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Department of Informatics

The Influence of AI on Education

An Impact Analysis for Primary Schools in the Lehrplan 21 Area

Master Thesis
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Zusammenfassung

Skills und Kompetenzen sind wichtige natürliche Ressourcen in der Schweiz und in Liechtenstein. Da die künstliche Intelligenz (KI) immer mehr Aspekte unseres Lebens durchdringt, ist es von grösster Bedeutung, die Auswirkungen zu verstehen, die sie auf unser Grundschulsystem haben wird. Die Grundlage für diese Arbeit bildet eine Literatur- und Nachrichtenrecherche und wird durch Experteninterviews ergänzt. Diese Elemente werden verwendet, um eine Skill Gap-Analyse durchzuführen, die die Erstellung von Szenarien unterstützt, die von zwei Faktoren geprägt sind (Entwicklung von KI und Rahmenbedingungen).

Die im Lehrplan 21 enthaltenen und in der Realität gelehrten Skills und Kompetenzen sind weitgehend auf die Bedürfnisse der Zukunftsprojektionen ausgerichtet. Die Lehrer sind meist in der Lage, die bisher verbleibenden Lücken zu schliessen. Dennoch ist es wichtig, den Lehrplan kontinuierlich an die sich schnell verändernde (digitale) Welt anzupassen und ein Bildungssystem zu adaptieren, das die schnell erodierenden Skills und Kompetenzen laufend aktualisiert. Darüber hinaus werden softwarebasierte Lehr- und Lernmittel in der Ausbildung an Bedeutung gewinnen. Durch diese Werkzeuge sind Pädagogen in der Lage, das Kompetenztraining in einem neuen Masse zu individualisieren.

Um die praktische Anwendung dieser entdeckten Möglichkeiten zu verstehen, werden verschiedene Erkenntnisse von nationalen Pionieren, führenden Unternehmen und Bildungssystemen aus Liechtenstein und der Schweiz mit den Forschungsergebnissen verknüpft und von Experten vorgeschlagene Instrumente vorgestellt. Aus den kombinierten Erkenntnissen werden dann vier Subszenarien gebildet, die durch die beiden Treiber (Entwicklung von KI und Rahmenbedingungen) geteilt werden. Die jeweiligen Szenarien wurden in zwei gegensätzliche Richtungen (worst, best) entwickelt und sich gegenübergestellt, um das Spektrum der möglichen Ergebnisse aufzuzeigen.

Im Gegenteil zu der Annahme, dass sich die Bildung langsamer entwickelt wie die digitale Technologie und insbesondere die KI, hat diese Arbeit ein recht fortschrittliches und adaptives Bildungssystem in der untersuchten Region aufgezeigt.

Aufgrund der weitgehend unbekannten Auswirkungen der KI auf den Arbeitsmarkt und unser Leben im Allgemeinen muss die Lehre mit der sich schnell verändernden Welt Schritt halten und in bestimmten Fällen neue Kompetenzen und insbesondere Werkzeuge hinzufügen, um die Arbeitskräfte von morgen zu schaffen. Letztendlich sind die Kompetenzen des Lehrers entscheidend.

Abstract

Skills and competences are key natural resources in Switzerland and Liechtenstein. Since artificial intelligence (AI) is penetrating more and more aspects of our lives, it is of paramount importance to understand the impact that it will have on our primary school system. The basis for this thesis is formed by literature and news research and is complemented by expert interviews. These elements are used to conduct a skill gap analysis supporting the creation of scenarios shaped by two drivers (development of AI and framework conditions).

The skills and competences included in the Lehrplan 21 and taught in reality, are mostly aligned with the need dictated by projections of the future. Teachers are mostly able to close the remaining gaps so far. Nevertheless, it is important to continuously update the curriculum according to the fast changing (digital) world and adapt a continuous education system updating fast eroding skills and competences. Additionally, software-based teaching and learning tools will become more important in training skills. Enabled by these tools, educators are able to individualise skill and competence training to a new extent.

To understand the real-life application of these opportunities discovered, a variety of insights from national pioneers, leading companies and education systems from Switzerland and Liechtenstein are linked to the research results as well as tools suggested by experts are presented. The combined insights

are then used to form four sub-scenarios divided by the two drivers (development of AI and framework conditions). The respective scenarios were developed into two opposite directions (worst, best) and differently juxtaposed in opposition to show the spectrum of possible outcomes.

After a perceived lag of education behind the development of digital technology and specifically AI, this thesis on the contrary discovered a quite advanced and adaptive education system in the examined region. Due to the widely unknown impact of AI on the job market and our lives in general teaching must keep up with the fast-changing world around it and in certain cases add new competencies and especially tools to create the workforce of tomorrow. In the end, the competences of the teacher are key.

Acknowledgments

Without the help of some people it would not have been possible to do this work. I don't want to miss the opportunity to thank them .

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Figure 1: School in the information society, poster to debate digital media in school life from 2010, from Petko (n.d.)

Contents

"Education is the most powerful weapon which you can use to change the world."

Nelson Mandela

1 Introduction

1.1 Motivation

The current paradigms are changing. When information was scarce in the past, nowadays we are inundated by information and therefore it is less useful to cram students with information (Furger & Burri, 2018). Society changes and the future will consist of greater volatility, uncertainty, complexity, and ambiguity (VUCA) (Fadel, Bialik, & Trilling, 2015). Digitalisation is one of the most significant changes of the last decades and changes our society in a fundamental and sustainable way where almost no part of our lives remains unaffected. (Regierung des Fürstentum Liechtenstein, 2019) Digitalisation also plays an important role in education. Both, the teaching staff and the pupils should develop their skills and competences in dealing with digital tools, but also raise awareness of responsibility and dangers. Digitalisation should also open up new avenues for efficient learning. (Regierung des Fürstentum Liechtenstein, 2019)

> "The demands on learners and thus education systems are evolving fast. In the past, education was about teaching people something. Now, it's about making sure that individuals develop a reliable compass and the navigation skills to find their own way through an increasingly uncertain, volatile, and ambiguous world. These days, we no longer know exactly how things will unfold. Often we are surprised and need to learn from the extraordinary, and sometimes we make mistakes along the way. And it will often be the mistakes and failures, when properly understood, that create the context for learning and growth. A generation ago, teachers could expect that what they taught would last for a lifetime for their students. Today, schools need to prepare students for more rapid economic and social change than ever before, for jobs that have not yet been created, to use technologies that have not yet been invented, and to solve social problems that we don't yet know will arise." (Fadel et al., 2015)

This is particularly important because Switzerland and Liechtenstein don't have a lot of unique natural resources but our resources are knowledge and research. The importance of education is reflected in several aspects such as the sustainable development goals (see SDG 4), defined by the UN (UNESCO Institute for Statistics, 2018). As stated in the *Bildungsstrategie Fürstentum Liechtenstein 2020* (Regierung des Fürstentum Liechtenstein, 2011), there are several current developments and discussions that stress the importance of an elaboration of the actual education strategy.

Education is a fundamental part of the development of every citizen of every country on earth. Education is an important part of people's development and social process. It prepares students to thrive in the world, as more empowered and happier individuals, which leads to more peaceful, sustainable societies, with more economic progress and fairness. (D-EDK, 2016a; Fadel et al., 2015)

Digitalisation also plays a decisive role in this change. Thereby, technology, including AI is transforming all other sectors in society and it is starting to affect education.(UNESCO, 2019a). AI has enormous opportunities as R. Bucher (2018) revealed. It is expected, that the market of *Education and AI* will explode in the next three to five years (Khan, 2019). In 2015, AI papers reached a percentage of 6% of all global scientific paper output, according to China Institute for Science and Technology Policy (2018) It is imporatant that the whole society acquires better digital skills.

AI can help us in several ways, according to PWC (2019): *Assisted intelligence* helps people to perform tasks faster and better. When humans dissapear, *automated intelligence* appears and works is automated. One speaks of *augmented intelligence* when AI is used to help people to make better decisions. The highest level are *autonomous intelligence* systems that automate the decision making processes without human intervention. As humans and machines collaborate more closely, and AI innovations come out of the research lab and into the mainstream, the transformational possibilities are infinite. (PWC, 2019)

1.2 Research Questions

Based on the bachelor thesis titled *Anwendungen von künstlicher Intelligenz in der Bildung - Chancen und Risiken* by Roman Bucher (2018), a deeper analysis of this topic shall be executed.

As illustrated in Figure 2, this thesis shall answer multiple research questions. The first research question (RQ 1) to answer is, which skills and competences are taught today, analyzing the Lehrplan 21. Second, what are the skills and competences, people need to have in the future (RQ 2). These findings, coming from literature research, will lead to a so called *skill gap* (RQ 3). This development will be described and some recommendations are made.

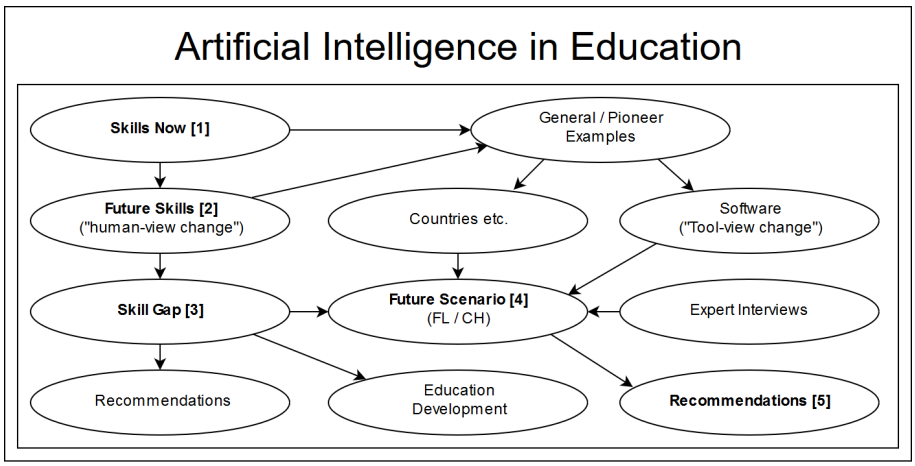

Figure 2: Overview and interconnections of the research questions (own figure, 26.04.2019)

Furthermore, a general approach to this topic is made and new examples of AI-based education tools and AI-pioneers in general are introduced. Different levels are studied here, starting with countries, then companies and their products (mainly applications).

Enhancing R. Bucher's scenarios witht the previously gained insights and expert interviews, a future scenario (RQ 4) on primary school level of education for the Lehrplan 21 area is further analysed and implications are identified (RQ 5)

The resulting research questions are:

- RQ 1: What skills and competences are learned in school today?
- RQ 2: What skills and competences are needed in future?
- RQ 3: Is there a skill gap?
- RQ 4: What are possible future scenarios?
- RQ 5: What considerations have to be taken into account?

1.3 Materials, Methodology and Interviews

This work is largely based on a literature research and, due to the topicality of the subject, a news research. Another reason is the specificity, since hardly any scientific papers on education in Switzerland or Liechtenstein are published. Based on this research some key knowledge shall be identified. Further, actual and future skills and competences (RQ 1, RQ 2, and RQ 3) shall be analysed through this research. Based on an interview (the whole interviews can be found on the CD delivered with the paper) and further literature, future scenarios to an AI-supported education (RQ 4) are examined. Potential risks are identified and recommendations are shown (RQ 5).

The aim of the interviews was to get an extra insight in specific expert domains. For the author, it was crucial to gain insights from the everyday life of teachers. For this reason, several conversations were held with different teachers, with two being recorded. Furthermore, two employees of the BKZ who worked out the Lehrplan 21 and one expert working for PHZH in the field of digital learning media and e-assessment have been interviewed. It has been tried to represent their opinion in this work. From the acquired knowledge, scenarios are created to introduce various possible futures and to illustrate a potential impact analysis. This is based on a methodology by Kosow and Gassner (2008).

> "We cannot solve our problems with the same thinking we used when we created them."
>
> *Albert Einstein*

1.4 Related Work

This section shows the current state of research. The basic of this work is the bachelor thesis titled *Anwendungen von künstlicher Intelligenz in der Bildung - Chancen und Risiken* by Roman Bucher. This work was also done at the University of Zurich, in the same department, also with Clemens Mader as supervisor and graded with the best mark. It is used as a basis for this work.

Probably the main reference of this work is the book *Mehr als 0 und 1 Schule in einer digitalisierten Welt* by Beat Döbeli Honegger (2016). Döbeli Honegger is a Swiss computer science didactician and director of the Institute for Media and School, at the University of Teacher Education Schwyz. He has been involved in research and teaching on all aspects of digitisation in education for 15 years and explains the current developments around the change of lead media in his book. He explains why informatics belongs in school education, recommends how this should be done and to what extent, explains important factors and risks and also establishes a future vision of textbooks.

Another interesting read is *The Future of Jobs Report 2018 Insight Report* by World Economic Forum (2018). It highlights various current developments in the labour market. it shows the most important changes and their consequences for employers and employees. Current and future jobs are examined according to region and industry.

Of course, the Swiss curriculum *Lehrplan 21* was examined more closely. The website and documents referenced on it were mainly used for this purpose.

A public discourse is currently taking place in Switzerland on the subject of technological development. This is being led by the *Foundation for Technology Assessment* (TA-Swiss), which is a centre of competence of the *Swiss Academies of Arts and Science*. Their objective is to identify the social, legal and ethical consequences of new technologies to offer further consultation (Christen & Mader, 2019).

In *The Four-Dimensional Education Model*, Fadel et al. (2015) present a framework, that introduces competences needed to succeed in the twenty-first century. In the authors opinion, it is an optimal extension of the *4C Model*. It adds character, knowledge and meta-learning to the skill level (4C). The work provides a good overview of the history, current changes, education goals for the twenty-first

century, a detailed explanation of the four dimensions and a conclusion.

1.5 Structure of the Work

The next section of this work introduces the *Theoretical Basics* of this topic, which contains a *Definition of Terms*, and a brief *History* to highlight some key concepts and events of education and cognitive science and computer technology, with a particular view on the AI-based revolution.

In the next chapter called *Skills and Competencies* as a first step the *Education System and Lehrplan 21* are analysed to disclose the actually taught skills and competences. As a next step, literature is scrutinised to elaborate *Future Skills and Competences*. A deeper look into different existing *Models* is provided, possible *New Jobs* are discussed and as a conclusion *Important Skills* are defined. In a last step, in subchapter 3.4 *Technology Affected Areas*, four areas of influence have been identified and will be discussed further. The *Curriculum*, *Further Education*, *Tools Used in Education* and *Methods to Teach*.

Chapter 5 *Examples* is broken down to show some worldwide examples, in particular *National Pioneers* where some progressive nations are introduced and the chapter *Companies* shows how artificial intelligence in education is used and commercialised. An excursion shows the development of *Tablet Classes in Liechtenstein*. The subsection *Examples in Switzerland and Liechtenstein* shows actual movements and practical examples in the Lehrplan 21 area and finally the last subsection *Relevant Aspects* highlights some particular features to be taken into account.

Based on expert discussions and literature, *Scenarios* are constructed. In *Expert Discussions* the experts are introduced followed by the *Scenario Set Up*. The scenario has two key factors, namely *Key Factor 1 (KF_1): Development of AI* and *Key Factor 2 (KF_2): Framework Conditions*. Ultimately the key factors are juxtaposed into scenarios in the *Scenario Generation*.

The final results are objectively presented in chapter 6.1: *Summary*. Further, the results are scrutinised in the *Interpretation*. *Limitations and Uncertainties* of this work are taken into consideration and ultimately a *Conclusion* is made. In the last part of this work, an *Outlook* where personal *Further Thoughts* are incorporated, and *Recommendations* are made.

In the *Appendix* several lists can be found; *List of Abbreviations*, *Bibliography*, *List of Figures*, *List of Tables*, *Additional Information*, *Additional Information about Interviewees*, and finally the *Content of the CD* is listed.

2 Theoretical Basics: AI and Education

"We live in a knowledge-driven world. Knowledge and smartness are the most valuable resources in any society. Hence, investing in research and education is smart. Investing in research and education in artificial intelligence is doubly smart: It gives intelligent people and machines."

Holger Hoos

2.1 Definition of Terms

This subsection describes some fundamental terms and concepts concerning artificial intelligence and education in alphabetical order, beginning with the former:

Artificial Intelligence

The first person using this term was John McCarthy, one of the fathers of AI, in the year 1955 and he defined it as follows:

> "For the present purpose the artificial intelligence problem is taken to be that of making a machine behave in ways that would be called intelligent if a human were so behaving." (Ostrowicz & Sacksick, 2017)

A broader definition is offered by Kaplan and Haenlein (2019, p.1), as they define a system artifical intelligent if it has the "ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation". There are different definitions and categorisations of artificial intelligence, where all processes include learning, reasoning and self-correction (UNESCO, 2018). The degree of intelligence depends on the degree of autonomy, the degree of complexity of the problem, and the degree of efficiency of the problem-solving process (Mainzer, 2016). Kaplan and Haenlein (2019, p.2) categorise AI by their evolutionary stages:

- **Artificial Narrow Intelligence** (ANI - weak, below human-level AI):
  - Applies AI only to specific areas
  - Unable to autonomously solve problems in other areas
  - Outperforms/equals humans in the specific area
  - Example: *Siri can recognise your voice but cannot perform other tasks like driving a car.*
- **Artificial General Intelligence** (AGI - strong, human-level AI):
  - Applies AI to several areas
  - Able to autonomously solve problems in other areas
  - Outperforms/equals humans in several areas
  - Example: *Siri evolves into a humanoid robot with wide capabilities including voice recognition, coffee preparation, and writing skills.*
- **Artificial Super Intelligence** (ASI - conscious/self-aware, above human-level AI):
  - Applies AI to any area
  - Able to solve problems in other areas instantaneously
  - Outperforms humans in all areas
  - Example: *Siri develops super-human capabilities such as solving complex mathematical problems instantaneously or writing a best seller in a heart (or clock) beat*

On the other hand, Kaplan and Haenlein (2018, p.4) differentiate AI by the different types of systems:

- **Analytical Artificial Intelligence**:
  - A cognitive representation of the world is generated and the past is used to learn.
  - Examples: *Fraud detection systems in financial sector, image recognition, or self-driving cars.*
- **Human-inspired Artificial Intelligence**:
  - These systems understand human emotions and consider them in their decision making, in addition to cognitive elements.
  - Example: *Advanced vision systems to recognise emotions like joy, surprise, and anger.*
- **Humanised Artificial Intelligence**:
  - Systems which show cognitive, emotional, and social intelligence.
  - These systems would be able to be self-conscious and self-aware in their interactions with others.
  - Example: *Not available yet.*

Artificial Neural Network

Artificial Neural Networks (ANN) are algorithms that can "learn" and perform "pattern recognition". They can be segmented by depth and are cosidered as *Deep Neural Networks* (DNN) when they have more than one hidden layer, as visualised in Table 3. (Golstein, 2018)

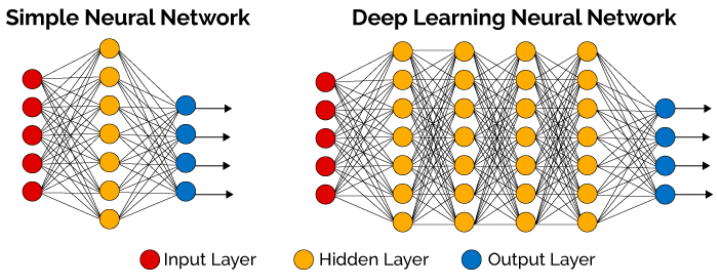

Figure 3: Simplified representation of a simple neural network and a deep learning neural network, from Golstein (2018)

If there is enough computing power and the depth of the network is increased - ceteris paribus - it increases the performance of the algorithm. Usually, if one speeks about *Deep Learning* a reference to deep neural networks is made, although there are other cases as well such as *Deep Belief Networks*. (Golstein, 2018)

MacKay (2005) distinguishes the different types of algorithms by three characterisations:

- **Architecture:** Involved variables and their topological relationship are speficied.
- **Activity rule:** Usually local rules define how activities of neurons interact, while the activity rules depend on weights in the network.
- **Learning rule:** This specifies how the network's weights change with time, depending on the activities of the neurons (also target value, teacher and current value of weights).

Golstein (2018) also differentiates between the **Algorithms**, here's a selection: *Simple Feedforward* is the basic ANN algorithm. It travels "through" the neural network in a single direction (see left part of Figure 3). Compared to *Recurrent Neural Networks* (RNN), where connections between the nodes may form a cycle. RNNs power many *Natural Language Processing* (NLP) applications. *Convolutional Neural Networks* (CNNs) are inspired by biological processes and the connectivity patterns between neurons resemble that of animals' visual cortex. They are particularly suitable for image recognition. *Generative Adversarial Networks* (GANs) have "two concurrent networks working in conjunction or in opposition, one often testing the work of the other." (Golstein, 2018)

They can be roughly divided into two classes of neural network algorithms: supervised and unsupervised. For more details, go to the passage *Learning Processes*.

Bias

The Cambridge Dictionary (n.d.) defines a *Bias* as "the action of supporting or opposing a particular person or thing in an unfair way, because of allowing personal opinions to influence your judgment". This fact of preferring a particular subject or thing can be unconscious. (Cambridge Dictionary, n.d.)

Artificial intelligence describes circumstances with a probabilistic accuracy. The input data are dependent and if they are not "perfect", a distorted view can be displayed. (Osoba & Welser, 2017)

Chatbot

A computer program that is capable of interacting with a human being using natural languages, simulating a human conversation. "The chatbot architecture integrates a language model and computational algorithms to emulate informal chat communication between a human user and a computer using natural language". (Shawar & Atwell, 2007, p.1).

