula. Even given the fact that practitioner integration is a smart and viable tool to engage students in practical project solving, there needs to be a discussion about what can be left out of curricula to free up time resources from all involved stakeholders. Teachers and policymakers can not forget that every additional effort necessitates that other areas fall short and can't get as many resources. This is an essential part that young minds need to learn and possibly some of us need to be reminded of, time management is a crucial skill in a world ever more complex and diverse. When options and capabilities are seemingly endless and our growing technology sector provides the environment to thrive in unprecedented ways, one of the last remaining limiting factors is time.

During this project's span, it became overwhelmingly obvious that young learners, as well as teaching staff and subject matter experts, struggle with the lack of time. Thus it becomes trivial to only suggest more practitioner integration if - and only if - stakeholders can be relieved of some other responsibilities instead.

In this day and age where teachers are already swamped with content that has to be taught, learners struggle with the sheer amount of topics and due to COVID-19 everybody was forced to become a medical expert, a statistician and a testing laboratory, it is ludicrous to propose additional responsibilities on top of all that.

An honest, clear and solutions-driven effort has to be made to make schools the places where we all can develop a problem-solving approach, that can overcome the hurdles of tomorrow.

7.3 Myth Busted: Technologies will save us!

Sure, up to a point technological advances might possibly save us, but ultimately human societies can only be supported and sustained by humans. It often has been said, concerning the climate crisis, that planet earth is not in any danger, it merely will decimate the human species. This equally fits with technologies in education, where virtual and remote learning can offer new spaces to the teaching environment. It can often even provide new and better spaces, giving more and more people from all over the world access to these virtual rooms. But ultimately they are and will always be tools handed to capable and skilled educators, offering connection and human interaction for a more powerful learning experience. Technologies like remote learning, video conferencing, augmented and virtual reality can improve interaction, they are capable of making interactions smarter, but the interactions need to happen. People are and will remain the most important factor in education, be it formal or informal education. Upcoming teachers, currently studying to learn their profession and all the intricacies of learning should be handed all the tools necessary to do their job. Even more importantly, teaching staff already in-service need to retrain their knowledge periodically to keep up to date with the technological improvements that happen in students' lives. The main and most important element of learning remains the human connection, the efficacy of teachers and their willingness to listen. Lifelong learning is not a buzzword, it

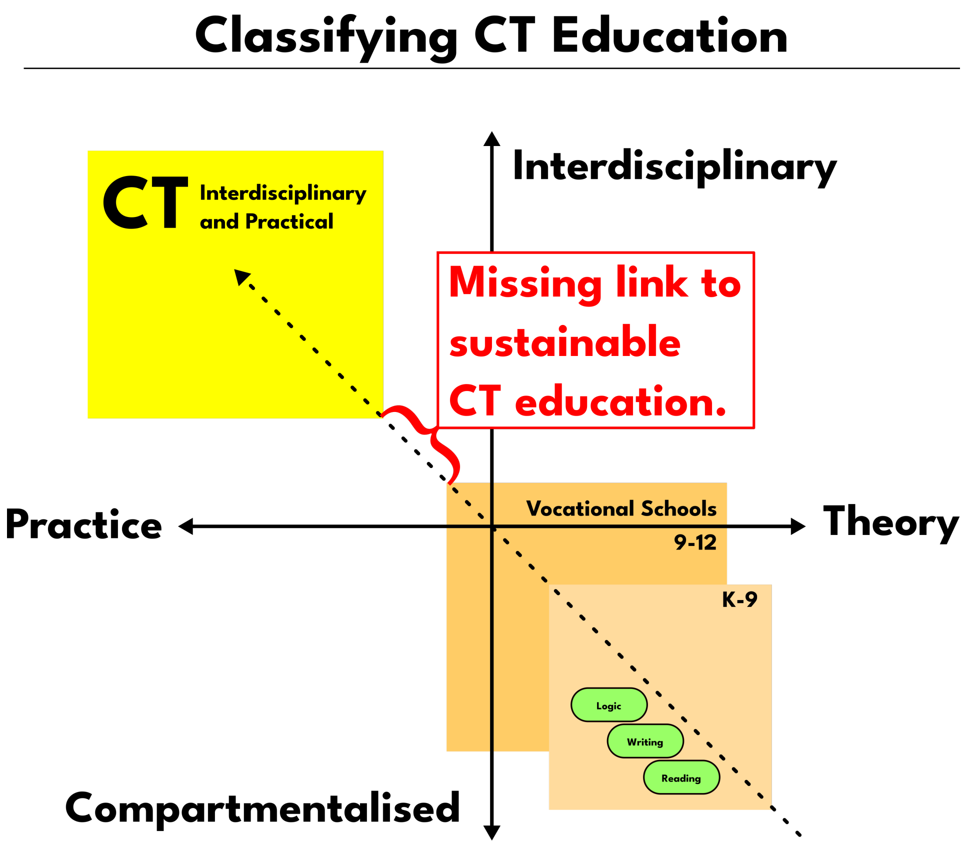


Figure 7.1: Practical CT Knowledge needs Practice.

is a necessary concept in a world that develops much faster than our educational institutions.