Data

Elias (2017) defines *Data* as "any collection of information converted into a digital form". Digital data can be stored in a space-saving way and can be transmitted worldwide via data networks; the Internet is currently the largest such network. (Döbeli Honegger, 2016)

Data Mining

The systematic application of statistical methods by which patterns are discovered within large sets of data. The goal is to extract useful information like cross-connections and trends from it. (Elias, 2017)

Deepfake

The term is a combination of "deep learning" and "fake". The technology relies on machine learning algorithms where existing video and images of any random persons to superimpose the source images into a fake movie that make people appear to do or say things they never did. (Brandon, 2018)

This was even used to create fake porn switching faces with public figures, such as celebrities and politicians. Usually it required big data sets of images in order to create a realistic forgery. But recently, Samsung has developed a new artificial intelligence system that can create fake clips by feeding it only with one photo. (Solsman, 2019)

Deep Learning

As seen in Figure 5, deep learning is a a subset of AI and machine learning. The neural networks are layered (see *Neural Circuit*), combined with strong computing power, and given a huge measure of training data to create extremely powerful learning models capable of processing data in new and innovative ways in a number of different areas. (Elias, 2017)

Digital Citizenship

Defined by UNESCO (2018) as "the ability and ethical values to participate in society online".

Digital Native

Young people who have grown up with digital media and are accordingly competent in their use and handling. Marc Prensky has coined this buzzword for years. However, it is criticised that neither a clear age limit is defined, nor that people of the same age have the same media competence. In addition, it is attributed to young people that they only master and understand superficial interaction and no underlying technical and economic laws. This has led to the development of the term *digital naïves*. (Döbeli Honegger, 2016)

Digitalisation

In the process of *Digitalisation*, more and more analogue data is converted into digital form. Digital means that all possible data can be represented with the same alphabet, consisting of the two characters 0 and 1. This binary representation makes it possible to store all possible types of data electronically on the same data medium. (Döbeli Honegger, 2016)

Expert Systems

Expert Systems are collections of rules (e.g. if-then statements) which are programmed by humans. They do not learn autonomously from external data. In order to build an expert system, knowledge must be formalised, represented in the computer and manipulated according to a problem-solving strategy. (Puppe, 1991, p.2) Expert systems have a high performance on a very specific domain Michalski, Carbonell, and Mitchell (1983).

Gamification

The academic concept of *Gamification* is defined as the use of game design elements in non-game contexts. This differentiates it from serious games and design for playful interactions as seen in Figure 4. (Deterding et al., 2011)

Gamification can face the problems of student motivation and engagement improving problem-solving skills, persistence, creativity, resilience. (Lee & Hammer, 2011, p.1)

Figure 4: Delimitation of gamification (Deterding et al., 2011, p.2)

Industry 4.0

Industry 4.0 refers to the intelligent networking of machines and processes in the industry with the aid of ICT. (Bundesministerium für Wirtschaft und Energie, n.d.)

Schwab (2017) distinguishes the third from the *Fourth Industrial Revolution* by the following three differences: The velocity of this revolution is rather exponential than linear, because of the deeply interconnected, multifaced world we live in and the extremely developed technology. This revolution is much broader and deeper; based on the digital revolution but combining multiple technologies it has potential to shift paradigms in economy, business, society, and individually. Further, it has a system impact which involves the transformation of entire systems across and within countries, companies, industries and society as a whole. (Schwab, 2017, p.3) Examples could be flexible production; convertible, modular factories; customer-centric solutions (prosumer); optimised logistics etc. (Bundesministerium für Wirtschaft und Energie, n.d.), whereas the four main physical manifestations of the technological megatrend are autonomous vehicles, 3D printing, advanced robotics, and new materials (Schwab, 2017, p.15).

> "If intelligence was a cake, unsupervised learning would be the cake, supervised learning would be the icing on the cake, and reinforcement learning would be the cherry on the cake. We know how to make the icing and the cherry, but we don't know how to make the cake."
>
> *Yann LeCun*

Learning Processes

Knowledge representation plays an important role in machine learning (ML). A distinction is made between symbolic approaches in which knowledge is explicitly represented, and non-symbolic approaches such as neural networks, which are "trained" to behave predictably. (Langley, 2011)

Langley (2011) writes in his paper, that the "purpose of learning is to improve performance on some class of tasks." In Table 1 the learning processes are divided by method and a few algorithms are given as examples (Golstein, 2018). Kaplan and Haenlein (2019) defines the three types of learning processes respectively algorithms as follows:

- **Supervised Learning**:
  - Kotsiantis (2007, p.1) defines it as "algorithms that reason from externally supplied instances to produce general hypotheses, which then make predictions about future instances" and lists multiple algorithms (see Kotsiantis, 2007).
  - Some authors define **semi-supervised learning** (Salian, 2018) or **self-supervised** as an own, very promising category. (Perez, 2019; Synched, 2018b)
  - Methods: Linear or logistic regression, classification trees, neural networks etc.
  - Example: *Use large database of labeled images to learn how to differentiate Chihuahuas and muffins.*
- **Unsupervised Learning**:
  - An algorithm infers the structure of the labeled inputs and groups the elements into similar categories, but neither the structure of those clusters nor their number is known in advance.
  - Perez (2019) defines it as "the ability of a machine to model the environment, predict possible futures and understand how the world works by observing it and acting in it".
  - Sometimes cited as "predictive learning". (Perez, 2019)
  - Methods: Clustering, anomaly detection, association, autoencoders etc. (i.a. Salian, 2018)
  - Example: *Speech recognition technologies like Apple's Siri or Amazon's Alexa.*
- **Reinforcement Learning**:
  - A system receives a series of decisions that can be taken to impact the output variable that needs to be maximised. When the desired result is produced, the machine receives positive reinforcement, and negative reinforcement when they do not (Elias, 2017). As Salian (2018) explains, thereby the system relies on learnings from past and exploration of new tactics.
  - Methods: Monte Carlo, brute force etc.
  - Example: *System learns the game "Pac-Man" by knowing the rules (Pac-Man can move up, down, left and right) and that the objective is to maximise the score obtained in the game. Alpha Go used this algorithm (Larus et al., 2018).*

Other authors, like Michalski et al. (1983) classify machine learning systems along different dimensions. For example by the **underlying learning stategy**. Different approaches are rote learning and direct implanting of knowledge; learning from instruction; learning by analogy; learning from examples; or learning from observation and discovery. Further, a categorisation by the **representation of knowledge** includes parameters in algebraic expressions; decision trees; formal grammars; production rules; formal logic-based expressions and related formalisms; graphs and networks; frames and schemas; computer programs and other procedural encodings; taxonomies; or multiple representations. The last category differentiates ML by the **application domain**. Examples are agriculture; chemistry; cognitive modeling; computer programming; education; expert systems; game playing; general methods; image recognition; mathematics; medical diagnosis; music; natural language processing; physical object characterisations; physics; planning and problem-solving; robotics; sequence prediction; or speech recognition.

Learning Process	Method	Application
Unsupervised Learning	Clustering	Customer Segmentation Recommender Systems Targeted Marketing
	Dimensionality Reduction	Big Data Visualisation Feature Elicitation Meaningful Compression Structure Discovery
Supervised Learning	Classification	Customer Retention Diagnostics Image Classification Identity Fraud Detection
	Regression	Advertising Populatiry Prediction Estimating Life Expectancy Market Forecasting Population Growth Prediction Weather Forecasting
Reinforcement Learning		Game AI Learning Tasks Real-Time Decisions Robot Navigation Skill Acquisition

Table 1: Machine Learning Segmentation, Own Table Derived from Golstein (2018)

Machine Learning

As seen in Figure 5, machine learning (ML) is an application of artificial intelligence (AI). The program's decisions are not explicitly programmed, but the system is "trained" from (big) data and learns from it, meaning it automatically increasing efficiency and effectiveness from experience. It is also possible to make predictions about the future. These programs provide solutions to problems that are very difficult to express. (Elias, 2017; Larus et al., 2018)

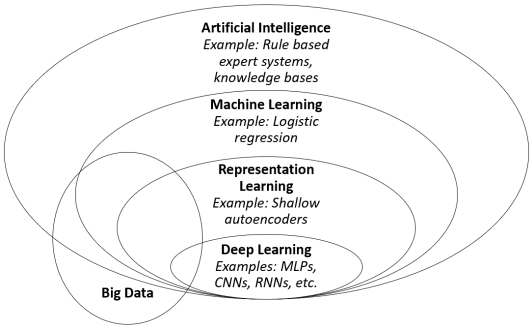

Figure 5: Venn diagram of artificial intelligence showing its subsets (own illustration)

ML offers multiple advantages and has numerous fields of application e.g. recommendation services from Amazon and Netflix, Facebook's face recognition or automated organising, recognising spam or patterns in general. (Manhart, 2018)

There exist two systems in machine learning: First, symbolic approaches such as propositional systems in which knowledge - both the examples and the induced rules - is explicitly represented. Secondly, sub-symbolic systems such as artificial neural networks, which function according to the model of the human brain and in which knowledge is implicitly represented. The algorithmic implementation of machine learning takes place with supervised or unsupervised learning. (Manhart, 2018)

"First we build the tools, then they build us."

Marshall McLuhan

Technological Singularity

Technological Singularity is a future period in which technical progress will be so rapid and its effects so profound that human life will undergo irreversible change (Kurzweil, 2014, p.7). The imminent emergence of singularity follows from the fact that the progress of man-made technology is accelerating, with its efficiency increasing exponentially (Kurzweil, 2014, p.8). This historic milestone might be in 2045. This year humans will overcome their biological limitations with the help of technology and machine intelligence and humans would merge. (Kurzweil, 2014)

"Any AI smart enough to pass a turing test is smart enough to know to fail it."

Ian McDonald

Turing Test

This is a method to determine machine intelligence. The idea was published in 1950 by Alan Turing under the name *Imitation Game* (Turing, 1950). The experiment is defined as follows: Someone talks with two other entities in writing, to avoid bias of voice simulation. One is a machine, that imitates human intelligence, the other is a human. If the first person is not able to determine who is the person and who is the computer, the AI passed the test. (Kaplan & Haenlein, 2019; Ostrowicz & Sacksick, 2017; Turing, 1950) The test is controversial in the measurement of intelligence and there exist some extensions.

Here follow some key terms and concepts concerning education and cognitive science:

Artificial Intelligence in Education

The topic of AI in education is increasingly getting more attention as in 2018, almost a billion dollars worldwide was spent on AI in education, but that number is expected to grow to over $6 billion by 2025. (Davis, 2019) According to the report, presented by Davis (2019) and HolonIQ (2019), there are five core areas of application:

- **Algorithms**: "Learning algorithms" provide personalised, adaptive learning paths.
- **Hardware**: Different devices powererd and extended by AI, robotics and IoT.
- **Natural Language**: Machines understand humans and give feedback, assess and detect plagiarism.
- **Vision**: When recognising emotions, (e.g. confusion) appropriate reactions can be given.
- **Voice**: Literacy and language learning can be supported through text-to-voice interfaces.

Kristian Simsarian said that educators should think of AI in terms of literacy and 21st century skills:

> "AI as technology has many aspects, including automation, machine learning, machine intelligence, robotics, data mining, and human-robot augmentation to name a few. Children will need to develop AI literacy about these different aspects as well as the application domains including medicine, law, farming, government, transportation and beyond." (Synched, 2018a)

Bloom's Taxonomy

A model to classify education learning objectives, elaborated by Benjamin Bloom and his collaborators in 1956. The higher categories in the cumulative hierarchical framework, change from simple to complex and from concrete to abstract as seen in Figure 6. (Krathwohl, 2010)
The second volume "Handbook II: Affective" was published in 1964 and ultimately the revised model from 2001, which also includes a separate taxonomy of the types of knowledge used in cognition, namely factual, conceptual, procedural, and metacognitive knowledge. (Krathwohl, 2010)

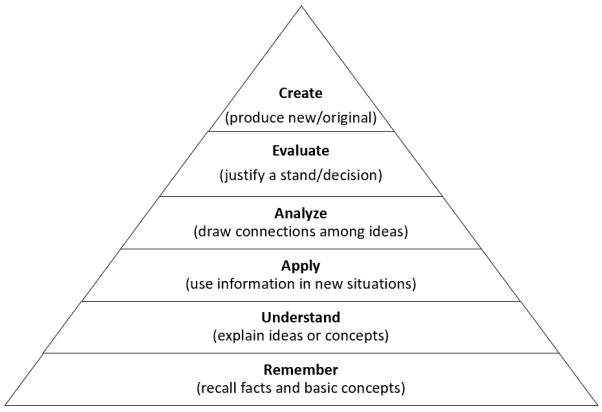

Figure 6: Six major categories of Bloom's framework, own graphic, adopted from Krathwohl (2010)

Learning researchers today claim that the different levels can be effectively mixed together in learning activities. They contradict Blooms belief, that they need to be sequential. (L. W. Anderson & Krathwohl, 2001)

BYOD: Bring Your Own Device

BYOD is the term used to describe the integration of private mobile devices into the networks of schools (or similar). Döbeli Honegger (2016) enumerates five reasons for bringing your own device with you. The most obvious is that most people already own a device, so it makes sense to use it in class. This consideration applies not only economically, but also ecologically. The third argument is the digital working world, in which the pupils have to learn to move anyway. BYOD allows individual (equipment-) needs to be met and the school can make recommendations. As a final argument, he mentions that with one-to-one equipment, there is a certain expectation pressure to use the devices. This can be minimised with BYOD.

Cognitive Science

The interdisciplinary field of cognitive science is the scientific study of the mind and its processes. This field originated in the 1950s, with influence of multiple disciplines such as psychology, anthropology and linguistics which were redefining themselves, neuroscience and computer science (special interest: artificial intelligence) as disciplines which were coming into existence, and philosophy, which had to free itself from behaviorism. (G. A. Miller, 2003)

Drill and Practice

This defines a method of instruction "characterised by systematic repetition of concepts, examples, and practice problems. *Drill and practice* is a disciplined and repetitious exercise, used as a mean of teaching and perfecting a skill or procedure." (Lim, Tang, & Kor, 2012, p.1040)

Inclusive Education

(UNESCO, 2018) explains that inclusiveness is only possible if the universal design for learning (UDL) and principles of non-discrimination, information accessibility, and gender equality in the delivery of education are taken into account. Furthermore, it is also necessary to take into account that actions are based on fundamental human rights and freedoms.

Human Intelligence

It is difficult to define intelligence, but it is a collective term for the cognitive performance of human beings. One of the most fundamental attributes of intelligent behaviour is to learn (Michalski et al., 1983). Thereby, is important to interpret and manipulate independently (Haugeland, 1989). Sternberg (1985) explains intelligence as one of the most elusive concepts to describe. In his book *Beyond IQ* he differentiates between explicit and implicit theories of intelligence:

Explicit theories of intelligence are based and tested on data collected from people which perform a task which is presumed to measure intelligent functioning. The two most influential forms are differential and cognitive theorising. Of course there are other advanced views, see e.g. Hebb (1949) and Hendrickson (1982) for psychological views, and Piaget (1972) for a genetic-epistemological view.

- **Differential** (or psychometric) theories of human intelligence have in common their attempt to understand intelligence in terms of a set of underlying abilities, which can be identified through a mathematical technique called factor analysis. Examples of theories which differ primarily between the **number of factors** used by the theory, are:
  - Spearman (1927) proposed in his theoriy that intelligence comprises two kinds of factors, a general (intellectual) factor and a specific factor (for more details, see below).
  - Thurstone (1938) proposed that intelligence comprises seven "primary mental abilities".
  - Guilford (1982) proposed in his reviewed theory that intelligence comprises up to 150 distinct factors (his former theory from 1967 differentiated between 120 factors). He states every mental task consists of an operation (5 types: cognition, memory, divergent production, convergent production, and evaluation), a content (5 types: visual, auditory, symbolic, semantic, and behavioral), and a product (6 types: units, classes, relations, systems, transformations, and implications).

  On the other hand, the **geometrical arrangement** of the factors with respect to one another may lead to different outcomes, even with the same contents for factors, the four best-known structures are:
  - An unordered list of factors is used by Thurstone (1938), meaning that they are equally important.
  - A cubic theory is proposed by Guilford (1982), where each dimension of the cube corresponds to one of the three categories.
  - Hierarchical arrangements are the most popular in the literature of intelligence. Abilities are not of equal importance, for example Spearman (1927) introduces a specific factor which is less important than the g factor. Further theories come from Holzinger (1938), Burt (1940), and Vernon (1971).

  - A radex structure for intelligence is proposed by Guttman (1965), where measured abilities which are more "central" are nearer in the center of the circle.
- **Cognitive** (or information-processing) theories of human intelligence understand human intelligence in terms of the mental processes that contribute to cognitive task performance. A range of levels of processing have beed studied: Pure speed of information processing (simple-reaction-time paradigm), a "choice-reaction-time" paradigm which is a combination of speed and decisions to simple stimuli, speed of lexical access implies profit per unit time of presented information aber therefore a better performance, and the speed of reasoning process which has two main emphases: performance process and executive process. For more information see Sternberg (1985, p.10pp).

Implicit theories of intelligence are based and tested on people's conceptoins of that intelliegence is, they are rather "discovered" than "invented". They define intelligence in terms of what people say intelligence is. Neisser (1979) stipulates that intelligence does not exist except as a resemblance to a prototype - the degreee of similarity between some ideally intelligent person and the actual person. The rising question of whose conception of intelligence should be used can be answered with two answers: Experts in the field (Sternberg, 1985, p.32) and laypersons in our culture (Sternberg, 1985, p.33).

In addidion, here is a selection of the best-known models:

- The **"G Factor"** (general factor of intelligence) by **Charles Spearman**. It is based on the statistical observation that a general intelligence factor is involved in most intelligence services. This justifies speaking of "intelligence" in a simplistic way. (Stemmler, Hagemann, Amelang, and Spinath, 2016, p.157; Sternberg, 1985, p.20; Wikipedia, 2019a)
- The **"Triarchic Theory of Intelligence"** or "Theory of Successful Intelligence" by **Robert Sternberg** which proposes three fundamental aspects of intelligence: Analytic (componential), Creative (experiential) and Practical intelligence (contextual). The three aspects of intelligence are referred to as processing skills. (Sternberg, 1985; Wikipedia, 2019a)
- The **"PASS Theory of Intelligence"** by **Alexander Romanovich Luria**. The theory proposes that cognition is divided into three systems and four processes, called "Planning", "Attention", "Simultaneous" and "Successive Processing". (Wikipedia, 2019a)
- **Jean Piaget** explains in his **"Theory of Cognitive Development"** how a child constructs a mental model of the world. The cognitive development is a process that appears through biological maturation and interaction with the environment. Therefore, he uses four main stages, called sensory motor stage (first two years), pre-operational stage (from 2 to 7 years), concrete operational stage (from 7 to 11 years), and formal operations stage (from 11 to 16+ years). The theory disagrees with the idea that intelligence is a fixed trait. (Piaget, 1972; Saul, 2018; Wikipedia, 2019a)
- The **"Theory of Multiple Intelligences"** from the American developmental psychologist **Howards Gardner**, which he developed in 1983. Gardner defines intelligence as "biopsychological potential to process information that can be activated in a cultural setting to solve problems or create products that are of value in a culture." (Gardner, 1999, p.33) The definition includes linguistic, logical-mathematical, and (visual-)spatial intelligences, which are regular intelligences tested in IQ tests. His original model described in the book *Frames of mind: the theory of multiple intelligences* also includes musical (creative), bodily-kinesthetic, interpersonal, and intrapersonal intelligence. (Gardner, 1999) He even broadened this definition a few years later from seven to eight items with the naturalist intelligence . Some years later he speculated about three other possible intelligences: existential intelligence , (teaching-)pedagogical intelligence , and moral intelligence. In 2016, Gardner explicitly refused some other suggested intelligences like humour, cooking and sexual intelligence. (Wikipedia, 2019c)

– Nevertheless, one should keep in mind, that all theories can be criticised by a lack of empirical evidence.

Intelligent Tutoring System (ITS)

These computer systems aim to provide immediate and customised instructions to learners, usually without the intervention of a human teacher. ITS are more knowledge-intensive compared to ILEs. AI improved the efficiency of intelligent tutoring systems enormously. (McArthur et al., 2005)

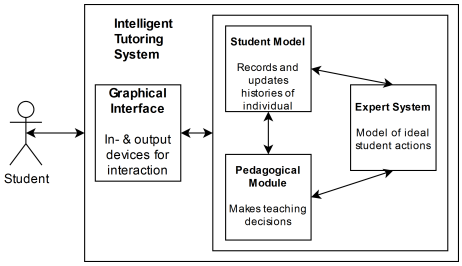

Figure 7: Components of a generic intelligent tutoring system, own graphic, adopted from McArthur et al. (2005, p.45)

There are several reasons for the success of ITS: So called "micro-tutoring" delivers highly detailed feedback, the tutor has (high) control of the learning process and proposes different adjusted options, because it is assumed, that the tutor knows the student model, the pedagogical module and the expert system, as seen in Figure 7. In addition, they offer impasse-driven coaching, meaning that if the system recognises the student having difficulties it delivers immediate feedback. Further, ITS fit well into classrooms as they aim at the same outcomes as already embedded in traditional curricula and they adopt popular methods of teaching and learning. (McArthur et al., 2005) This leads to multiple advantages like significantly improved speed and quality of students learning (McArthur et al., 2005).

Interactive Learning Environment (ILE)

A collective term for inquiry-based education systems which are structurally and conceptually much more diverse than ITS. The principles that tie ILEs together include; construction instead of instruction, student control not tutor control, individualisation determined by the student not the tutor, and rich feed generated by the student's interaction with the learning environment no the tutor. Microworlds are one particular kind of ILE. (McArthur et al., 2005)

Knowledge Society

A society that fosters its diversity and takes advantage of its many knowledge forms. "This concept emphasises that knowledge is not only produced in a scientific laboratory but is also represented in the accumulated experience of humankind in all nations." (UNESCO, 2018)

It's people acquire information but also transform it into knowledge and understanding. Further, the sharing of knowledge and information (particularly through ICT), has the power to transform economies and societies. (UNESCO, 2018)

Lehrplan 21

This is the new curriculum for the 21 German- and multilingual Swiss cantons. The *Lehrplan 21 project* was initiated in 2004 and handed over to the cantons for introduction in 2014. (BKZ, n.d.-a) Today it is mainly adopted. For further information about the *Lehrplan 21* see chapter 3.1 and chapter 3.2.

One-to-one (1:1) Equipment

Every student has its own device, thus they have a personal device at their disposal at all times. Experience has shown that personal devices are handled more carefully and can be adjusted more individually. Compared to BYOD (bring your own device), the devices are usually paid by the institution. The expression "1:1" has become obsolete in the meantime, as more than 2.5 internet-enabled devices per student are expected from 2014 onwards. (Döbeli Honegger, 2016) References to detailed and current recommendations as well as numerous project descriptions can be found at www.1to1learning.ch .

Open and Distance Learning / Education

UNESCO defines these term as follows:

> "The terms *Open Learning* and *Distance Education* represent approaches that focus on opening access to education and training provision, freeing learners from the constraints of time and place, and offering flexible learning opportunities to individuals and groups of learners. Open and distance learning is one of the most rapidly growing fields of education[...]" (Moore, Tait, Khvilon, & Patru, 2002, p.7)

Open Educational Resources (OER)

Any free resources to support teachers and students in their teaching, respectively learning process (UNESCO, 2018). The learning materials should be freely usable in three dimensions. Firstly, the use is free of charge, secondly, the terms of use of OER allow the use and distribution of modified materials. Thirdly, OER should be available in open data formats that can be processed with freely available programs. (Döbeli Honegger, 2016) An example for teaching materials for secondary schools in Switzerland is *swisseduc.ch*, and *Flexbooks* is an American example from the California non-profit organisation *CK-12 Foundation*.

Trivium and Quadrivium

The most influential formulation of traditional knowledge disciplines of the early Western were *Trivium* (including three linguistic subjects) and *Quadrivium* (including four advanced mathematical subjects) which is a medieval revival of the classical Greek educational theories. They define seven liberal arts ("thinking skills") for higher education: grammar, logic, rhetoric, astronomy, geometry, arithmetic, and music. (Fadel et al., 2015)

As today, a certain "common knowledge" of these liberal arts is a requirement for further studies. Back then, the completion of the study of the seven liberal arts qualified one for further studies (e.g. philosophy, theology, law, and medicine). (Fadel et al., 2015)

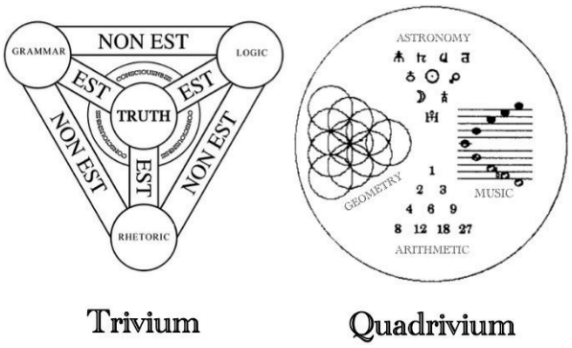

Figure 8: The seven liberal arts: *Trivium* and *Quadrivium* , from Fadel et al. (2015, p.46)

Virtual Reality (VR) and Augmented Reality (AR)

Virtual Reality (VR) is a real-time, computer-generated simulation of an environment that a person can interact with. The person is able to manipulate objects or perform a series of actions in this simulated environment. *Augmented Reality* (AR) is a view of a real-world environment whose elements are extended by computer-generated images that superimpose the physical environment in real time. AR changes a person's current perception of a real-world environment, while VR replaces the real environment with a simulated one. (UNESCO, 2018)

VR can enable experiential learning by simulating real-world environments. For visual learners and people with learning difficulties, VR offers an alternative medium. One of the advantages of integrating VR/AR technology into the education experience is that students are able to participate in a life-like engagement, which leads to easier application and retention of the topic. (UNESCO, 2018)

2.2 History

In this subsection some changes in education are presented and further some milestones in the history of artificial intelligence are listed.

History of Education

As a first note, It should be mentioned, that education changes much slower than technology. Interestingly, almost all subjects have remained remarkably consistent over the last millennia, as shown in Figure 9. Some new subjects such as higher level mathematics and sciences have been added to the curriculum, and subjects including rethoric abilities have been discarded.

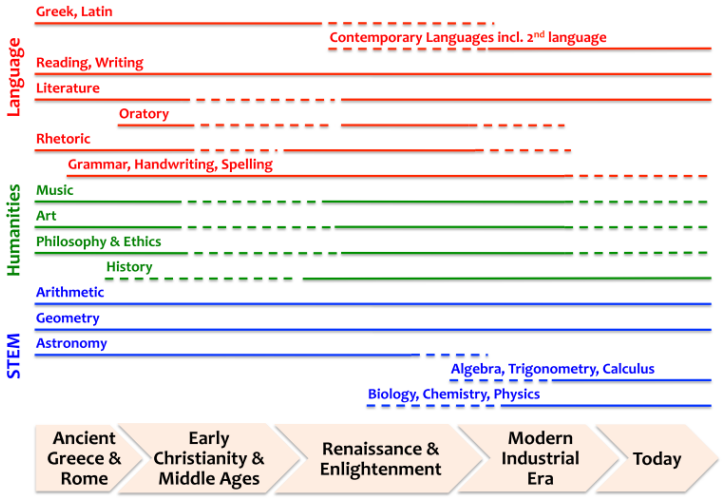

Figure 9: School subject evolution, illustration by CCR from Fadel et al. (2015)

Rosa (2016) distinguishes between three epochs of teaching, where *premodernism* is the first and is characterised by "learning by doing". It was a labour-intensive period with crafts and agriculture. They had personal teachers on site who strictly controlled. Science and abstract thinking was only possible for "the 0.1%". The main medium was the language and the prerequisite was to understand it and a functioning biological sensory apparatus. (Rosa, 2016)

In the next epoch, education institutions and textbooks were developed, and systematic learning in subjects was introduced. School became more efficient as few teachers were responsible for many students who understood written assignments and carried them out independently. Learning to learn was partly possible and abstract thinking was made possible for the general public. In this time, it was problematic that "dead knowledge" had to be learned by heart instead of understanding topics. The main medium of this period was the printing press, which led to widespread literacy. There have been improvements in didactics, standardisation systems in the curriculum, among other things, and external evaluation systems. (Rosa, 2016)

As last epoch, the *society of today and tomorrow* is named. It is more self-deterministic, leading to control gains for learners. In addition, personalised learning, incredible diversity of information and easy access, a high degree of exchange and collaboration, potentially higher thinking for everyone is possible. Risks of this time are a higher risk of data disclosure (Dig Data, AI), the "filter bubble" and "information overload". This time is characterised by de-standardisation and repersonalisation. The Internet is regarded as the leading medium, self-evaluation comes to the fore, control is given up, and increased (media) literacy is promoted. (Rosa, 2016)

Baeker defines the communication media as trigger for change of the leading media. With the advent of writing, the language society developed into the manuscript society. Through book printing, it became a book printing society and finally, through ICT, an information society. (Döbeli Honegger, 2016, p.25)

To put it simply, the learning theory of *Behaviorsimus* that prevailed at the beginning of the 20th century was based on the assumption that schoolchildren could be taught the subject matter with the *Nuremberg funnel*. The teacher explains the right way to do something and supports the learning process with rewards. Figure 10 illustrates the Nuremberg funnel with the subtitle "If you miss wisdom in some fields, let you bring the Funnel from Nuremberg". (Döbeli Honegger, 2016, p.51)

At the beginning of the 21st century, the perspective on the learning process changed fundamentally. According to constructivistic epistemology there is no possibility of direct knowledge transfer and pupils have to build up and expand their own knowledge structures. (Döbeli Honegger, 2016, p.51)

Between the change from book to ICT and the change from behaviorism to constructivism, parallels can be drawn. In the 20th century it was enough to reproduce information (behavioristic) in today's information society, information must be increasingly questioned (constructivism). Today, the contents can also be represented more individually through technology. (Döbeli Honegger, 2016, p.51f)

Figure 10: Nuremberg funnel on a stamp from 1910, illustration from Wikipedia (2018)

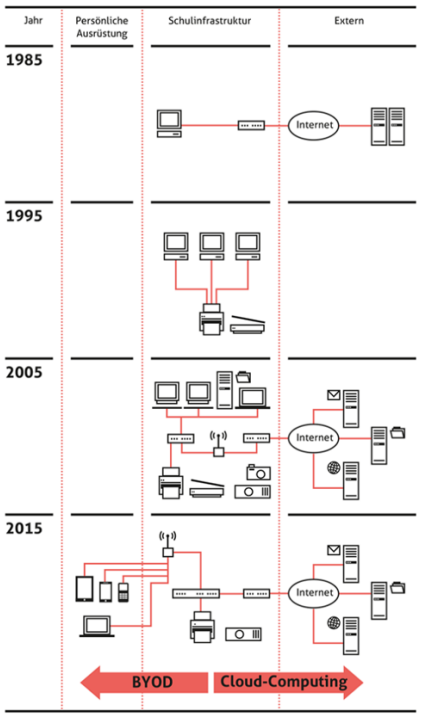

Figure 11: Phases of ICT equipment in schools 1985 to 2015, illustration from Döbeli Honegger (2016, p.123)

Usage of Technology in Education

Before the introduction of IBMs first computers, there were hardly any computers in schools and frontal teaching using a blackboard was common practice. Some schools gained access to mainframes via a terminal (e.g. from a university), as the first part of Figure 11 illustrates. (Döbeli Honegger, 2016)

Ten years later, in many places already unnetworked computer rooms were being used at secondary level, and media corners were established in primary schools. (Döbeli Honegger, 2016)

Another decade later, Internet connection is provided in many schools. The schools begin to set up their own servers, the range of hard and software becomes much more diverse: Servers, beamers, printers, scanners, digital cameras and much more is being used. Technical support becomes more important and there is often too little ICT know-how available in this increasingly complex area of application. (Döbeli Honegger, 2016)

Finally personal computers, tablets and mobile devices are used in class. Technological possibilities are fully exploited. Asynchronous learning may use technologies such as learning management systems (e.g. OLAT), email, blogs and wikis to im-

prove classes. Müller replies that pedagogy has always been
subject to fashion trends, as there have always been innovations or things are at least newly named (Müller, 2019, 51:35) He sees digitisation as a major topic in education, but adds that it is not a new topic; it definitely needs to be changed, but it takes a long time (Müller, 2019, 51:50).

As early as 2014, 95 percent of twelve- and thirteen-year-olds in German-speaking countries already had their own mobile phones. It is expected that this trend will continue and that the age limit above which 95% own a personal device will continue to fall. (Döbeli Honegger, 2016) This leads to the question of what is the best way to equip children with ICT: BYOD, school equipment or a mixed form.

A problem that arises in the acquisition of ICT in schools is, that they are often sold enterprise ICT solutions and it is neglected that schools have different ICT requirements. (Döbeli Honegger, 2016)

Media as teaching and learning aids should become common (Regierung des Fürstentum Liechtenstein, 2019).

In the field of education, digitisation provides access to new forms of adult education and training to facilitate lifelong learning. New forms of didactics in public and secondary schools or universities enable young people at an early age to come into contact with and deal with digital offers. This increases their digital competence to recognise the opportunities and dangers of digital offers, which promotes the development of the next generations and enables long-term success in their private and professional environment. (Regierung des Fürstentum Liechtenstein, 2019)

Usage of Artificial Intelligence in Education

AI is in a early stage in the education industry. Although, there is a huge discussion about AI and education, a lot of products are not really AI or are immature. (Khan, 2019) Today's commercial AI technology clearly falls into the category of "narrow AI" (Jones, 2018). What can be said with certainty is that there is a growing trend towards this topic. For example in China, almost every benchmark regarding "AI + education" is increasing. (Khan, 2019)

> "At first artificial intelligence was only limited to measurements and such small activities, then it started to push through to increase the learning efficiency of the students and now it is helping teachers with their teaching method and as well as the teaching content. AI is trying to make education more personalised and change the mainstream method of big class education, but not only in the back end system voice but also through cartoons, pictures of robots and as well as through an image of a real teacher." (Khan, 2019)

Currently, AI in education is mainly used in the form of personalised and customisable content through adaptive learning programmes and software. Tracking and monitoring diagnostics detect the student's level and difficulties and react adjusted. Grading can be automated, admin tasks can be streamlined and some tasks can even be delegated to an AI tutor. This improves teaching quality and grants teachers additional time for understanding and adaptability. (Khan, 2019; UNESCO, 2018)

AI can be used to help students to develop and strenghten skills and competences and teachers with testing systems. AI might help to fill needs gaps in learning and teaching and allow schools and teachers to be more efficient. (Khan, 2019)

> "The purpose of AI + education has always been to serve people, to liberate people from simple, mechanical, and burdensome work. The most important purpose of artificial intelligence for education should be to allow teachers to free up more time and energy, to innovate educational content, and to reform teaching methods, which will be more helpful to children's growth." (Khan, 2019)

The combination of machines an teachers leads to best outcome for students (Khan, 2019). But there are definitely some risks. There is development from algorithms that support tutoring lessions to surveillance systems that monitor the entire classroom progress (Houser, 2019). This should be critically questioned.

Education AI can be subdivided into different sectors, such as K-12, language training, vocational education, and many other specific educational fields. (Khan, 2019)

Milestones in Computer History

Here a timeline of milestones related to automatisation, roboterisation, (smart) computer history, and artificial intelligence which should serve as an overview:

1804/05: Joseph-Marie Jacquard invented the first programmable machine, the Jacquard loom. (Crevier, 1993; Deer, 2010)

1822: Charles Babbage tried to develop the *Difference Engine* which is a mechanical calculator (Campbell-Kelly, William, Ensmenger, & Yost, 2018)

1850s: George Bool published a first version of the *Boolean algebra*. (Crevier, 1993)

1920: The term "robot" is first used in the play *Rossum's Universal Robots* by Čapek. (Deer, 2010)

1931: Vannevar Bush created an analog calculator that could solve differential equations. (Crevier, 1993)

1939: General Motors created the idea of an automated mobile cart called "Futurama" (Marr, 2018) and Westinghouse Electricat introduces a "mechanical man" (Deer, 2010) at the World's Fair in New York.
Alan Turing develops his groundbreaking algorithms and Bombe machine that allows the decryption of the German code Enigma during the second world war. (Rogers, 2019)

1945: John von Neumann published his computer architecture, embodied in virtually all computers since the Second World War, that breaks a computer into two parts. (Crevier, 1993)

1946: The first "general-purpose electronic computer" is built at the University of Pennsylvania called *ENIAC* (Electronic Numerical Integrator and Computer). (Frangoul, 2018)

1950: Alan Turing created the first "Turing Test" called the *Imitation Game* (Turing, 1950) and the American writer Isaac Asimov published the *Three Laws of Robotics* (Deer, 2010).

1951: *Ferranti Mark I*, the second commercially available universal computer, successfully uses an algorithm to master the game checkers. (Rogers, 2019)

1956: Ideas such as neural networks and machine learning are emerging when John McCarthy coined the term "artificial intelligence" at the Dartmouth Conference (Marr, 2018) and the first functional AI program is written (Deer, 2010).

1958: John McCarthy designs the early programming language Lisp, which rapidly becomes the favoured programming language for AI. (Rogers, 2019)

1964: In his dissertation, MIT student Danny Bobrow shows that computers can understand natural language well enough to solve algebra word problems correctly. (Rogers, 2019)

1966: ELIZA, the world's first chatbot is developed at MIT by Joseph Weizenbaum. (Marr, 2018)

1970s: The first expert systems are created but also the first *AI winter* hits (Rogers, 2019).

1970: WABOT-1, the first anthropomorphic robot, is developed by a team at Waseda University in Japan. The robot can communicate with humans in Japanese, and measure distances and directions to external objects. (Rogers, 2019)

1980: At Stanford University, the first national conference of the American Association for Artificial Intelligence (AAAI) is held. (Rogers, 2019)

1981: IBM's personal computer are released and become very popular. (Frangoul, 2018)

1984: Apple's Macintosh, the first mass-market personal computer that featured a graphical user interface, built-in screen, and mouse, was sold. (Frangoul, 2018)

1985: Microsoft launches Windows which was rather a interface manager than a complete operating system. (Frangoul, 2018)

1988: *A Statistical Approach to Language Translation* was published by IBM researchers introducing principles of probability. Until then the field of machine learning was rule-driven and now finally tackled the challenge of automated translation between human languages. (Marr, 2018)

1989: Tim Bernes-Lee submitted a proposal for a "distributed information system" at CERN and one year later, the first website and server went live at CERN. (Frangoul, 2018)

1991: Berners-Lee publishes the *Hypertext Transfer Protocol* (HTTP 0.9). (Marr, 2018)

1997: IBM's Deep Blue Supercomputer out-calculates Grand Master Garry Kasparov at chess. (Larus et al., 2018; Marr, 2018; Rogers, 2019)
NaturallySpeaking, a speech recognition software, is implemented on the Windows operating system (Rogers, 2019).

2000s: Broadband internet and connected living penetrate society. (Frangoul, 2018)

2002: Roomba, the autonomous vacuum cleaner by iRobot is able to navigate around obstacles. (Rogers, 2019)

2005: A race for autonomous vehicles called the "DARPA Grand Challenge" across over 100 kilometers of off-road terrain in the Mojave desert. For the first time, vehicles managed to complete the course. From these five vehicles, the team from Stanford University taking the prize for the fastest time. (Marr, 2018)

2007 Apple releases the first iPhone. (Deer, 2010)

2011: Apple's personal assistant *Siri* is the first smartphone app that uses natural language to answer questions and perform actions. (Rogers, 2019)

2014: The computer programme *Eugene Goostman* passed the Turing Test for the first time. (University of Reading, 2014)

2015: Algorithms compete to show their proficiency in recognising and describing a library of 1000 images at the *ImageNet Challenge*. When the contest was launched in 2010, the accuracy rate of the winning algorithm was by 71.8% compared to 97.3% in 2015. (Marr, 2018)
DeepMind, a program by Google, beats the three-time European champion Fan Hui at Go

(Rogers, 2019). Go has more possible board configurations than there are atoms in the universe (Larus et al., 2018). This milestone could be reached by employing two neural networks powered by sophisticated "automated decision making" (ADM) algorithms. (Larus et al., 2018; Marr, 2018)

2017: AlphaGo Zero, the descendant of AlphaGo, becomes the strongest Go player on the planet. It was programmed only by the rules of the game and trained the game playing against itself (unsupervised). (Larus et al., 2018)

2018: Google Duplex makes phone calls on your behalf using AI in natural language understanding, deep learning, and text-to-speech. (Mashable Deals, 2018)

2019 Academic publisher *Springer Nature* publishes the first research book *Lithium-Ion Batteries: A Machine-Generated Summary of Current Research*, generated using machine learning. (Springer Link, 2019)
Samsung's deepfake AI can create a video using a single picture. (Solsman, 2019)

As shown in Figure 12, Moore's law states that the complexity of integrated circuits doubles regularly with minimal component costs about every two years (other sources say 12-24 months: Döbeli Honegger (2016), Wikipedia (2019b)). What is also noticeable is that the milestone are getting closer and closer. An striking example is the reachability:

> "To reach an audience of 50 million people it took radio 38 years, television 13 years, the Internet four years, and Facebook only two years. The speed of technological change today is vastly greater than it was even several years ago — innovations in technology are being adopted at exponential rates, vastly more rapid than in any prior time in civilisation." (Fadel et al., 2015, p.10)

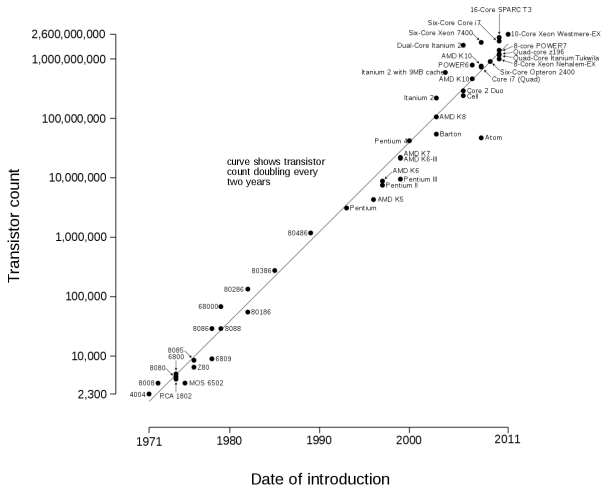

Figure 12: Moore's law describes the number of transistors doubles about every two years, illustration from Wikipedia (2019b)

The Waves of Artificial Intelligence

In the history of AI there have been several waves that have witnessed strong development. John Launchbury (DARPA) described the *three waves of AI* and refers to them as the state of artificial intelligence capabilities in the past, present and future (Golstein, 2018). Jones (2018) added a fourth stage to account for what many believe will be the ultimate phase of artificial intelligence: human-level intelligence (AGI) and beyond (ASI). Jones (2018)

Between two waves of AI, respectively summers, there is a so-called *AI winter*. They occur whenever the promises of AI exceeds their capability to deliver which results in a loss of funding from entrepreneurs (Mueller & Massaron, 2018). Depending on the author, we are currently in the second wave (Golstein, 2018) or in the third summer (Grudin, 2009; Mueller & Massaron, 2018). The first winter was already from 1974 to 1980, argues Mueller and Massaron (2018).