7.4 A Future Model for CT Education

The formal education system has a problem as this work clearly has shown. Especially in the field of Computational Thinking, the flaw can be traced back to the lack of interdisciplinary and practical teaching. The complexity of real-world projects can not be approximated by narrow school subjects and curricula focused on the theoretical baseline of knowledge. CT needs a solid foundation in K-9 and K-12 educational settings to foster the required understanding of the world. But - and this is especially important for formal education - the practical problem-solving approach of CT as envisioned by Wing and all the other scholars is inherently practice based and interdisciplinary, as it looks to identify all elements and stakeholders of a given problem. Figure 7.1 shows the problematic missing link identified during this research project and gives a baseline for a future model framework for sustainable CT education. Vocational school settings like the partner schools try to equip learners with practical knowledge and for a long time now schools strive towards interdisciplinarity. But for realistic, sustainable CT exploration the crucial links are missing in most formal schools today, the lack of interdisciplinarity and authentic, practical projects.

This future model derived from the experiments conducted with two partner schools shows the fundamental potential of practitioner integrated education in a CT context. The case studies clearly highlighted that additional effort is necessary to introduce outside experts and practitioners into a classroom, especially without clearly defined guidelines. The model framework proposes that the additional time spent causes a significant increase in knowledge and understanding due to authentic, interdisciplinary and contextualised projects. CT can only be grasped with its full potential when utilised by learners to solve real-world challenges. This also requires a certain baseline theoretical knowledge that interdisciplinary efforts can be anchored in, so this model and the underlying understanding of CT can only be utilised with learners above the K-9 grade, see figure 7.2. Practitioner integrated education offers a unique link to let learners grasp the power of CT for their future understanding of the world's challenges.

7.5 Future Research

The development of CT and research based on it seems to conclude in a creative, cooperative form of teaching and learning. Developing the skills needed is vital to a prosperous and sustainable future for society. On the one hand, this research showed me and hopefully the community the importance of opening up formal education to the outside world, allowing practitioners and experts from the field to engage with and learn from the young minds sitting in classrooms around the

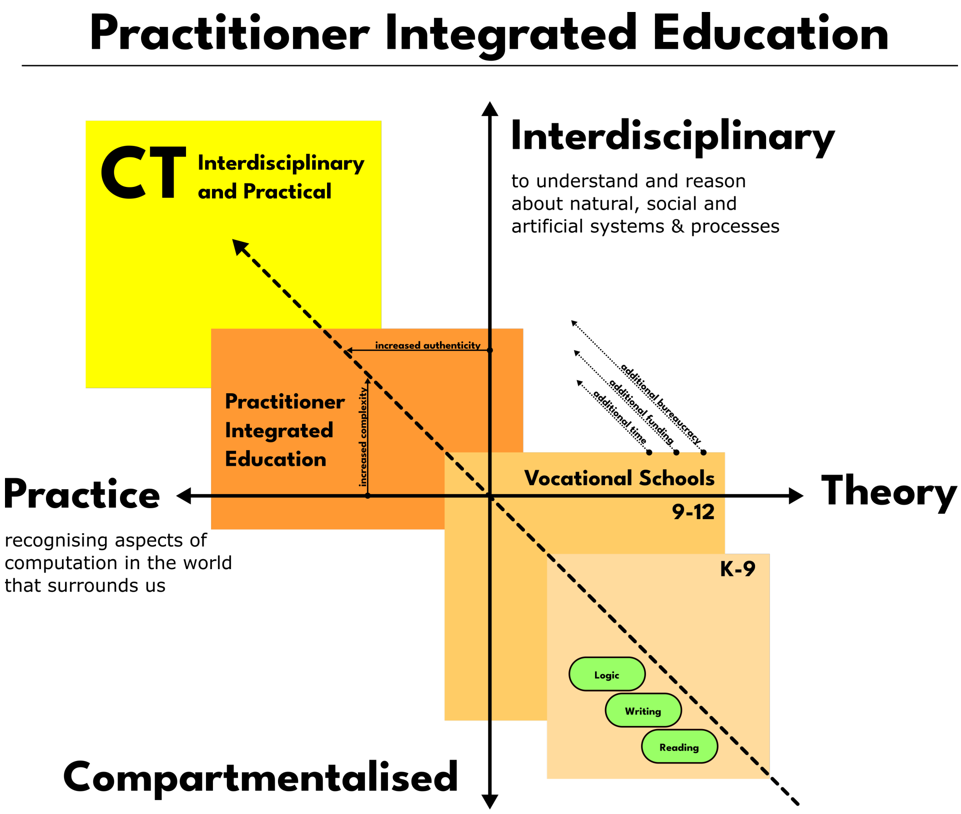


Figure 7.2: The New Practictioner Integration Model creates a Link.

world. On the other hand, I became very sceptical about the grandiose claims surrounding CT and its status as the next big thing. As a concept, an idea, CT has been promising over the last decade, striving for technological solutions to great problems. But after working with the problem solving approach over the past few years the cracks became blatantly obvious. It is a great starting point for problem-solving and certainly well suited for technical projects potentially developed at schools but frustratingly lacking the crucial human factors. Really big problems like the healthcare crisis and the devastating effects of manmade climate change have to be solved with humans. Technologies alone will never be able to combat these challenges, one of the most current being the vaccination dispute. Providing a human element to solutions can not be underestimated, and CT does not necessarily account for this. Updated iterations have been developed by the research community, ideas like computational making - integrating creativity and human cooperation - have gained traction, but it is important to understand the potential downfalls of CT in the context of education.

Of course, some elements and sectors of this thesis need more research, but it is obvious how the interdisciplinary cooperation and introduction of practitioners in the learning process can lead to better outcomes. Especially for rural communities and schools access to knowledge and technology is problematic, to combat that we focus efforts within the countryside in the northern part of Austria, where partner schools and collaborating practitioners are located.

As our makerspace in rural Austria was built starting in 2020 and waiting for more face to face participation after the pandemic is finally beaten. This concept also showed how maker education is capable of distributing knowledge within a community even in situations where face to face workshops are not possible.

Linked to this new endeavour is the question of how after school settings and initiatives can best approach young and curious minds with limited resources. With the goal to assemble a diverse community it is important to understand, experiment and research the effects of different approaches and develop guidelines for this specific space as well as other efforts.

This research is far from done, just like most work in the arts, researching, experimenting and writing is never really completed but merely at some point abandoned. Personally, I am looking forward to exploring other pathways to interact and work with even more incredible educators and share my passion for learning, entrepreneurship and making. This research will keep on going as we establish a makerspace in a rural area of Lower Austria, invite practitioners and experts to visit either remote or in-person and share with future generations of creators what we learned, inviting them to explore together, how to make our quest sustainable.

Striving for a future worth living.

Appendix

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Abbreviations

- AI: Artificial Intelligence
- AR: Action Research
- BBB: BigBlueButton, an Open Source Virtual Classroom Software
- BBC: British Broadcasting Corporation
- BLM: Black Lives Matter
- BYOD: Bring Your Own Device
- CER: Computing Education Research
- CMU: Carnegie Mellon University
- CoP: Community of Practice
- COVID-19: Coronavirus Disease 2019
- CPE: Computer Aided Project Development
- CS: Computer Science
- CT: Computational Thinking
- CTS: Computational Thinking Scales
- CTt: Computational Thinking Test
- DIY: Do It Yourself
- EU: European Union
- FFF: Fridays for Future or Swedish SKOLSTREJK FÖR KLIMATET
- GDPR: General Data Protection Regulation
- GPL: GNU General Public License
- HAKWT: Handelsakademie Waidhofen an der Thaya
- HCI: Human Computer Interaction
- HTLHL: Höhere Technische Lehranstalt Hollabrunn
- IDE: Integrated Development Environment
- IoT: Internet of Things
- ISCED: International Standard Classification of Education
- IT: Information Technology
- Java: High-level programming language

- JS: JavaScript, a programming language
- K-12: Age bracket from Kindergarten to Grade 12, 6 to 18 years of age
- LEGO: A Danish brand of educational building blocks
- LGBTQ+: Lesbian, Gay, Bisexual, Transgender, Queer and other people
- LGPL: GNU Lesser General Public License
- LMS: Learning Management System
- LXD: Learning Experience Design
- MIT: Massachusetts Institute of Technology
- MS: Microsoft Corporation
- NASA: National Aeronautics and Space Administration
- OSS: Open Source Software
- PHP: for PHP: Hypertext Preprocessor, a programming language
- PISA: Programme for International Student Assessment
- SDG: Sustainable Development Goal
- STEAM: Science, Technology, Engineering, Art and Mathematics
- STEM: Science, Technology, Engineeringand Mathematics
- TIMMS: Trends in Mathematics and Science Study
- UN: United Nations
- UNESCO: UN Educational, Scientific and Cultural Organization
- VR: Virtual Reality