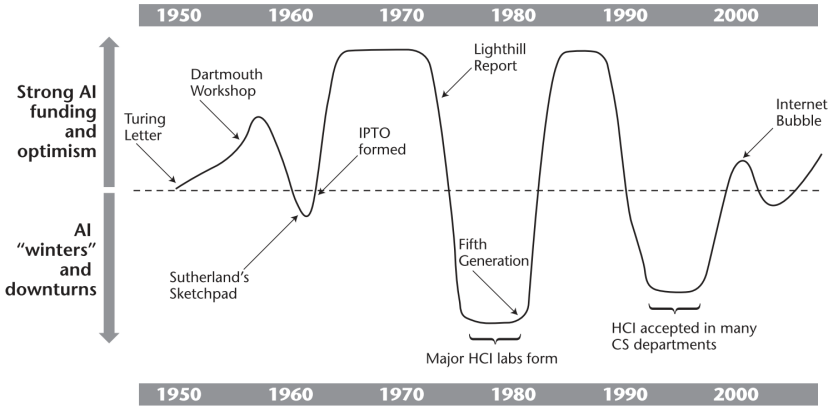

Figure 13: The changing seasons of AI , illustration from Grudin (2009)

The first wave of AI, was good at explaining the exact way in which it had been programmed. Typically this was done by following a series of "if-then"-rules but the system did not learn and develop. (Golstein, 2018) The second phase of stagnation was between 1987 and 1993 according to Mueller and Massaron (2018), but Golstein (2018) argues the first wave ended in the late 1990s. The second wave, which began in the early 2000s and systems have drastically increased ability to perceive and learn on a narrow scope (Golstein, 2018). This wave is dominated by deep learning and statistical, big data approaches (Jones, 2018). According to other authors, we're in the third AI summer, already (Mueller & Massaron, 2018). Both hypes ultimately failed due to the fact that computers are not advanced enough to properly process the huge amount of data required for successful AI applications (Mueller & Massaron, 2018; Rogers, 2019).

The third wave, expected in the 2020s or 2030s, will add to its perceptual abilities the ability to generalise from its narrow to a broader range, with the ability to adapt contextually Golstein (2018).

This intelligence will not only be able to recognise a cat, but will be able to explain *why* it came to this conclusion and *how*. It will also be able to learn in a way that is much more similar to the way people learn. and is capable to learn from descriptive, contextual models. This reduces the dependency on large data sets and also solves the problem of distorted training data. (Jones, 2018) The fourth wave would initiate artificial general intelligence (Golstein, 2018).

This section wants to highlight, that in the history of AI already a lot of ups and downs have taken place. Nevertheless, AI continues to evolve, maybe sometimes at a glacial pace.

"Any fool can know.
The point is to understand."

Albert Einstein

3 Skills and Competencies

In this chapter, first skills and competencies are defined, then the Swiss education system is introduced including the *Lehrplan 21*. An analysis of the *actually taught skills and competences* is made in chapter 3.2 making an as-is analysis of the Lehrplan 21 and the taught subjects. In a further subsection important new *future skills and competences* are analysed from literature and explained using relevant models, which illuminate different perspectives. The transformation of jobs is enlightened and finally important skills and competences are defined. In chapter 3.4 areas affected by the changes are outlined. The curriculum, training courses, tools used and new learning and teaching methods are discussed.

Traditionally, one differenciates between *hard skils* and *soft skills*, where hard skills define technical competencies and soft skills include intra- and interpersonal competencies. (Laker & Powell, 2011)

Burning Glass Technologies (2015) defines hard skills as cognitive skills such as programming or bookkeeping. They usually can be formally taught or self-taught and are to some extent measurable. Soft skills, in constrast, are intuitive "people skills", often considered part of emotional intelligence. There exist many programs to train people in soft skills such as customer service, but employers state that these skills are hard to find and define (Burning Glass Technologies, 2015). One study finds 57% of senior leaders prefer soft skills over hard skills (Petrone, 2019).

Because skills and competences are defined differently across disciplines and countries (Fadel et al., 2015, p.33) a selection of models is introduced. Fadel et al. (2015, p.33) explains: "These competencies are diverse in scope ranging from core skills, content knowledge, cognitive skills, soft skills, to occupational skills and enable us to meet a complex demand or carry out a complex activity or task successfully or effectively in a certain context."

According to Baumgartner (2014), one can distinguish four types of competences, structured according to their context (translated from German):

- **Basic cometences**: Erpenbeck and Sauter differentiate four subareas:
  - **Technical-methodical:** expert knowledge, interdisciplinary knowledge, planning behaviour etc.
  - **Social-communicative:** persuasiveness, willingness to communicate, openness etc.
  - **Activity and implementation:** initiative, energy, readiness to execute etc.
  - **Personnel:** self-confidence, courage, creativity etc.
- **Derived competences** are more specifically and contain operational context conditions, which are listed e.g. in job descriptions.
- **Cross-section competences** are defined by context, such as intercultural competences, media competence, leadership competence or innovation competence.
- **Meta competences** are general skills for self-organisation such as self-knowledge, self-distance, value relativism, empathy, situation and context identification, intervention and solution skills. These are, so to speak, competences of the second order.

To make things clear, in this work *skills* are defined as job-specific and more economically oriented characteristics. They are the ability to effectively use what one knows.

Competences go beyond that and can be interdisciplinary. They are internal prerequisites for self-organisation which cannot be conveyed directly. Instead, didactic settings must be developed that help to build up the ability to think and act in a self-organised way. (Baumgartner, 2014) Competences have a rather broader application area.

In the Lehrplan 21 no no distinction is made between skills and competences.

"Education has never changed in the past ten years or even a thousand years. The emergence of AI has subverted traditional education and various forms and contents."

Victor Wang

3.1 Education System and Lehrplan 21

Most education systems around the world teach the following *traditional disciplines* according to (Fadel et al., 2015): Mathematics, science, languages (usually one domestic and one foreign language), social studies like history, geography, civics or economics, arts and music, and physical education (see *Trivium and Quadrivium* on page 20)

This is also the case in the Swiss curriculum. Figure 14 illustrates which subjects are taught in what cycle.

The control of the Swiss federal education system is based on the principle of subsidiarity: Each federal level (confederation, cantons, language regions, communes, institutions) is responsible for and regulates certain areas and sets targets for the next level, which in turn has room for action and, if necessary, makes specifications for the next level. The subsidiarity principle also applies to quality assurance and development and thus structures evaluation activities in the field of education. (Rhyn, 2009)

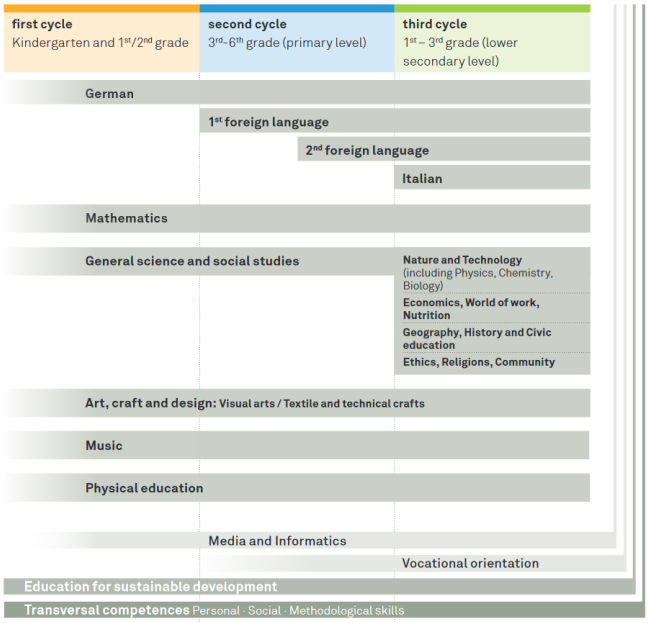

Figure 14: Subject areas of compulsory schooling of the Lehrplan 21, retrieved from (D-EDK, n.d., p.2)

In Switzerland, the education system is a duty of the state from entry into compulsory schooling to tertiary level. Responsibility for education lies primarily with the 26 cantons, attendance is free and lasts eleven years. The division of the eleven years into three cycles can be seen in Fig. 14. The cantons and their communes finance 90% of public spending on education. (EDK, 2017)

This work will only analyse the first two cycles, both of which cover four years, as they are the only ones that concern primary school. Primary school - including two years of kindergarten or the first two years of an entry level - lasts eight years. There are significant differences between the cantons (D-EDK, 2014; EDK, 2017).

Around two thirds of young people switch to an apprenticeship that combines school and practice (dual vocational training) after completing compulsory schooling. It leads to a vocational skills certificate and can also be completed with a vocational maturity certificate. Approximately one third of all young people go on to school-based training (vocational secondary school or gymnasium) that prepares them for studying at a university. More than 90% of young people acquire a degree at upper secondary level. (EDK, 2017)

Development of the Lehrplan 21

The *Lehrplan 21 project* was initiated in 2004 (BKZ, n.d.-a). In 2006, the Swiss electorate voted to harmonise the targets of the individual levels of education (D-EDK, n.d.; Loacker, 2015). With this first joint curriculum for primary school, the 21 German- and multilingual cantons (AG, AI, AR, BE, BL, BS, FR, GL, GR, LU, NW, OW, SG, SH, SO, SZ, TG, UR, VS, ZG, and ZH) implemented article 62 of the federal constitution to harmonise the school's objectives (D-EDK, n.d.). At the end of 2016, Liechtenstein decided to also apply the Lehrplan 21 and implemented it in the summer of 2019.

The project was divided into two parts: In a first phase, the foundations of the curriculum were developed (2006 - 2010). In a second phase, the curriculum was developed (2010 - 2014).

Bucher explains, during the preparation of curriculum, all possible curricula were compiled for each subject area. Furthermore different models from various countries have been collected, examined and merged. This resulted in a conglomerate of curricula, models and relevant documents. (Bucher & Zemp, 2019, 4:00) Around 200 experts took part in the elaboration of this curriculum (Loacker, 2015). This allowed to align with other curricula and the latest state of research in terms of structure, content and competence orientation (Bucher & Zemp, 2019, 6:25).

One requirement was to incorporate the *HarmoS educational standards* (Intercantonal agreement on the harmonisation of compulsory schools) into the basic competencies of the four key subjects school language, first foreign language, mathematics and NMG (Bucher & Zemp, 2019, 5:00). The national educational standards contribute to harmonising the teaching objectives of compulsory schools throughout Switzerland. They are also a basis for reviewing the quality of the education system in the area of compulsory education and form the legal basis for the development and future application of national educational standards. HarmoS specifies two types of educational standards: *performance standards*, which describe subject-related competence levels which have to be achieved by the pupils, and *other standards* (Art. 7 para. 2). Work is in progress and further standards can also be developed for other subjects. (Educa, 2019b)

Next to the subject areas, there are two modules, as illustrated in the lower part of Figure 14. *Media and Informatics* (MI) has been widely extended and a lot of new ICT-competences have been added and *Vocational orientation* is aimed at students from the third cycle (Müller, 2019, 43:55). Both areas is given more weight (D-EDK, 2016a, 2017).

The *Hasler Foundation*, among others, was involved in the preparation of the curriculum for MI. As well as the ETH, which was particularly active in the second phases. (Bucher & Zemp, 2019, 6:40) In the course of the development of the curriculum, the subject MI was given more weight because of the reactions of involved parties. The importance became clear and the curriculum was expanded. (Bucher & Zemp, 2019, 31:20)

From the third grade onwards, one lesson per week is assigned to *Media and Informatics*. It is important to stress that in the subject MI, pupils don't sit in front of the computer for the whole lesson but it is more about propagating a conscious approach, how to behave in the Internet and some basic knowhow about technology and even artificial intelligence is offered. The active usage of a computer is a negligible part. The students should be shown advantages like an improved workflow, the networking etc. but also disadvantages and risks are introduced. Furthermore, the influence on humans shall be described, e.g. how we can be manipulated. It is about a healthy, critical approach and about being prepared for the future. (Marogg, 2019, 10:35-13:20) Dealing with computers is also a fundamental requirement in general. It is necessary that pupils can use keyboards, but it is less important how to write (e.g. it's not necessary to use the "ten-finger typing system"). A basic understanding of Microsoft Windows is required and also the folder structure and different types of data should be known. Further, Microsoft's standard programs and Microsoft Office are taught. (Marogg, 2019, 17:40)

Turkawka points out that he welcomes the fact that not only programming but also digital and media literacy is taught in MI (Turkawka, 2019, 25:10). Bucher confirms this distinction and stresses the importance of both, physical and digital-virtual education and switching between the two. (Bucher & Zemp, 2019, 33:30)

The Lehrplan 21 distinguishes between three cross-disciplinar *Transversal competences* , which partly overlap. They are called personal (self-reflection, independence and autonomy), social (ability to engage in dialogue and cooperation, ability to deal with conflict and diversity) and methodological competences (language ability, using information and solving tasks/problems). (D-EDK, 2016e) Transversal competences are always taught on the basis of a learning object - the subjects. (Bucher & Zemp, 2019, 40:50)

Education for sustainable development (BNE) is a new subject in the curricula, where cross-references are made to the following seven interdisciplinary topics: Politics, democracy and human rights; natural environment and resources; gender and equality; health; global development and peace; cultural identities and intercultural understanding; and economy and consumption (D-EDK, 2017). According to Marogg, this subject was built into the curriculum, based on a UNO treaty that obliges the members to implement this topic in the curriculum. It is about promoting awareness of a healthy earth, healthy use of materials and limited resources and alternative thinking. There are no lessons assigned to this topic but it should be integrated into other subjects. (Marogg, 2019, 13:35-15:10)

The *Lehrplan 21* is neither a new invention nor a counterprogram but a re-prioritisation. There are not so many changes in content according to Kerf and Sted (2014). The most important change is the switch from pure knowledge transfer to the competence model. They developed 363 competences (divided into 2304 competence levels (Loacker, 2015)), where competences are the ability of pupils to apply the knowledge they have learnt. (Kerf & Sted, 2014)

In autumn 2014, the Swiss-German directors of education approved the submission of the Lehrplan 21. There is a template for Lehrplan 21 and the cantonal versions. Today, most cantons have already implemented the curriculum. (BKZ, n.d.-a; D-EDK, n.d.)

In concrete terms, the curriculum becomes standardised; this is reflected in the fact that compulsory schooling is extended to eleven years throughout Switzerland; overarching objectives for compulsory schooling are to be introduced; instruments for quality assurance and quality development are named at national level; instruments for binding educational standards are defined; and the school is to be adapted to national and international portfolios. (Loacker, 2015)

Focal Areas of the 1st Cycle

At the beginning of the first cycle , the lessons are mainly organised and structured in an interdisciplinary way. The Lehrplan 21 accordingly offers nine development-oriented approaches like perception, temporal orientation or language and communication. These development-oriented approaches build a bridge from the development perspective to the subject area structure of the curriculum and make it easier for teachers to plan and access cross-curricular teaching. (D-EDK, 2016b)

During the first cycle, the children's thinking and learning changes from a "play-and-learn" environment. Increasingly, they are able to focus their attention on external learning content and learn more systematically. (D-EDK, 2016b)

Focal Areas of the 2nd Cycle

Classes in the second cycle build on what has been acquired so far, the professional and interdisciplinary competences are deepened and expanded. The essential skills reading, writing and arithmetic are further practiced, developed and consolidated. Classes focus on the subject areas, while interdisciplinary

teaching and corresponding projects continue to take place. (D-EDK, 2016c)

The competencies for systematic learning are continuously being developed and expanded and the development from concrete to abstract thinking is being driven forward. Pupils are instructed to reflect on their learning and work and to steer it increasingly independently and with more personal responsibility. The examination of oneself and other people as well as learning in groups are important components of the lessons. (D-EDK, 2016c)

Pupils expand their radius of movement in this learning and life stage. They develop social contacts outside their family and neighbourhood. Ultimately, the transition to the 3rd cycle takes place. This is usually anticipate by a procedure in which the school performance of the pupils is assessed. (D-EDK, 2016c) When assessing students, almost as much attention is paid to personal and methodological competencies as to technical competencies (Marogg, 2019, 7:40).

Education Goals

Education has multiple objectives. Each of the subjects has three aspects of value: *Practical*, meaning that students understand the concept and can use it in their everyday lives. *Cognitive*, when higher level thinking is enhanced, and these skills transfer to other subjects and contexts. *Emotional*, when a subject area has inherent beauty and power to help understand the world, and serves as a source of motivation for students. All of the three aspects can be learned simultaneously. But they might change over time, so it is possible that something that had a huge practical value in the past, does not have it today. (Fadel et al., 2015)

Taxonomies of Educational Objectives			
Bloom (1956)	Anderson & Krathwohl (2001)	Marzano & Kendall (2006)	PISA (2000)
Evaluation	Create	Self-System Thinking	Communicate
Synthesis	Evaluate	Metacognition	Construct
Analysis	Analyze	Knowledge Utilization	Evaluate
Application	Apply	Analysis	Integrate
Comprehension	Understand	Comprehension	Manage
Knowledge	Remember	Retrieval	Access

Figure 15: Different goals of education, from (Fadel et al., 2015, p.76)

Bloom's Taxonomy of Educational Objectives is the most famous description, but multiple other characterisations have been made. Figure 15 shows a comparison of some selected taxonomies showing progression from lower levels of knowledge access (knowledge, remember, retrieval, access etc.) to a more progressive level of use and understanding (analysis, synthesis, evaluation etc.). (Fadel et al., 2015)

Turkawka highlights that, education is only one part of the school's tasks. School takes care of the children so that the parents can work. Children learn to socialise, how to deal with other people, how to behave in unusual situations and how to solve problems in groups. (Turkawka, 2019, 52:55) School also serves as a compensation, insofar as things that are not taught at home are made up at school (Bucher & Zemp, 2019, 34:00).

Education systems (K-12) provide in addition to the important *integration function* (EDK, 2017), also four common education services. Fadel et al. (2015) identify similar services like Turkawka that provide benefits and value the society:

- **Child Care**: Education aggregates the task of taking care of multiple children from various families. This saves resources, because not every family needs to provide daily child care.
- **Socialisation**: Students learn basic social skills through interactions with others and ultimately leads to more complex socio-emotional skills and character qualities.
- **Accreditation and Evaluation**: A successful completion of a certain degree signalises an adequate level of core knowledge to others. It indicates a standardisation of similar learning experiences and assures a minimal level of quality.
- **Education Goals, Standards, and Curricula**: A foundational understanding of relevant subjects and essential skills is key to get by in today's world. Common knowledge, skills, and other competencies binds societies together.

"Während eine Gruppe von nur 100 Top-Leuten ein neues informationstechnisches System planen und in Jahresfrist in Produktionsreife umsetzen kann, bedarf es tausendfacher Diskussion und jahrelanger Abstimmungen, bis eine einzige neue Organisationsform für den Bildungsbereich realisiert wird."

Klaus Haefner

3.2 Actually Taught Skills and Competences

The actual transition the the *Lehrplan 21* is mostly completed on primary school level. The new curriculum aims for harmonisation and places a stronger focus on linking and applying knowledge, as well as on capabilities and skills. Furthermore, STEM subjects become more important, more specifically general science and social studieds (NMG, Natur, Mensch, Gesellschaft). (Marogg, 2019, 16:40)

Complete standardisation and strict structuring make no sense, not least because of the four national languages in Switzerland. However, cantons within a language border want to ensure a certain harmony among themselves. (D-EDK, 2017) The main goal was not to reform school, but to harmonise compulsory education, which has multiple advantages. (BKZ, n.d.-b; D-EDK, n.d.)

Table 2: Compulsory lessons summarised over six years of the 21 German cantons in the school year 2017/2018. (D-EDK, 2018)

Subject	Average Weekly Lessons	Minimum Weekly Lessons	Maximum Weekly Lessons	Reference Value
German (Deutsch)	33 (20%)	30 (AG, UR)	48 (VS)	32 (19%)
First Foreign Language (Erste Fremdsprache)	10 (6%)	8 (SZ, AI)	11 (SG)	10 (6%)
Second Foreign Language (Zweite Fremdsprache)	5 (3%)	0 (AI)	6 (8 cantons)	French: 6 (4%) English: 4 (2%)
Mathematics (Mathematik)	31 (19%)	28 (29)	36 (VS, SZ, AI)	30 (18%)
General Science and Social Studies (Natur, Mensch, Gesellschaft, NMG)	31 (19%)	24 (VS)	36 (BE, BL, BS)	35 (21%)
Artistic, Textile and Technical Design (Bildn., Textiles und Techn. Gestalten)	26 (16%)	23 (SG)	29 (TG)	24 (14%)
Music (Musik)	11 (7%)	6 (ZG, AI)	14 (SH)	12 (7%)
Exercise and Sports (Bewegung und Sport)	18 (11%)	18 (19 cantons)	20 (FR, SG)	18 (11%)
Media and Informatics (Medien und Informatik, MI)	2 (1%)	0 (6 cantons)	4 (SO, AI)	2 (1%)
Total	167 (100%)	161 (GR)	178 (VS)	161-173 (average: 168)

In the following analysis, a deeper look is taken at the class schedule. In Table 2 all the taught subjects are listed. Each lesson has 45 minutes and is summarised over six years of primary school where the

average, minimum, maximum and the reference value are disclosed. A less detailed overview can be found in Figure 14 and a more detailed table can be found in the appendix of D-EDK (2018).

The expert report *Fachbericht Stundentafel* elaborated by D-EDK (2014) suggests a range of 161 to 173 lessons per week accumulated over six years. There are already various indications of harmonisation, e.g. 20 out of 21 cantons (GR having a minimum of 161, and VS having a maximum of 178)) lie within this range compared to ten in 2012 (min: 155, max: 187).

What immediately catches the eye are the many lessons of German in the canton of Valais. It should be noted here that this is the only canton that is explicitly mentioning writing as an incorporated subject. The greatest differences between the cantons are in the subjects NMG and arts. This has to do with the fact that in these fields the traditions of the previous timetables also showed the greatest differences. (D-EDK, 2018)

Referrals in Table 2 are below the average values for German, maths and art. these lessons ought to be reduced according to the new curriculum. Music lessons would have to be slightly increased. NMG would have to be increased significantly (4 lessons), which reflects the importance of STEM skills. It is striking that the canton of Appenzell Inner-Rhodes (AI) does not teach a second foreign language in primary school.

In the module *Media and Informatics*, two cantons are well above the benchmark (4 instead of 2 weekly lessons). The other cantons do not assign any lessons to this module up to 4th grade, but prescribe the integration into other subject areas (namely German, mathematics and / or NMG). In the 5th and 6th grade, 14 cantons have their own MI lessons in the timetable. The other cantons also prescribe integration into other subject areas in these classes. (D-EDK, 2018)

A focus on certain subjects can be observed. Overall, an average of 20% of the time is used for German, 19% for mathematics respectively general science and social studies and 16% for artistic, textile and technical design. (D-EDK, 2018)

In total, first class students have on average 24.6 lessons per week (min: 23, max: 27) with growing timetables to an average of 29.9 in sixth class (min: 27, max: 31). The difference between the canton with the highest and lowest number of lessons has also been significantly reduced. (D-EDK, 2018)

Competencies

With the Lehrplan 21 the basic competences stay almost the same but they are described in a competence-oriented way. Turkawka (2019, 9:50) explains, the competences were made explicit, but they had already been there before. It has always been about the application and not just the knowledge. And as Turkawka explains, in the application of knowledge there is the competence.

A learning objective, written in the form of competences in the subject German for the area of competence "4 - Writing" would be "Pupils can hear individual sounds, assign them to the appropriate letters and type individual words faithfully", for more information about competence areas and the corresponding aspects of action see the Tables 5 - 15 in the appendix, you can find an excerpt at Loacker (2015) or see the full list at D-EDK (2016d).

Critique

The new **curriculum** has been criticised because the focus is set on the acquisition of competences which leads to education content becoming arbitrary (Schoenenberger, 2013). This new orientation of the Lehrplan 21 is criticised because competences do not measure what students know, but what they should be able to do. However, the Lehrplan 21 only defines in a few areas what education content teachers should teach students. Most important is the development of measurable skills, which can usually be acquired from content that can be exchanged randomly. (Loacker, 2015)

Furthermore some critics state that initially, the participating education researchers failed to explain

the advantages of the competence model over conventional teaching to the teaching staff. The critics felt excluded from the debate on this basis orientation of the curriculum. (Schoenenberger, 2013) The D-EDK contradicts the criticism expressed by the *Sonntags Zeitung* that the harmonisation of the education system is stagnating and that the confusion in the compulsory school system has increased since the vote on the education articles (Moser, 2015). Bucher and Zemp also disagree. They claim that it is precisely this involvement from so many parties – which took some time – has contributed to the success of the curriculum. (Bucher & Zemp, 2019, 29:40)

The idea of the Lehrplan 21 was supposed to make school easier, states Loacker (2015) but the result was a "bureaucratic monster": The first version had 557 pages, the second one still 470. Experts were working behind closed doors for almost eight years but no one talks about the total costs . (Loacker, 2015) Bucher (2019, 27:50) counters, that the length and costs of the curriculum is within the range of other curricula.

Loacker (2015) criticises for teachers it might be difficult to supervise the current status of the competencies of each of his pupils. The new curriculum comprises 363 competences, divided into 2304 competence levels; the first version had even 829 more. Müller (2019) agrees, but replies that it was difficult before.

Marogg criticises the fact that in primary school no emphasis is placed on the assessment of creative subjects by pupils. He regrets that math and German, and sometimes English, are the most important specialist skills and that too much value is placed on them. (Marogg, 2019, 6:15) In general, one risk might be that in the future, teachers will focus primarily on the examinations ("teaching to the test"), which does not lead to very sustainable learning. This focus on the assessable is also critisised by Loacker (2015).

Marogg thinks school should be more adaptive and should be able to react faster. The same is true for the Lehrplan 21, which was approved in 2014, and actually you would have to work on a new version again. Marogg explains that the first iPad was launched in 2010, during this time the Lehrplan 21 was developed - and quite sure at that time nobody would have thought that it is possible to teach with this tool. This makes it more important to stay up-to-date, be flexible as a teacher and use technology for its benefits. (Marogg, 2019, 26:20) Zemp then asks how strongly new methods and tools influence the competences that students must have. In his opinion, most competences do not change with technological development and therefore the curriculum does not need to be revised. The development simply gives more freedom and possibilities to the involved parties. (Bucher & Zemp, 2019, 25:30) Bucher adds that technological development will continue to occupy our society. Therefore, curriculum and the competences have to be separated from the tools, because the former doesn't change as quickly as the latter. What should be noted, is that the MI curriculum needs to be revised earlier than others. This is also documented in a report. (Bucher & Zemp, 2019, 26:20)

There is also critique regarding the **education system**:

Furger and Burri (2018) criticizs, that many schools concentrate too much on stuffing students with knowledge. This has been useful in the past when information was scarce. Today you are flooded with information and it is much more important to interpret and classify them correctly.

Turkawka criticises that in most schools pupils are trimmed to meet the teacher's expectations. Students know very well what they have to do to satisfy the teacher or not. They adapt their actions accordingly. Because of this, the teachers have a huge responsibility. (Turkawka, 2019, 1:40)

The focus is set too little on how to learn properly, meaning learning to learn accordingly. People learn differently and it is important to know how you learn the best (Turkawka, 2019, 2:25). Bucher & Zemp (2019, 16:00) contradict and say, that understanding of learning has been built into the curriculum, but

the responsibility to implement it accurately lies with the teachers. Learning in general has a higher priority in the new curriculum (Bucher & Zemp, 2019, 17:55).

Turkawka criticises that the competences are listed, but hardly explains how they are to be operationalised in class. Furthermore, there is no recommendation as to how these competences should ultimately be measured. (Turkawka, 2019, 10:20) He further criticises the fact that the current grading system is not aligned with competences. Because it is difficult to grade a competence and to make competences comparably makes little sense. For the competence concept to be fully effective, the evaluation system would have to be changed from the political level. (Turkawka, 2019, 11:15)

Conclusion

The Lehrplan 21 did not change a lot for pupils, but rather for teachers. (Kerf & Sted, 2014) For Müller it doesn't make a big difference in everyday school life. He assesses the curriculum as more modern but it can be confusing which student has already acquired which of the more than 2000 competences (Müller, 2019, 45:40).

The curriculum allows a more individual education for the students. There are no grade level goals but a time horizon is defined for the competences in each cycle. This allows students to have their individual pace in different subjects. (Bucher & Zemp, 2019, 17:15)

Scientific goals and contents (STEM) have been increasingly included in the subject NMG (1st and 2nd cycle), and is prominently represented in the 3rd cycle in *Nature and Technology*. Technology is also included in *Art, Craft and Design*. Computer science is part of the module *Media and Informatics*. (D-EDK, 2017) Marogg sees a problem in the given weighting of the subjects. In the 6th grade, students are mainly assessed in the subjects math, German and English before transferring to secondary school. He could imagine arts or NMG being given more weight. (Marogg, 2019, 15:30) A change in the schedule regarding NMG can be expected. The current average is 32 total weekly lessons, but the recommended value is 35 as seen in Table 2.

Finally, the following has changed in the curriculum: The curriculum is competence-oriented, allowing students to individualise through the definition of basic requirements and advanced competences based on competence levels per cycle, some subjects have been renamed, new modules have been introduced, the division into three cycles is new, the interdisciplinary competences are more clearly required in all subject areas and linked to the content and, of course, the harmonisation of all German-speaking Swiss cantons. (M. Bucher, 2015) This uniformity allows a closer cooperation in the field of the production of teaching materials. (Kerf & Sted, 2014)

Müller estimates that the Lehrplan 21 is in good condition and has been well made. Care was taken not to impart product knowledge but long-term competence knowledge. The Lehrplan demands a lot in the digital field, which is a good thing. (Müller, 2019, 56:30) In the *Future of Jobs Report 2018*, Switzerland is the best prepared country regarding average reskilling needs in days (World Economic Forum, 2018, p.22).

There are two points to highlight in the Swiss education system. It is permeability, which offers different possible ways, and the open access to the various education opportunities (EDK, 2017). Ultimately, teaching depends very much on which school, in which canton, with which teachers, with which infrastructure. But the pupils themselves also have an influence on what and how they teach. (Turkawka, 2019, 1:10) The cantons, schools and teachers have a major responsibility and must play their part in improving school education.

"We are currently preparing students for jobs that don't yet exist, using technologies that haven't been invented, in order to solve problems we don't even know are problems yet."

Richard Riley

3.3 Future Skills and Competences

Three reasons have been determined to improve peoples cognition and autonomy Rosa (2016). Firstly, more and more work is taken over by machines. Secondly, each new job demands more complex thinking, situated self-responsible decisions and relationship ability. And thirdly, the social problems to be solved are so complex that they can only be solved with collective intelligence.

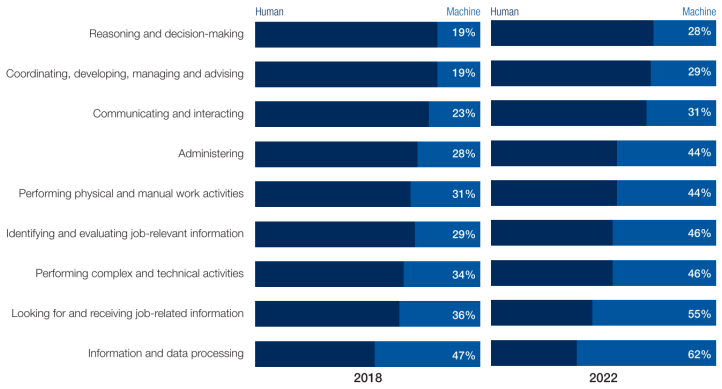

Figure 16: Ratio of human-machine working hours, 2018 vs. 2022 (projected), retrieved from World Economic Forum (2018, p.11)

Basic knowledge, that is taught in school like languages, mathematics, NMG, arts, music and physical education have proven their legitimacy over centuries as illustrated in Figure 9. But there are changes like the *Fourth Industrial Revolution*, that will lead to an increased part of machines executing work. For example, the majority of an organisation's information and data processing and information search is projected to be performed by automation technology, as seen in Figure 16. There are also other critical effects on the job market, which in return requests different new skills. Table 3 summarises the top ten trends to impact business growth positively respectively negatively.

Shifts in technology and in occupational structures are transforming at a faster pace than ever before. Lifelong learning, technology-related and non-cognitive soft skills become a prerequisite to be able to survive successfully in this world. (World Economic Forum, 2018, p.22)

It is important to emphasise that education is one of the biggest challenges in the 21st century. Fadel et al. (2015) clarifies the education system hasn't changed significantly in centuries, yet the knowledge, skills, and character needed now are fundamentally changing. He adds, schools realise this trend and education is becoming more about the *4 Cs* (communication, collaboration, critical thinking and creativity), technology and character qualities. (Fadel et al., 2015)

A lot of knowledge and assumptions have turned out to be wrong. Bailey (2012) explains, scientific data is doubling every 15 years and thus a lot of knowledge one knows are probably wrong.

As Klaus Haefner already postulated in 1982: If the computer automates activities, then schools must concentrate on teaching competences that cannot be automated. (Döbeli Honegger, 2016)

Table 3: Top ten trends set to impact business growth up to 2022, own table derived from World Economic Forum (2018, p.6)

Trends to positively impact business growth	Trends to negatively impact business growth
Increasing adoption of new technology	Increasing protectionism
Increasing availability of big data	Increase of cyber threats
Advances in mobile internet	Shifts in government policy
Advances in artificial intelligence	Effects of climate change
Advances in cloud technology	Increasingly ageing societies
Shifts in national economic growth	Shifts in legislation on talent migration
Expansion of affluence in developing economies	Shifts in national economic growth
Expansion of education	Shifts of mindset among the new generation
Advances in new energy supplies and technologies	Shifts in global macroeconomic growth
Expansion of the middle classes	Advances in artificial intelligence

3.3.1 Models

In this work multiple models of skills and competences are identified. This subsection highlights several models from different perspectives. They are divided in *economically motivated models* and *educationally motivated models*.

Firstly, economically motivated models are introduced. These models are categorised as economically motivated if they're either created by a business-oriented organisation or the described skills are very economically oriented.

Future-Skills-Framework

On the basis of statements made by HR managers as well as incorporating existing concepts, Stifterverband and McKinsey have developed the *Future Skills Framework* that defines competencies that are assumed to become significantly more important for professional life or social participation over the next five years. The model distinguishes between technological skills, basic digital skills and classical skills. (Kirchherr, Klier, Lehmann-Brauns, & Winde, 2018)

The O*NET Content Model

This database is sponsored by the U.S. Department of Labour and is the nation's primary source of occupational information (O*Net, 2019a). The framework identifies the most important types of information about labour market and integrates them into a theoretical and empirical system (O*Net, 2019b). Thereby it describes the different mixes of knowledge, skills, and abilities, of any occupation (O*Net, 2019a). The model distinguishes between multiple descriptors, which are organised into six major domains; worker characteristics, worker requirements, experience requirements, occupational requirements, workforce characteristics, and occupation-specific information.

Baseline vs. Technical Skills

Burning Glass Technologies (2015) have analysed the American job market and define two types of skills: Baseline (or foundational) and technical skills. The former are defined as general, non-specialised skills. These skills are requested in job ads across almost every industry and occupation, regardless of its actual requirements. They include communication, problem solving, detail-orientation, and creativity, but also things like basic computer literacy or knowledge of specific software packages like Microsoft Word and Excel that increasingly represent a minimum qualification for even low-wage jobs. In job postings, on average, every third request is a baseline skill. (Burning Glass Technologies, 2015)

Technical skills can be taught and are specific to a particular occupation or industry. Explementary skills are the usage of specific software programs like Adobe Photoshop, SPSS or CAD. They can be self-taught or learned in a formal setting, but the demand for these skills is limited to specific industries or roles. (Burning Glass Technologies, 2015)

In the following educationally motivated models are introduced. These models are claimed educationally motivated if they're either created by a education-oriented organisation or the described skills are aligned with educational values.

Battelle for Kids: Partnership for 21st Century Learning (P21)

Battelle for Kids is a national not-for-profit organisation with its headquarter in Columbus, Ohio. Their collaboration with school sysems and communities has the goal to realise the power and promise of 21st century learning for every student. (Battelle for Kids (A), n.d.; Battelle for Kids (B), n.d.)

Framework for 21st Century Learning (P21)

This framework was developed using input from educators, education experts and business leaders. The outcome is a summary of elements that ensure 21st century readiness. (Battelle for Kids (A), n.d.)

Although the elements are illustrated distinctly in Figure 17 for descriptive purposes, the five components are fully interconnected (Battelle for Kids (B), n.d.):

Key Subjects and 21st Century Themes (green):

- **Key Subjects:** English, reading, or language arts; world languages; arts; mathematics; economics; science; geography; history; and government and civics
- **Interdisciplinary 21st Century Themes:** Global awareness; financial, economic, business and entrepreneurial literacy; civic literacy; health literacy; and environmental literacy

Learning & Innovation Skills (4Cs: orange):

- **Creativity & Innovation**: Think creatively; work creatively with others; and implement innovations
- **Critical Thinking & Problem Solving**: Reason effectively; and solve problems
- **Communication & Collaboration**: Communicate clearly

Information, Media, & Technology Skills (purple):

- **Information Literacy**: Access and evaluate information; and use and manage information
- **Media (& ICT) Literacy**: Analyse media; create media products; and apply technology effectively

Life & Career Skills (turquoise):

- **Flexibility & Adaptibility**: Adapt to change; and be flexible
- **Initiative & Self-Direction**: Manage goals and time; and work independently
- **Social & Cross-Cultural Skills**: Interact effectively with others; and work effectively in diverse teams
- **Productivity & Accountability**: Manage projects
- **Leadership & Responsibility**: Guide and lead others; be responsible to others; and 21st century learning environments

For more information see the *21st Century Skills Map* (Partnership for 21st Century Skills, 2011).

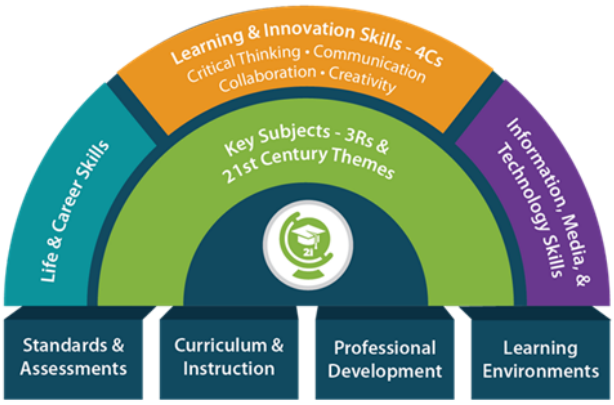

Figure 17: Framework for 21st Century Learning (retrieved from Battelle for Kids (A) (n.d.))

Technology-Pedagogy-Content Knowledge (TPACK) Framework

Mishra and Koehler identify three knowledge competencies which, when combined, enable a meaningful integration of ICT into teaching. This framework is called *Technological Pedagogical Content Knowledge* (TPACK or TPCK). (Döbeli Honegger, 2016)

Even before digitisation, teachers had to have the necessary *content knowledge* (CK) to communicate and to know how to teach (*pedagogical knowledge*, PK). The intersection of these two areas, *pedagogical content knowledge* (PCK), is the knowledge necessary to convey a certain subject area, i.e. the didactic knowledge of the subject. In this model, the *technological knowledge* (TK) was added to the considerations of Shulman's (1986) idea of *Pedagogical Content Knowledge*. Teachers therefore need technical, pedagogical and content training and further education which represents the center of the Venn diagram in Fig. 18. (Döbeli Honegger, 2016, p.113f; Koehler, 2012)

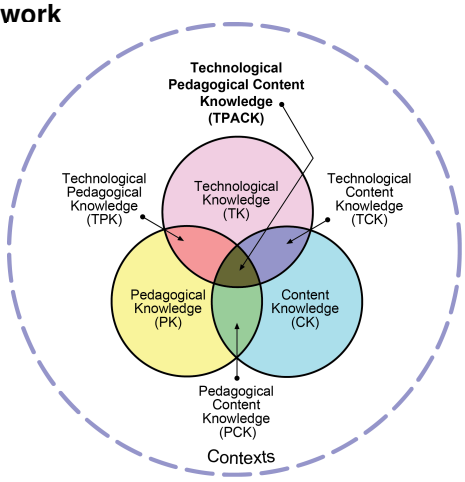

Figure 18: The TPACK framework, retrieved from Koehler (2012)

Four-Dimensional Education

This framework is described by Fadel et al. (2015, p.2) in the following way: "It provides a clear and actionable, first-of-its-kind organising framework of competencies needed for this century. Its main innovation lies in not presenting yet another one-size-fits-all list of what individuals should learn, but in crisply defining the spaces in which educators, curriculum planners, policymakers and learners can establish what should be learned, in their context and for their future."

The framework by the *Center for Curriculum Redesign* (CCR) defines twelve competencies with corresponding subcompetencies: There are four competences in the skills dimension (4Cs), six are linked to the character and two are associated with meta-learning. (CCR, 2019)

Compared to skills, character qualities define how a person engages and behaves in the world. This expression is recognised by all cultures, although it is sometimes charged with non-education connotations. In the present model the six important character qualities are: mindfulness, curiosity, courage, resilience, ethics, and leadership. (Fadel et al., 2015)

The knowledge dimension is divided into traditional, modern, and interdisciplinary knowledge and themes: *Traditional and modern knowledge disciplines* reflect the traditional subjects in school. *Modern interdisciplinary knowledge* deals with topics such as human lifespan extension; connected people, organisations, and planet; the rise of smart machines and systems; big data and new media; environmental stresses and demands; and amplified humans (Fadel et al., 2015). Relevant *themes* identified by CCR are, global literacy, information literacy, systems thinking, design thinking, environmental literacy, and digital literacy (Fadel et al., 2015, p.62).

Figure 19 represents the four dimensions and how they interact with each other. For example, each knowledge discipline needs to include the learning of skills, character qualities, and meta-learning strategies that are most aligned with it. (Fadel et al., 2015)

For a summary of the knowledge framework, see Figure 34 in the appendix.

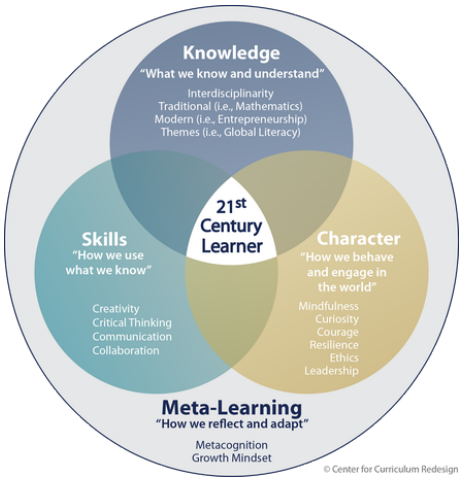

Figure 19: Four-Dimensional Education framework by the *Center for Curriculum Redesign*, retrieved from Fadel et al. (2015, p.43)

Summary

In this thesis, the economic models only serve as an overview and the pedagogical models are given more weight in the evaluation.

The following models were examined, but not further elaborated. The *Supporting Students Individual Advancement via Tech* (SSIAT) which includes the TPACK-Model and recommends useful applications for the classroom. (Rodemerk, 2016). The *UC San Diego Competencies* counts twelve competencies, most of them are incorporated in previous models (UC San Diego, n.d.). Fadel et al. (2015, p.42) made a comparison regarding commonalities between thirty-two frameworks around the world and confirmed general agreement on these four dimensions of the *Four-Dimensional Education Model*. Furthermore, a comparison between prominent skill frameworks was performed (Fadel et al., 2015, p.71).

Schöneberg (2018) states that the *4C model* became known through Andreas Schleicher, OECD Director of Education and responsible for the PISA studies. These *21st Century Skills* should be a suitable basis to prepare the students for future challenges in an increasingly automated (working) world (Schöneberg, 2018). The *4C model* was explicitly not introduced, because it is integrated into the (*Framework for 21st Century Learning* and in *Four-dimensional Education*). Nevertheless, everyone interviewed in the scope of this work mentioned the *4C model* (specificly: Marogg, 2019, 25:20; Turkawka, 2019, 14:05).

Knowledge is an important part of the learning process (see Figure 19). Only the process of the personal appropriation of information to knowledge turns the learning process into an education process. The knowledge of theories, works of art or languages allows people to look at the world differently. The *4C Model* lacks in areas like the development of one's own personality, empathy, solidarity and decision-making ability. 4C is also seen as a narrowed image of humanity because it comes from the OECD environment, where education is seen from an economic perspective. (Schöneberg, 2018)

The definition of the *4C model* is seen as too brief (Schöneberg, 2018) . Therefore the *Framework for 21st Century Learning* and the *Four-dimensional Education* are prefered because they are much more extensive and therefore better suited. The *TPACK-Framework* is especially interesting from the perspective of a teacher. It describes very precisely the very current situation regarding ICT in teaching.

"Just as it was impossible for us to predict that an Uber driver or a Didi driver would be a job 10 years ago, to predict what jobs exist in eight to 10 years is nearly impossible"

Kai-Fu Lee

3.3.2 New Jobs

The *Future of Jobs Report* (World Economic Forum, 2018) reveals a lot of changes in the workforce e.g. applied technology adoption; broader adoption rates in robotic technologies; changing geography of production, distribution and value chains; employment types; tasks executed by machines; possibility of an increased job supply; emerging demand for technology enhanced jobs; growing skill instability; necessary reskilling; and presumably insufficient reskilling and upskilling (World Economic Forum, 2018). It can be expected that the future of jobs develops with different characteristics across the world (World Economic Forum, 2018, p.17).

However, it is predicted, that within the next 15 to 25 years between 35 and 60 percent of jobs globally will be lost due to automation (Arntz, Gregory, & Zierahn, 2016; Liu, 2019). According to Fadel et al. (2015), there exist two key characteristics that determine which jobs will remain in the future. First, if *personal delivery* is required, offshore possibilities are limited. Second, if the task is *non-routine*, automation is limited. He further explains that some tasks are easier to automate than others. The simplest tasks are *rules-based* when deductive rules can be applied by a computer , e.g. the calculation of numbers. *Pattern recognition* allows a computer to use inductive rules, e.g. speech recognition. Most difficult to program is *human work* where rules cannot be articulated and/or necessary information cannot be obtained, e.g. moving furniture into a third floor apartment Fadel et al. (2015, p.16).

There are huge concerns about the rapid automation of jobs which even affects cognitive professions, and this trend does not seem to be weakening. (Osoba & Welser, 2017)

> "Automation is not a new phenomenon. Horses were replaced by cars, medieval scribes by the Gutenberg printing press, and launderers by washing machines, cashiers by checkout barcode scanners, credit card readers, mobile phone payment chips, and so on. And recently, retailer *H&M* has admitted to using mannequins' bodies "with no flaws" in place of human models." (Fadel et al., 2015)

Today, the biggest change is the pace at which has an impact on most aspects of human life (World Economic Forum, 2018, p.22). Digitalisation and automation have changed the job profiles considerably in recent years (Regierung des Fürstentum Liechtenstein, 2019). Routinised, impersonal tasks lose their legitimation and complex, personal, creative tasks that only humans can do well need to be promoted. A growing demand for programmers and other science and technology specialists as technology progresses is expected but also also a growing demand for people who excel at creative and interpersonal tasks (Fadel et al., 2015).

It is even predicted that advances in automation might result in the wholesale replacement of the human workforce, but the *Future of Jobs Report* shows a different picture. Currently, the work performed by humans is being complemented and augmented by machine and algorithmic labour. (World Economic Forum, 2018, p.10)

Not only jobs change, but also the underlying models. Technological progress in the *Fourth Industrial Revolution* will reduce the number of workers required to perform certain work tasks (World Economic Forum, 2018, p.10p). But the intuitive notion that this advancements would make jobs easier and create more leisure time turns out to be wrong (Fadel et al., 2015). People work as much, if not longer, and harder and produce more and more. It is expected that technology will also create new tasks and jobs (Fadel et al., 2015; World Economic Forum, 2018, p.10p).

> "Increased job creation in such project-based, temporary and freelancing roles, pointing to structural labour market transformations in terms of contractual arrangements and employment relations as well as occupational profiles." (World Economic Forum, 2018, p.8).

For companies, there are two crucial investment decisions, which will shape the future of jobs: the question of whether to prioritise automation or augmentation and the question of whether or not to invest in workforce reskilling. (World Economic Forum, 2018, p.9) Technology augments existing jobs and frees up workers from the majority of data processing, information search tasks, reasoning and decision-making (World Economic Forum, 2018, p.3).

The *Future of Jobs Report* identifies a set of new (and emerging) roles (World Economic Forum, 2018, p.8) and important emerging technologies (World Economic Forum, 2018, p.viii). Linkedin has made similar observations and the most important listed the 25 *hard skills* companies need most in 2019 (Petrone, 2019). World Economic Forum (2018, p.11) lists multiple tasks that have thus far remained overwhelmingly human. Mueller and Massaron (2018) count the following ten professions, grouped in three categories as *AI-Safe occupations*: The first group called *performing human interaction* includes teaching children, nursing, addressing personal needs and solving developmental issues. The next cluster is about *creating new things* and counts inventing, being artistic and imaging the unreal amog them. *Making intuitive decisions* is the last set and contains investigating crime, monitoring situations in real time and separating fact from fiction (Mueller & Massaron, 2018) But a lot of jobs in the future do not exist yet (Synched, 2018a).

3.3.3 Important Skills and Competences

Of course, key competences a pupil needs to learn are according the key subjects taught in school. The reference values in the time table distribution in primary schools of 30% languages, 21% NMG (STEM) and 18% mathematics (see Table 2) is seen as an appropriate prioritisation by the author. Different countries and fields have varying perceptions of key competences (IBE-UNESCO, n.d.). The European Union updated and categorised eight areas of key competencies that describe the timetable in detail. The competences are the following: Literacy, multilingual, mathematical competences and competence in science, technology and engineering, digital competence, personal, social and learning to learn competence, citizenship competence, entrepreneurship competence, and cultural awareness and expression competence European Commission (2019b).

> "Today it would be difficult to name two more powerful engines for lifelong learning than knowing how to read and write, and knowing how to harness the power of digital technology and navigate the internet." (UNESCO, 2019b, p.11)

With increasing automation, new skills are are considered valuable in the age of AI and are often not the focus of K-12 education (Synched, 2018a). It is complicated to define the skills wich are needed in future, because of multiple reasons. On one hand, there are an incredible number of skills. According to Petrone (2019), Linkedin counts at least 50'000 professional skills in the world. On the other hand, the future is practically unpredictable. Nevertheless, there is the general assumption that some skills are more relevant than others. Mankind needs to improve those skills, machines can't learn (Furger & Burri, 2018). Typical human competencies such as teamwork, social competence and creativity are gaining in importance (Döbeli Honegger, 2016). Properties that computers can do better than people, become obsolete.

> "For the majority of humanity's history, it was commonplace to hold entire books in one's mind, a skill that has become obsolete, and thus, no longer practiced." (Fadel et al., 2015)

Fadel et al. (2015) states education success is no longer mainly about content knowledge repdocution, but it is important to know how to apply it, how to behave, and how to adapt.

Müller complements that it is difficult to predict which professions the job market demands in 15 years' time. The change is very fast. At school, children are not trained for industry to become good workers, but they become responsible citizens. That is the education mission. In other words, they should not be able to know products, but competences. They must be competent to understand any new things. (Müller, 2019, 48:25)

The experts conducted, have mentioned the 4C as important competencies, as well as a number of authors (Battelle for Kids (A), n.d.; Fadel et al., 2015; Schöneberg, 2018). As Döbeli Honegger (2016) draws the conclusion that the 4Cs differentiate us from computers and therefore are the most important competences:

"Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand."

Albert Einstein

Creativity

Creativity and lateral thinking become more important in a digitalised world, because the computer has already solved a lot of problems and thus the solutions of tomorrow become more complex (Döbeli Honegger, 2016; Furger & Burri, 2018) Creativity teaches students to think outside the box. This means that you are able to think differently than convention demands — don't do thinks the way they've always been done, look at problems from multiple perspectives — including those that others may not see and figure out a new, better way. Furthermore, it is critical to be motivated to share that creativity with others, so other people become inspired to try something new, too. (Applied Educational Systems, n.d.)

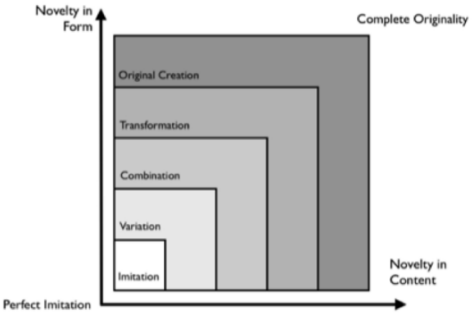

Figure 20: Levels of creativity, from Fadel et al. (2015, p.74)

> "Most of the things that are interesting, important, and human are the results of creativity... When we are involved in [creativity], we feel that we are living more fully than during the rest of life." (Fadel et al., 2015)

Creativity is an integral to a wide range of knowledge and skills, including scientific thinking, entrepreneurship, design thinking, and mathematics (Fadel et al., 2015). It was named the most important leadership quality to meet the challenges of increasing complexity and uncertainty in the world and further is an extremely fulfilling human activity (Fadel et al., 2015). *Creativity, originality and initiative* is listed as the third most emerging skill by 2022 according to World Economic Forum (2018, p.12). According to Linkedin data, creativity is the most wanted soft skill, companies were looking for in 2019 (Petrone, 2019). *Innovation & entrepreneurial thinking* has also been identified as an important competence by (Regierung des Fürstentum Liechtenstein, 2019; Synched, 2018a; UC San Diego, n.d.).

There are several ways to foster this competence in school e.g. by changing the perspective, the methods, or by "making the problem the solution" (Furger & Burri, 2018). Another possibility is to playfully teach, because to play in general is uniquely suited to enhance creative thinking (Fadel et al., 2015).

> "Broadly speaking, teaching for creativity is complementary with teaching for content knowledge. Open-ended, problem-based learning is more likely to encourage students to think creatively than paper and pencil exercises in which there is only one right answer." (Fadel et al., 2015)

> "Education must enable one to sift and weigh evidence, to discern the true from the false, the real from the unreal, and the facts from the fiction. The function of education, therefore, is to teach one to think intensively and to think critically."
>
> *Martin Luther King, Jr.*

Critical Thinking

In 1962, Ennis who is one of the greatest exponents of *critical thinking*, defined it in his first version as "the correct assessing of statements", but later defined critical thinking as "reasonable and reflective thinking focused on deciding what to believe or do". Critical thinking dispositions and abilities can be found in the appendix of Ennis (2011). A more extensive explanation from *The National Council for Excellence in Critical Thinking* (1987) defines critical thinking as the "intellectually disciplined process of actively and skillfully conceptualising, applying, analyzing, synthesising, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action." (Foundation for Critical Thinking, n.d., para.3)

Critical thinking is all about ploblem solving and also includes skepticism which becomes more important because it is harder than ever to verify accurate information. It allows to question claims, seek the truth, and learn how to discover the facts and figures for oneself. (Applied Educational Systems, n.d.) Teaching critical thinking can come in many different forms as Fadel et al. (2015, p.77) enumerates.

Critical thinking is not a new topic in education, since it it can be traced back to Socrates, who encouraged his students to think critical (Fadel et al., 2015). As Turkawka complements, it has always been important, but is today needed more diversely. There is much more information available which increases the possibility of getting influenced by fake news or propaganda enormously. (Turkawka, 2019, 20:45)

The importance is confirmed by different sides, as *critical thinking and analysis* is listed as the fifth and *complex problem-solving* is listed as the sixth most emerging skill by 2022 according to World Economic Forum (2018, p.12). Other models have identified this skill as an important process skill (O*Net, 2019b). UC San Diego (n.d.) combines *critical thinking and problem solving* to one of the key competences needed in the twenty-first century.

Media literacy has also been added to this competence. A media literate person is able to decode, evaluate, analyse, and produce print and electronic media. Critical autonomy in relationship to all media is the fundamental objective of media literacy. (Aufderheide, 1997) The CRR framework also defines *information literacy* as one key theme in the knowledge dimension (Fadel et al., 2015).

Especially the handling of social networks and one's own digital profiles are topics that have to be dealt with. Turkawka thinks it is important that you either maintain your profile or don't use it at all. Everything in between is dangerous because you give up control over your data. It can become a problem that this data is never deleted. (Turkawka, 2019, 21:55) Deep learning algorithms in combination with fake news, called *deepfakes* make this even more complex. (Turkawka, 2019, 21:00) Döbeli Honegger (2016) concludes, "collecting information" used to be – today, "filtering information" must be applied.

> "The most important thing in communication is hearing what isn't being said. The art of reading between the lines is a life long quest of the wise."
>
> *Shannon L. Alder*

Communication

This skill is needed in virtually all professions in various forms on a regular basis and is taught from preschool to medical school (Fadel et al., 2015). *Communication* lets students learn how to best convey their ideas which is especially important when communicating with different layers of communication or missing layers of communication (e.g. text-based communications lack tone). Also, it is important to be able to read an audience (Applied Educational Systems, n.d.). Here, rather a basic understanding of interaction, including oral, written and digital communication is meant, instead of a foreign language (Müller, 2019, 50:00).

Criticism and dialogue skills have been identified as an important key competence by mutliple authors (Battelle for Kids (A), n.d.; Regierung des Fürstentum Liechtenstein, 2019, p.16). It has also been identified as an important competence by UC San Diego (n.d.) and Turkawka (2019, 14:20). According to Burning Glass Technologies (2015), it is the skill that is sought most in most industries. According to Linkedin data, *persuasion* is the second most wanted soft skill, companies were looking for in 2019. The range of products on offer is enormous and therefore persuasiveness is becoming increasingly important. (Petrone, 2019)

According to Fadel et al. (2015) the best two methods to improve communication are peer tutoring and collaboration. Peer tutoring promts students to tutor their classmates or younger students, which builds authentic communication skills. Collaboration can also improve communication skills, because it is an important way to learn, measure, and get relevant feedback. Collaboration requires two-way communication which brings us to the next key competence (Fadel et al., 2015).

> "Collaboration sometimes causes conflict, and sometimes it's easy, but the bringing together of great minds only adds."
>
> *Cary Fukunaga*

Collaboration

The joining together of various individuals in service of working toward a common goal is called *collaboration* (Fadel et al., 2015). This is a crucial competence because we will be interacting with other people for the rest of our lives for the reason that groups can create something bigger and better than individuals. Collaboration leads to better outcomes, because it allows for the consideration of multiple viewpoints – but if executed badly , can lead to even worse resluts (Fadel et al., 2015). Collaborating helps to understand how to address a problem, pitch solutions, and decide an appropriate course of action. It teaches (how) to speak up in groups with people of diverse cultural origins, which appreciate different ideas, perspectives, and values. (Applied Educational Systems, n.d.) When solving multifaced problems, it is important to involve collaboration among people with different skills, backgrounds, and perspectives, to get the best result (C. Miller & Ahmad, 2000).

According to Linkedin data, *Collaboration* is the third most wanted soft skill, companies were looking for in 2019. It's importance grows, because projects grow increasingly more complex and global in the age of AI. (Petrone, 2019) It has also been identified as an important competence by (Battelle for Kids (A), n.d.; Regierung des Fürstentum Liechtenstein, 2019; Synched, 2018a; UC San Diego, n.d.).

Turkawka adds, this skill needs to be learned by both pupils and teachers. Lessons are more collaborative as before: Classrooms are more open, there are team discussions, class camps are organ-

ised together, etc. This also applies to the private sector, science and almost all cognitive-creative jobs. (Turkawka, 2019, 17:45)

Fadel et al. (2015) list several tactics that have been proven effective to promote collaboration skills in the classroom. Among them he counts establishing group agreements and accountability, practicing and demonstrating the skills of negotiation, and teaching listening skills and the art of asking good questions (Fadel et al., 2015).

To really succeed, students need to use all four of these skills together and in combination with knowledge:

> "These skills [4C] are inseparably connected to content knowledge, as it is implausible to teach skills independent of a content knowledge base — e.g., it is impossible to think critically about nothing." (Fadel et al., 2015)

"I am uneasy to think I... decide concerning truth and falsehood, reason and folly, without knowing upon what principles I proceed."

David Hume

Computational Thinking

Processing information using higher-order or critical thinking is called *computational thinking* and sometimes seen as the fifth "C" in the 4C model (Grover, 2018). It is a prerequisite for a lot of fields to "think logically and algorithmically, and use computational tools for creating artifacts including models and data visualisations". (Grover, 2018; Noonoo, 2019) The framework always looks the same: First, one looks at the provided information, then narrows it down to the most valuable data, and finally find patterns and identify themes. (Noonoo, 2019) UC San Diego (n.d.) has identified *research ability* as an important competence. *Reasoning, problem-solving and ideation* is listed as the ninth most emerging skill by 2022 according to World Economic Forum (2018, p.12).

It is a omnipresent topic, because everywhere is data and technology. Data literacy also includes the ability to analyse data and statistics, and basic knowledge of coding and programming. Students should understand intelligent machines, the digitalisation in general and it's impact on culture, jobs etc.

"Computing is not about computers any more. It is about living."

Nicholas Negroponte

Digital Literacy

Digital skills are relevant to almost all digital and traditional industries and it is hard to find appropriate personnel (Cruz, Funes, Aguirre, Deeg, & Hoefnagels, 2018). UNESCO defines *digital literacy* broadly as "the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital devices and networked technologies for participation in economic and social life". (UNESCO, 2019b, p.13)

To increase the digital literacy, these technologies should be integrated into the school environment, which by now is a "obsolete, technology-hostile place". (Furger & Burri, 2018)

In the UK, students perceive that they don't get the digital learning they need and therefore asked the government to add digital literacy to the curriculum (Rogers, 2019). It is assumed, that the demand for digital skills will increase dramatically over the next three to five years (Rogers, 2019). A considerable share of insufficient digital skills have also been observed in the EU (Cruz et al., 2018).

When digital natives use ICT, Müller says they have a what he calls "wipe competence" (they know how to wipe on a tablet), but digital literacy is much more, e.g. how the technology works, how to behave in the Internet etc. (Müller, 2019, 53:40) .

Digital skills and competencies have moved from optional to essential and open pathways to further learning and skills development (UNESCO, 2019b). The importance is reflected in the fact that even the UN mentions digital skills explicitely in their fourth indicator of the SDGs (UNESCO Institute for Statistics, 2018). *Technology design and programming* is listed as the fourth most emerging skill by 2022 according to World Economic Forum (2018, p.12). Other models have identified this skill as important as well, e.g. Furger and Burri (2018); O*Net (2019b) or the TPACK model (page 40). The *Future-Skills-Framework* predicts that digital skills will have increased importance within the next five years, see page 38. According to their report, around 700,000 additional tech specialists will be needed by 2023. (Kirchherr et al., 2018). *Analytical thinking and innovation* is listed as the most and *systems analysis and evaluation* as the tenth most emerging skill by 2022 according to World Economic Forum (2018, p.12). UC San Diego (n.d.) identified *digital information fluency* as an important competence, and the European Union defined *digital competence* as one of the eight key competences (European Commission, 2019b). *Technological literacy* is identified as a key competence by Synched (2018a). Fadel et al. (2015) defines digital literacy as a key theme in the knowledge dimension.

Networked thinking

This key competence means to think independently, think critically, create awareness of global developments and contexts. Further aspects are political thinking, the ability to draw a distinction between opinions and facts, and social and societal responsibilfity - all in a holistic view. It is important to think beyond borders, outside the box, not only to know facts but have the ability to check, weight and classify them. One expert says "disputes over content are the best antidote to radicalisation on the Internet" while another suggests that global awareness is best learned outside the classroom. (Furger & Burri, 2018)

Understanding global context has also been identified as an important competence by (UC San Diego, n.d.). Fadel et al. (2015) describe *global literacy* and *systems thinking* as important themes in the knowledge dimension, where the latter has also been identified by other authors (Döbeli Honegger, 2016; Synched, 2018a).

Self-mindfulness

The ability to cope with crises, dealing with pressure and stress as well as resilience. This competence includes self-reflection, -respect, -confidence, and -discipline and has been identified as an important competence by multiple authors (Furger & Burri, 2018; UC San Diego, n.d.). These skills are required in a future which changes rapidly, people need to organise themselves and need to know what is good for them. One possible method to improve self-mindfulness is to write a diary or to learn self-organised. (Furger & Burri, 2018)

Mindfulness is one of the six character qualities defined in the *four-dimensional education model* where the individual qualities are listed by Fadel et al. (2015, p.85)[1].

Turkawka mentions several times how important it is to know oneself, e.g. knowing how to learn the best, where and how one wants to position oneself in order to ideally promote oneself. (Turkawka, 2019, 3:10, 14:20)

[1] It includes qualities such as self-awareness, self-actualisation, observation, reflection, consciousness, compassion, gratitude, empathy, growth, vision, insight, equanimity, happiness, presence, authenticity, listening, sharing, interconnectedness, interdependence, oneness, acceptance, beauty, sensibility, patience, tranquility, balance, spirituality, existentiality, social awareness, cross-cultural awareness, etc. (Fadel et al., 2015, p.85)

Resilience

Today's society and requirements change as fast as it ever has changed. Therefore, an adaptable mind is an essential tool for navigating today's world, as yesterday's solutions won't solve tomorrow's problems. (Petrone, 2019) It is important to be versatile to survive in this chaning world (Fadel et al., 2015).

Müller (2019, 52:35) identifies this as an important skill and *resilience*[2] is one of the six character qualities defined in the *Four-Dimensional Education Model* (Fadel et al., 2015).

Flexibility was identified as one key competence by Regierung des Fürstentum Liechtenstein (2019); Synched (2018a, p.16) and Müller (2019, 52:25) emphasises the importance of resilience. According to Linkedin data, *Adaptability* is the fourth most wanted soft skill, companies were looking for in 2019 (Petrone, 2019). *Career development*, meaning to transfer skillls into the job, has been identified as an important competence by (UC San Diego, n.d.).

> "The greatest glory in living lies not in never falling, but in rising every time we fall."
>
> *Nelson Mandela*

Environmental Literacy

This competence area deals with nature experience, animal welfare, consumption and the use of our resources. Experts argue it is the "counter program for digitalisation" and technology has made it unnecessary to memorise capitals and rivers. The freed capacity should be used for environmental and climate issues. Some methods to impart these contents, would be to go out "into the wild without electricity", manage a chicken farm or an apiary, have a garden, investigate different ecosystems, and go out on an excursion more frequently in school. (Furger & Burri, 2018) The CCR framework (Fadel et al., 2015) and an the interviewed experts (Bucher & Zemp, 2019) confirm the importance of environmental literacy.

> "I have no special talents.
> I am only passionately curious."
>
> *Albert Einstein*

Lifelong Learning

Lifelong learning has always been an important competence, but today it is more important than ever, as things change faster these days. Labour markets are constantly changing and workers need to change their skills as well. (Turkawka, 2019, 42:15) It is important to know about yourself how to learn best.

Active learning and learning strategies is listed as the second most emerging skill by 2022 according to World Economic Forum (2018, p.12). The need for lifelong learning strategies has been confirmed by other authors (Döbeli Honegger, 2016; do Nascimento & Valdés-Cotera, 2018; European Commission, 2019b). The O*Net Model identigies active learning and learning strategies as important process skills (O*Net, 2019b). The author has included *curiosity* to this skill which is one of the six character qualities defined in the *Four-Dimensional Education Model* (Fadel et al., 2015)[3].

Courage

Courage is seen as the ability to act despite fear or uncertainty (Fadel et al., 2015). It is important not to be intimidated in a world full of VUCA.

[2] It includes qualities such as and includes perseverance, grit, tenacity, resourcefulness, spunk, self-discipline, effort, diligence, commitment, self-control, self-esteem, confidence, stability, adaptability, dealing with ambiguity, flexibility, feedback, etc. (Fadel et al., 2015, p.85)

[3] It includes qualities such as open-mindedness, exploration, passion, self-direction, motivation, initiative, innovation, enthusiasm, wonder, appreciation, spontaneity, etc. (Fadel et al., 2015, p.85)

This is one of the six character qualities defined in the *Four-Dimensional Education Model* (Fadel et al., 2015)[4].

Ethics

This is one of the six character qualities defined in the *Four-Dimensional Education Model* (Fadel et al., 2015)[5]. *Civic engagement, social responsibility, professionalism and integrity* have been identified as important competences by UC San Diego (n.d.).

Leadership

This is one of the six character qualities defined in the *Four-Dimensional Education Model* (Fadel et al., 2015)[6] and has also been identified as an important competence by other authors (Battelle for Kids (A), n.d.; UC San Diego, n.d.). *Leadership and social influence* is listed as the seventh most emerging skill by 2022 according to World Economic Forum (2018, p.12).

Conclusion

To conclude the subsection, these are the most important skills and competences are not included sufficiently in the curriculum. These skills distinguish us from computers and cannot be automated. The list highlights a selection of skills roughly sorted by importance, starting with the most important 4Cs. Table 4 summarises the skills demand for 2018 and makes a prediction for 2022.

Table 4: Comparing top ten skills demand, 2018 vs. 2022, from World Economic Forum (2018, p.12)

2018	**Trending, 2022**	**Declining Skills by 2022**
Analytical thinking and innovation	Analytical thinking and innovation	Manual dexterity, endurance and precision
Complex problem-solving	Active learning and learning strategies	Memory, verbal, auditory and spatial abilities
Critical thinking and analysis	Creativity, originality and initiative	Management of financial, material resources
Active learning and learning strategies	Technology design and programming	Technology installation and maintenance
Creativity, originality and initiative	Critical thinking and analysis	Reading, writing, math and active listening
Attention to detail, trustworthiness	Complex problem-solving	Management of personnel
Emotional intelligence	Leadership and social influence	Quality control and safety awareness
Reasoning, problem-solving and ideation	Emotional intelligence	Coordination and time management
Leadership and social influence	Reasoning, problem-solving and ideation	Visual, auditory and speech abilities
Coordination and time management	Systems analysis and evaluation	Technology use, monitoring and control

[4] It includes qualities such as bravery, determination, fortitude, confidence, risk taking, persistence, toughness, zest, optimism, inspiration, energy, vigor, zeal, cheerfulness, humour, etc. (Fadel et al., 2015, p.85)

[5] It includes qualities such as benevolence, humaneness, integrity, respect, justice, equity, fairness, compassion, kindness, altruism, inclusiveness, tolerance, acceptance, loyalty, honesty, truthfulness, authenticity, genuineness, trustworthiness, decency, consideration, forgiveness, virtue, love, care, helpfulness, generosity, charity, devotion, belonging, etc. (Fadel et al., 2015, p.85)

[6] It includes qualities such as responsibility, abnegation, accountability, dependability, reliability, conscientiousness, selflessness, humbleness, modesty, self-reflection, inspiration, organisation, delegation, mentorship, commitment, heroism, charisma, followership, engagement, leading by example, goal-orientation, focus, results orientation, precision, execution, efficiency, negotiation, consistency, socialisation, diversity, decorum, etc. (Fadel et al., 2015, p.85)

> "One of the biggest flaws in the common conception of the future is that the future is something that happens to us, not something we create."
>
> *Michael Anissimov*

3.4 Technology Affected Areas

From the beginning of the research on the application of AI, there is an overwhelming prediction that the development and application of AI-based technology in education will make a profound change in education systems. However, today, this huge change is still very hard to see. (Khan, 2019)

Emerging technologies (World Economic Forum, 2018, p.7), transformational key drivers (World Economic Forum, 2018, p.VII), job disruptions (Kharpal, 2017), and further trends (Table 3) impact the job market enormously. New technologies lead to new skills demanded on the job market and thus the education system must adapt accordingly.

It is important to close this gap as it will lead to a further increase in the skills shortage and would have significant implications for employers (Cruz et al., 2018). This gap must be diminished by companies on the job market through re- and upskilling, but also through governments that create an adequate educational environment and teach appropriate skills and competences (World Economic Forum, 2018, p.V). The World Economic Forum (2018, p.IX) lists multiple current strategies for addressing skill gaps. Turkawka stresses that change initiatives should work very closely with educational institutions (Turkawka, 2019, 51:15).

As elaborated in the previous chapter, there is a small gap regarding digital and soft skills. Industries also complain about skill gaps in various areas (Burning Glass Technologies, 2015; World Economic Forum, 2018, p.6). In the last few centuries, however, there have always been drastic gaps on the job market (e.g. due to the invention of book printing, computers etc.) as explained by Turkawka (2019, 38:40).

Switzerland is flexible, adaptive and has the necessary resources to close this gap. Furthermore its excellent infrastructure, good foreign policy relations, and strong economic situation makes Switzerland a well placed country to meet the challenges of the future. (Turkawka, 2019, 39:00)

Müller argues that it is not a question of age how good ICT skills are. He says teachers need a lot of further training. (Müller, 2019, 55:35) The most important factors are explained in the following model developed by Gerald Knezek et al. (2000). The *Will-Skill-Tool Model* postulated three factors to explain the degree of ICT integration in teaching. These are a *positive attitude* (will) of the teacher towards the use of computer technologies in the classroom, good *technological skills* (skill) and *sufficient access* to technology (tool). (Döbeli Honegger, 2016)

The next subsections show what aspects of school will be affected by technological progress and AI. Four areas have been identified that will be discussed below. The first area is the *curriculum* which can be influenced mainly by the political level. *Further education* is also in the hands of politics and individual schools. The last two areas, *tools used in education* and *methods to teach* can be chosen independently by the responsible teacher and differs enormously, as Marogg (2019, 8:45) says.

"Wir müssen unsere Kinder auf etwas vorbereiten, wir wissen aber noch nicht auf was."

Mathias Marogg

3.4.1 Curriculum

It is of crucial importance to adapt the learning content to the requirements of the labour market (Regierung des Fürstentum Liechtenstein, 2019). The most important thing is to continuously question, adapt and improve the curriculum. Fadel et al. (2015) enumerates two reasons why a curriculum should not be complete. Firstly, the knowledge base grows and changes and so should the curriculum. Secondly, an adaptable curriculum that can be tailored to each individual student's needs is crucial to students' motivation and positive learning outcomes.

The currently learned skills and competences are considered important, but small adjustments are well conceivable. There is a demand for faster adaptation of the curriculum (Fadel et al., 2015). Multiple authors emphasize the importance of updating the curriculum continuously (do Nascimento & Valdés-Cotera, 2018; World Economic Forum, 2018) and demand for new subjects (do Nascimento & Valdés-Cotera, 2018; Fadel et al., 2015, p.31,60). Although this leads to resistance on several levels, as Fadel et al. (2015, p.27) further elaborates.

> "If a curriculum is not adaptive, it becomes rigid. There is no such thing as a perfect curriculum that does not need updating, because the world continues to change and the goals of an optimal curriculum changes with it." (Fadel et al., 2015)

There are two possible effects that technological development and AI can have on the curriculum. On the one hand, technological development leads to increased demand for technological skills and competences in the job market, which should in turn be incorporated into the curriculum. Moreover, technology pervades all domains of life and AI must therefore be informed and educated to a good extent. On the other hand, technological progress and the resulting automation demand alternative, (rather) creative skills and competences.

Lehrplan 21 Area

In Switzerland, the new curriculum has introduced two new subjects (*Media and Informatics* and *vocational orientation*) and two new modules (*education for sustainable development*, BNE and *transversal competences*) (M. Bucher, 2015). At the same time, ICT projects are launched to expand the infrastructure of public schools and equip them with mobile devices (Schwendener, 2019).

Besides, care was taken to incorporate new competences such as the one identified in the *4C model* into the curriculum. On the one hand in the transversal competences and BNE but also in the individual subject areas. For example, collaborative learning was explicitly incorporated into languages or visual design. (Bucher & Zemp, 2019, 39:40) It is conceivable that new subjects will be included in the timetable in the future.

> "Föderalismus und Subsidiaritätsprinzip in deutschsprachigen Bildungssystemen verhindern einheitliche Initiativen, ermöglichen dafür mehr Experimente und erhöhen die Flexibilität." (Döbeli Honegger, 2016, p.119)

Döbeli Honegger (2016) criticises the Swiss education system for the fact that all initiatives are divided and watered down by numerous hierarchical levels. Thus, subordinate organisations wish for more autonomy and accuse superordinate ones of having no idea of school practice.

3.4.2 Further Education

This section investigates the teachers' curriculum, introduces ICT relevant trainings for Swiss teachers and international frameworks regarding ICT training.

It is not only a question of time and financial resources to organise such training and further education. It is also a challenge to organise them in a target-oriented way. For the general promotion of the actual use of the locally available ICT infrastructure, internal school training courses would be desirable, since the appropriate equipment is available. However, an extremely broad spectrum of prior knowledge and the level and subject specific needs of the teachers are assumed. (Döbeli Honegger, 2016)

Bucher (2019) explains the syllabus itself does not provide any guidelines for further training. This is in the cantons' responsibility. They specify how much and which further training has to be conducted. Thereby, an internal investigation of the BKZ reveals major differences. (Bucher & Zemp, 2019, 7:35) Marrogg adds, for teachers there is no specification on how many further training courses must be carried out per year. The standard describes a guideline of five to six courses per year. The head of the school is responsible for this. There are also one to three cross-school training courses where the whole teaching staff has to participate. (Marogg, 2019, 35:10) Turkawka stresses the importance of constantly updated professional skills in this fast moving environment regarding methods and technology. (Turkawka, 2019, 7:05)

The harmonisation of further training and the introduction of a central body were discussed, but rejected by the cantons. This sovereignty of the cantons is due to the federal system of Switzerland and has both advantages and disadvantages. Subsequent harmonisation is much more difficult but would be desirable, especially for teachers. (Bucher & Zemp, 2019, 8:35) Further education is offered by the different Universities of teacher education, e.g. SCHILF or SCHILW (Pädagogische Hochschule Zürich, n.d.-b).

ICT Relevant Education

The advantages of tools will be discussed in the next section but it is of enormous importance that the teachers get further training in technology usage, as Turkawka says (2019, 1:15:05). Bucher adds: "Teachers must be trained. They need to know what tools are available, how to use them optimally and which competences and skills are being promoted." (Bucher & Zemp, 2019, 38:35) As explained in the *TPACK model* (see page 40), it is important for teachers to have expertise in multiple fields and one of those is the *technological knowledge* (TK).

This can be managed by offering courses or contact points. In Zurich they are called *pedagogical ICT support* (PICTS) (Pädagogische Hochschule Zürich, n.d.-a) and in Liechtenstein these contact persons are called *pedagogical media consultant*< (MIB, Medien und Informatik Berater) (Turkawka, 2019, 28:00). Winterthur-based schools have a *Beauftragte(r) Schule und Computer* (BSC), which is responsible for assisting teachers at schools with questions about the use of computers and communication tools in class. They are the first point of contact for teachers with questions. (Stadt Winterthur, n.d.) Moreover, a similar division named *SCHU::COM* has been founded in 2005 (Müller, 2019, 0:35). This illustrates the significance to provide adequate support.

> "As technology progresses, the education necessary to utilise it effectively also grows, and education must adapt to keep up. In this way, technology and education are in a race." (Fadel et al., 2015, p.18)

It is important to also educate the schools management in order to have a strategic farsightedness. Therefore, how to provide teachers with advanced technological and pedagogical knowledge (see the

TPACK model on page 40) is a crucial task. (Turkawka, 2019, 27:35) The *CAS Digital Leadership in Education* offered by PHZH by January 2020, should close this gap on school management level. (Turkawka, 2019, 31:45) Turkawka would endorse the creation of a *Digital Transformation Manager* position in the school management. This person would be responsible for new, fast and frequently changing digital technology usage. (Turkawka, 2019, 30:25)

ICT Competency Framework for Teachers (ICT CFT)

This reference work under open licence is designed to help teachers with guidance and suggestions on how to successfully integrate ICT into the learning environment. It is "a response to recent technological and pedagogical developments in the field of ICT and Education, and incorporates in its structure inclusive principles of non-discrimination, open and equitable information accessibility and gender equality in the delivery of education supported by technology" (UNESCO, 2018, p.1). It addresses the impacts of recent technological advances on education and learning, such as AI, IoT, OER and mobile technologies to support the creation of inclusive knowledge societies. (UNESCO, 2018)

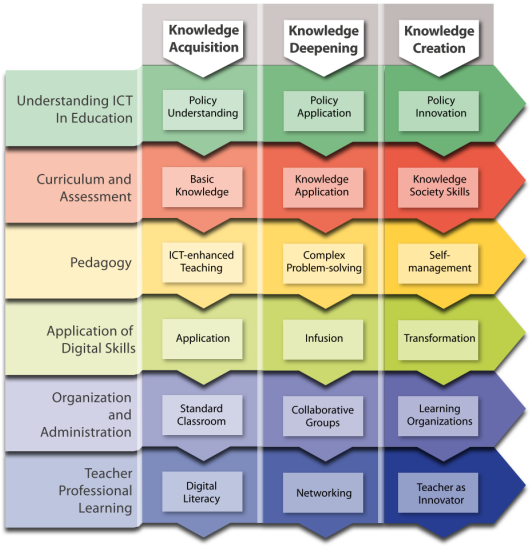

Figure 21: The UNESCO ICT competency framework for teachers (from UNESCO (2018))

As illustrated in the figure on the right, the framework "consists of 18 competencies organised according to the six aspects of teachers' professional practice, over three successive levels of teachers' pedagogical use of ICT" (UNESCO, 2018). The levels are aligned in the way how teachers typically adopt technology; first technology supplement, second exploit the true power and change behaviour, and third is transformative where knowledge is created. (UNESCO, 2018) Furthermore, it offers OER commons for each of the 18 competencies and further information, which can be found here: https://www.oercommons.org/hubs/UNESCO.

A few other frameworks that explicitly focus on digital competences have been investigated. The *Digital Competence Framework* (DigComp 2.0) identifies the key components of digital competence in five areas: Information and data literacy, communication and collaboration, digital content creation, safety and problemsolving (European Commission, 2019a). The newer version, designed for citizens *Digital Competence Framework for Citizens* offers eight proficiency levels and examples of use. They range from foundational to highly specialised, which cut across three aspects (complexity of tasks, autonomy and cognitive domain). Examples can be found on Carretero, Vuorikari, and Punie (2017, p.19). The *Digital Literacy Global Framework* adds two additional competence areas to the DigiComp 2.0 model, namely *devices and software operations* and *career-related competences*. (UNESCO, 2019b, p.14).

As Turkawka (2019, 26:10) also assesses, it is one of the most important things to educate teachers, especially regarding new tools and methods, which leads us to the next chapters. The benefits of new tools are explained in chapter 3.4.3 and examples are shown in chapter 4.4, morever an overview of new teaching methods is shown in chapter 3.4.4.

3.4.3 Tools Used in Education

One limiting factor in education in general is the time, and the easiest way to save time is using tools. Tools can help you with a numerous amount of things, as further described below. Digital solutions can help to manage people, training, classes, subjects, evaluations, certificates, absence systems, daily structures, case management, invoicing, communication etc. Arguments for ICT in school will be discussed in detail on page 56.

It is important to understand how to use the technology adequately, in what way technology is influencing us and how the learning experience can be influenced. The last point is explained by the next model.

SAMR Model

The *SAMR Model* (abbreviation for substitution, augmentation, modification, and redefinition) was developed by Dr. Ruben Puentedura. With its four different application levels, the model shows how new technologies can be integrated into teaching and learning processes so that they offer additional value. (Lozza, 2015)

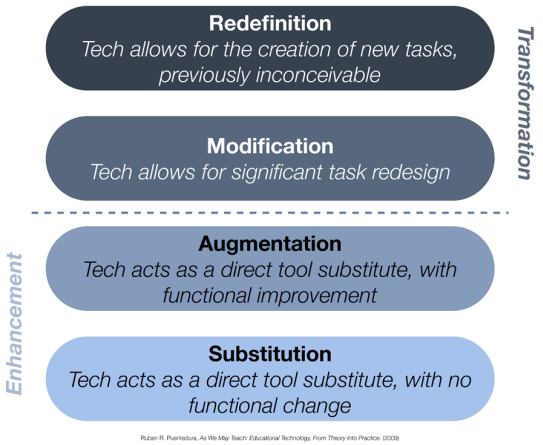

Figure 22: Four levels of the SAMR model on how ICT enriches the teaching and learning process in the classroom, illustration from Lozza (2015)

At the lowest level is substitution, where technology is used as a *substitute* for other learning tools (e.g. a tablet instead of pen and paper). However, a tablet also brings functional improvements: searching files, looking up information on the Internet. According to the SAMR model, this would already be the second stage, namely *augmentation*. The third stage of the model is defined by the *modification* of previous teaching and learning processes. In addition to the practical enhancements, new possibilities are also offered, e.g. taking photos or GPS function of tablet. At this level, teachers have new possibilities designing tasks and teaching. The last level of the model deals with the *redefinition* of teaching and learning processes. Here completely new didactic scenarios are made possible, which would not or only very laboriously be realisable without technologies, like e.g. decentralised working etc. (Lozza, 2015)

It is assumed, that technology today is rather on the lower level and with technological progress more and more applications and tools will climb up this level (Lozza, 2015). Like Müller (2019) mentioned in the interview, he could imagine to include *Cognitive Services* offered by *Microsoft Azure* into his platform (see Microsoft Azure (n.d.)). One area of application is text recognition and this would make it possible to program a dictation trainer that dictates and at the end also checks and corrects the photo of the written text. Another use case would be to extend the module *Basiswortschatztraining* with additional listening examples using a (good) text-to-speech tool, instead of recording all the scentences on his own. (Müller, 2019, 41:00-42:30) This would take the platform to a higher level in the SAMR model and allows new didactic scenarios.

As explained in the SAMR model, its about more than just having a new tool to teach (see Figure 22). The digital media in the classroom enhance (levels S and A) or change teaching and learning processes

(transformation: levels M and R).

The curriculum makes no recommendations for tools to teachers. This is done partly at cantonal level, mostly at community or school level, but ultimately, the teacher decides. (Bucher & Zemp, 2019, 19:40) It is important to consider the learning culture of the school (Bucher & Zemp, 2019, 20:35). Bucher explains, that the cantons want the initiative on tools to come from municipalities and schools and not "from above". Responsible teachers should make suggestions to the cantons and not vice versa. Bucher would prefer it if the initiative were taken both from above and below. The canton could at least make recommendations. (Bucher & Zemp, 2019, 23:15). Bucher emphasises that the creation of tools must be interdisciplinary. Specialist didacticians, psychologists, teachers, computer scientists and developers should collaborate. (Bucher & Zemp, 2019, 41:40)

Hands-on instruction and examples on pedagogical use of ICT is necessary to demonstrate how ICT could be used as vital tools in teaching and in facilitating learning process. In addition, professional development activities should encourage and support collaboration between teachers. (UNESCO, 2018)

It is important to add value using technology. Teachers sometimes need help identifying this added value e.g. through pedagogical media support. (Turkawka, 2019, 26:40).

> "Nobody complains in the workplace because you've googled a fact for your presentation. And by now we should be over the idea that tech in the classroom is some kind of 'cheat'. We've still got a long way to go... but let's not forget how far we've come."
>
> *Jason Caroll*

Arguments for ICT as Media

According to Döbeli Honegger (2016, p.64), there are four basic perspectives why ICT belongs in schools, both as a subject and as a tool. Probably the oldest, but also the most controversial perspective is the **learning perspective** from the point of view of media didactics. Digital media are said to have numerous learning potentials Döbeli Honegger (2016, p.65): ICT increases the variety of tools and methods in use, it broadens multimedia communication, collaboration and publishing capabilities, additional illustration using multimedia is possible, diverse use of media increases long-term motivation, immediate and sanction-free feedback, advanced adaptivity through learning analytics, students can have their own learning pace, interactive, digital simulations allow expensive, costly or dangerous experiments to be carried out in a resource-saving manner, and it offers actual up-to-date learning content and examples. Scientifically seen, there is no clarity about the didactic added value of digital media. In the metastudy *The no significant difference phenomenon* by Thomas L. Russell, a term was established, which has been shaping the discussion about the didactic added value of digital media for some time. (Döbeli Honegger, 2016) PISA results for students using new technologies did not recognise a noticeable effect in improvement in the students' performances for reading, mathematics or science (OECD, 2015).

Marogg (2019) and Müller (2019), however, observed a positive effect in their classes.

The **living environment perspective** argues that ICT belongs in the school environment because it reflects everyday reality and therefore prepares them for current and future life. It belongs to the repertoire of a competent citizen (Döbeli Honegger, 2016, p.69p).

The **professional world perspective** argues that ICT is ubiquitous in the professional world and digital skills are necessary cultural competences that are required at various levels of education. It is important to build them up at all school levels in an age-appropriate way (Döbeli Honegger, 2016, p.69p). Furthermore, computer science is recognised as part of general education (Döbeli Honegger, 2016, p.91pp).

The last perspective is not, like the previous ones, directed at the welfare of the pupils, but the **efficiency perspective** is aimed at the school as an institution. It is about administrative and organisational aspects that create space and time for learning processes. If all students have a personal digital device, they always have a pocket calculator, a timer and a camera with them - things that the teacher no longer has to worry about. This sounds like little, but practical experience shows that these small efficiency gains are worthwhile in such a one-to-one environment. In addition, quality can be improved, which has a positive effect on learning. (Döbeli Honegger, 2016, p.70p).

Advantages

Computers have multiple reasons why they are prefered as medium. They enable the capture and storage of digital data, but also their automatic rule-based processing is an immense advantage. Data can be automatically sorted, filtered and processed according to certain rules. Computers allow the automation of all processes that can be described precisely, i.e. formally exact. Digital data can be stored in a space-saving way and can be transmitted worldwide at low cost via data networks. Thanks to this networking, all recorded, processed data can be made available worldwide immediately. (Döbeli Honegger, 2016)

Digital books have several advantages as they are easier to create, revise, distribute, link and search than printed textbooks. Greater expectations than these efficiency-enhancing properties are raised by the extension of traditional books in the basic dimensions of multimedia, interactivity and interaction that digitalisation makes possible. (Döbeli Honegger, 2016, p.140pp)

The teacher can move freely during the explanation and is not bound to a blackboard having his back to the class. He has everything he needs in one device and one single device for for all subjects. What he emphasises, however, is that it should be used specifically and in combination with traditional teaching aids as a supplement. (MaethiFL, 2019, 1:50)

The following list is a summary of further advantages of AI and technology based applications:

- Automation technology can save time with repetive administrative work (e.g. see Gradescope on page 65). This reduces the risk of error and frees up time. (World Economic Forum, 2018, p.11)
- Digital teaching aids simplify the exchange among students and between students and teachers. Using a forum, the teacher is not necessarily in the center of a discussion and questions can be answered in a collective. (Döbeli Honegger, 2016; Jäggi & Bacher, 2018, 26:50)
- It allows teachers to choose from various digital teaching aids and to take the appropriate one depending on the subject (Rundu, n.d.). More different approaches in educating are offered (Turkawka 2019, 29:10) which enriches the lessons (Marogg, 2019; Müller, 2019).
- In closed exercises it is possible to provide feedback (assistance, stet-by-step solution, errors highlighted) to the students immediately and without sanctions (Logos Lehrerteam, n.d.; Schöneberg, 2017). Research shows that it is less annoying for students if a computer alerts them to an error several times than if a teacher does (Döbeli Honegger, 2016). Turkawka (2019, 1:00:40) adds, machines have greater persistence and more patience, at all times of the day.
- At the end of an interactive exercise, the students assess how difficult this task was for them (Turkawka, 2019, 44:50). This self-assessment also allows teachers to see immediately where each child still has a particular problem. (Logos Lehrerteam, n.d.)
- Adaptive textbooks that adapt to the learner's level and progress increase the efficiency and individuality of teaching (Döbeli Honegger, 2016) and increase individual support (Schöneberg, 2017).
- ICT tools promote independent working (Schöneberg, 2017).
- Learning progress and additional information about students is visible instantly - for oneself, parents and teachers. This makes immediately apparent which topics still require effort and what chapters therefore should be repeated (Logos Lehrerteam, n.d.). Software can measure additional information

like what exercises are used most, for how long etc. (Döbeli Honegger, 2016) This allows a much more individualised assistance. (Marogg, 2019, 23:10) There are more data available than in the past and they should be used for good (Turkawka, 2019, 9:05).
- Interactivity simplifies learning with the help of simulations and making it easier to discover relationships. (Döbeli Honegger, 2016) Most of the children are really attracted by these new interactive form of exercises. Especially if there is gamification and leaderboards included. (Müller, 2019, 15:50) Additional senses can be addressed (Schöneberg, 2017).
- Turkawka (2019, 29:10) states digitalisation has motivating effects and appeals to children on different levels (competitive, explorative).
- For students, changing the medium (especially to ICT) is unusual and exciting, which has a positive short-term effect on their motivation. Long-term books are prefered. (Noyes & Garland, 2006).

Also Rodemerk (2016) explains that the potentials of digital media often only reveal themselves through prior examination and testing in the classroom, many teachers have set out "on their own" to experiment with apps suitable for their lessons and, based on this, to drive the digital revolution "from below". However, it is important to stress that this is by no means an abrupt and fundamental change of the previous order, but rather the establishment of a fertile coexistence. (Rodemerk, 2016)

For further information about examples, in chapter 4 some worldwide examples are introduced and some cases for Switerland are shown.

The Other Side

Some teachers are overwhelmed with the variety of apps on the market or do not know where to start their search and how to implement the media (Rodemerk, 2016). As Marogg states in the interview, it is important to prepare the teachers both technically by showing them possibilities and mentally by taking away their fears. It is important for the teachers to see that ICT can help them and it does not change everything. (Marogg, 2019, 2:05) It is critical to motivate the teachers to use these applications (Marogg, 2019, 24:50). This is also considered in the *Will-Skill-Tool Model* on page 51.

Students in schools who use computers moderately have somewhat better learning outcomes compared to those who use computers very frequently or rarely. (OECD, 2015) Obviously a game of fire. But through software, it is possible to help the students to learn at their pace and give them the right amount of stretch (J. Anderson, 2019).

Döbeli Honegger (2019) collects more than 70 arguments against ICT in school on the website, categorised in the following groups: "Es schadet!", "Es lohnt sich nicht.", "Es geht nicht.", "Aber nicht so." and "Diverse". (Döbeli Honegger, 2019).

3.4.4 Methods to Teach

Bastian (2018) mentions three pedagogical tendencies in the education system. Firstly, from a teacher-centred approach to a learner-centred approach. Secondly, from knowledge transfer to problem/task/project-oriented learning and thirdly, from individual learning to collaborative learning. This is facilitated by technology.

Nowadays, care is taken to ensure that students receive more individual attention. Collaborative learning and active engagement in learning experiences typically leads to better learning outcomes (Fadel et al., 2015). Marogg describes everyday teaching today as much more personalisable and independent learning is more appreciated. The teacher becomes a kind of "coach" which he endorses. (Marogg, 2019, 10:00) Other authors agree with this trend (Loacker, 2015).

By educating people in various contexts and by using different techniques, they raise their ability to handle new situations (Cruz et al., 2018). As Turkawka concludes, it is important to allow students to learn more individually, which has only become possible to this extent through technology. (Turkawka, 2019, 32:05)

According to Barr and Tagg (1995), an important shift from *providing instruction* to *producing learning* has taken place. This tendency, away from only memorising things towards understanding the "big picture" has been confirmed by the intervieews and other authors (Liu, 2019). Today, in the information society where knowledge is easily available, it is less important to remember facts, because both the amount of new knowledge produced, and the ease of accessing this knowledge, expanded exponentially (Fadel et al., 2015).

Marogg doesn't do frontal teaching at all. He uses student-centred methods of which there are different characteristics. Working independently means that students work on different topics at different speeds. Stundets progress effectively, but this also has disadvantages, such as the lack of learning on a common thing (4Cs: collaboration). Marogg therefore recommends a mixed form. He also uses learning in a group on a regular basis, but this form also has disadvantages (free rider, coordination problems). (Marogg, 2019, 38:55)

Müller (2019) uses ICT as a part of "work rotation" to offer different ways to learn. Müller usually had exercise sequences in his lessons where one third of his class had to to one specific exercise, another third had to do another exercise and the third one used the computers in the classroom. They logged in on his website (www.schabi.ch) to use the individualised exercises to train in different ways. (Müller, 2019, 17:45)

The Lehrplan 21 deliberately does not provide any methodological guidelines. This was a requirement of the *Dachverband Lehrerinnen und Lehrer Schweiz* (LCH). (Bucher & Zemp, 2019, 15:35) The interviewed experts agree, that the teachers should continue to educate themselves in methodology as well. Cruz et al. (2018) advises a strong cooperation between vocational training and universities.

There exists dozens of new learning theories in education, see e.g. Heick (n.d.); McArthur et al. (2005). Therefore, a lot of possibilities in different approaches for students are available to fit the best effort for each individual. Here is a selection:

- **Blended Learning**
  Blended or integrated learning is a type of learning that combines the advantages of face-to-face, classrom-based courses and e-learning. (Sauter, Sauter, & Bender, 2004)
- **Integrated learning**
  Knowledge is learned in specially linked sets of systems. (Sauter et al., 2004)
- **Flipped Classrom**
  Flipped or *inverted classroom* is a teaching method of integrated learning. Homework and teaching are

flipped interchanged so that the learning content is developed by the learners at home and applied in the classroom. Flipped Classroom usually offers students a recorded lecture for self-study, while the lecture lesson is used for interactive seminar instruction. (Schulmeister, 2013)

- **Case-based Learning**
  Case-based learning (systems) access cases from past experiences and students need to bear on current situations to resolve the case. Instead of learning abstract rules applied to situations, they exploit analogies found in familiar cases to create their own decision rules. (McArthur et al., 2005, p.71)
- **Lifelong Learning (LLL)**
  The SDGs have reinvigorated lifelong learning as a humanistic, rights-based, holistic and sector-wide approach to education, and have been extremely well received (do Nascimento & Valdés-Cotera, 2018). This is an urgent approach, if as expected in the *Future of Jobs Report 2018*, by 2022, about 54% of all employees will require significant reskilling and upskilling (World Economic Forum, 2018, p.13).
- **Personalised Learning**
  Personalised learning is oriented towards the students personal needs. Learning must be meaningful for the individual, aligned with interests and ideally self-initiated. The speed at which this happens and the learning approaches must be adapted to the student. Goals, deadlines, and how the student wants to learn is determined by the learner and the learning coach. (Rudolph & Sparwald, 2016)
- **Project-Based Learning**
  Key element of this approach is the focus on self-organisation that teaches curriculum concepts through a project. Students have great freedom of choice in a student-driven learning process where the teacher only facilitates. Bell (2010)
- **Scaffolding, Scaffolded Instruction**
  Instructional scaffolding in the pedagogical-psychological context refers to support of the learning process by providing an aid in the knowledge gap in the form of instructions and other assistance. As soon as the learner is able to work on a certain subtask independently, this "scaffolding" is gradually removed again, leading to a more self-confident and capable learner. (Bell, 2010; The Glossary of Education Reform, 2015)
- **Social Learning**
  The basic idea of social learning is mainly based on group work in learning practice. Collective learning encourages students to articulate their own beliefs and experiences, listen to the opinions of others, and find consensus in divergent viewpoints (Toven-Lindsey, Rhoads, & Lozano, 2015, p.10).
- **Ubiquitous Learning**
  Mobile technologies allow it to learn anywhere and anytime. (UNESCO, 2018)

4 Examples

"The thing that's going to make artificial intelligence so powerful is its ability to learn, and the way AI learns is to look at human culture."

Dan Brown

The idea of this section is to offer an overview of pioneers in the sector of artificial intelligence, digital citizenship, and advanced education solutions. These pioneering solutions can be on different levels and developmental stages. Starting with national AI pioneers which are led by the United States of America and China. Next, innovative companies and then examples in the Lehrplan 21 area will be presented. Concluding with relevant aspects.

4.1 National Pioneers

Most leading economies in the world understand the importance of artificial intelligence. It might become a main driver in generating economic growth and therefore states promote investments accordingly. (Davis, 2019; Wade & Bris, 2018)

Nevertheless, in the report by HolonIQ presented by Davis (2019) is mentioned, that AI tools are not widely used to the standard K-12 curricula around the world, yet. Therefore this section shows the most advanced economies regarding artificial intelligence, some examples and trends how artificial intelligence influences countries.

PWC (2019) estimates that AI could contribute up to $ 15.7 trillion to the global economy in 2030. This is more than the current output of China and India combined. Around $6.6 trillion come from increased productivity and $9.1 trillion might come from benefits to consumers. (PWC, 2019)

Artificial intelligence will have a major impact on economies. According to Figure 23, China, North America and the Middle East will benefit most from this development.

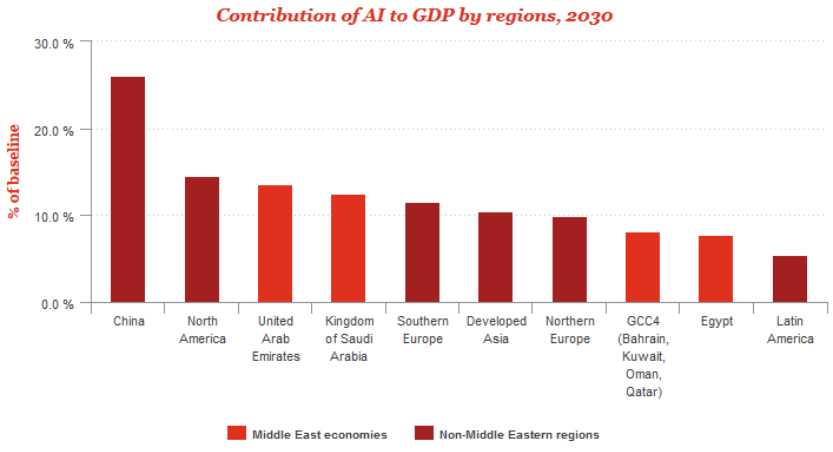

Figure 23: Contribution of AI to the GDP by regions by 2030, from PWC (2019)

In the field of AI technology development and market applications a "race of two giants" between China and the U.S. is taking place. The Americans have the lead in industry development and applications, enterprises, and core technology output, such as hardware and algorithms. Also when having a deeper look at AI talents, the United States, the United Kingdom, and Germany are still better prepared

than China. Chinese scholars, in turn, take the lead in available data, publishing papers, applying for patents, and AI application in some specific fields. (China Institute for Science and Technology Policy, 2018)

China

Chinese AI-focused companies can be accounted for nearly half of all global AI funding (Khan, 2019). China has chosen AI as a top priority which is reflected in a growth in artificial intelligence-based investment and research activity. The People's Republic plans to catch up with the West by 2020 and overtake it by 2025. (Wade & Bris, 2018) The State Council released the *AI Development Road Map* (China Institute for Science and Technology Policy, 2018) and a three step program that outlines its goal to use AI in a number of areas (Khan, 2019; Kharpal, 2017): Chinas goal is to develop a "new generation" of AI until 2020, make "major breakthroughts" in AI technology until 2025 and become the world leader in AI, with an industry worth $150 billion by 2030.

China has favourable framework conditions regarding the development of AI like fewer privacy regulations, which allows companies to extensively access consumer data. (Davis, 2019; Houser, 2019; Wade & Bris, 2018) Having more than 700 million Internet users, can lead to a clear advantage in data volume that can be used to train AI-learning algorithms what leads to possible leverage-effect (Wade & Bris, 2018). Houser (2019) adds that the government promotes AI incentivise through tax breaks. Furthermore, education innovation depends on parents' spending power and education may cost comparatively much in China. Therefore, education AI is more advanced in China when it comes to sophisticated adaptation to the needs of its pupils. (Houser, 2019; Liu, 2019)

According to LinkedIn's Global AI Talent report published in July 2017, China has been importing a lot of its AI talents from overseas. (Wade & Bris, 2018) Programming education is in China lower than in other countries (Synched, 2018a, para.6). To counter this trend, teaching material on AI for primary school students has been developed (Liu, 2019; Synched, 2018a, para.1, para.5), cloud-based AI e-learning platforms (Synched, 2018a, para.3) have been introduced and STEM degrees are promoted (Wade & Bris, 2018).

Artificial intelligence is one of the core topics for many education firms and financing increases enormously (Khan, 2019). China has numerous companies in the field of education and artificial intelligence. By the end of 2016 there have been more than 400 online education-related enterprises in China, with rising numbers, where most of them claimed to be AI oriented (Khan, 2019).

United States of America

China and the U.S. are the main players in artificial intelligence Davis (2019).

In May 2019, the American *Association for the Advancement of Artificial Intelligence* (AAAI) announced a joint initiative to develop nationalwide guidelines for teaching K-12 students about AI. They defined guidelines on what students should know about AI, machine learning, and robotics in each grade. (Synched, 2018a)

According to the *US Education Sector report*, it is expected that AI in U.S. education will grow by 47.5% from 2017-2021 (Khan, 2019).

Estonia

Also called *E-Stonia*, is the world's most digitally advanced society. Taavi Kotka, the Estonian government's chief information officer, explained that they can takle a lot of problems offering a digital answer. Government interactions are 98% online, each citizen has a card that contains his unique digital identifier. (Reynolds, 2016)

> "Thirty per cent of its citizens vote in elections over the internet, births, deaths and mar-

> riages can all be registered from home and almost all public spaces have been covered by free Wi-Fi for the last decade." (Reynolds, 2016)

An Estonian school principal explains, that since 2018 all teaching material is available in digital form, which has multiple advantages. (Rundu, n.d.).

The Netherlands

The Dutch National Technology Pact 2020 is responsible, that "the workforce in some of the EU countries like Luxembourg, Denmark and the Netherlands show above average levels for having digital skills" (Cruz et al., 2018, p.2).

Comprehensive policies can help to close the gap between education and the technological job market. The technological strategy for the Dutch follow three objectives: Choosing adequat technology, provide high quality technical education on all levels and offer a tech-friendly environment (Cruz et al., 2018).

Middle East

According to PWC (2019) the possible impact of AI in the Middle East might be up to US$ 320 billion by 2030, which is expected to accrue 2% of the total global benefits of AI in 2030.

The largest and most ambitious economic reform and transformation program in its history is taking place in **Saudi Arabia**. *Vision 2030* includes digitisation and AI as key enablers of these wide-ranging reforms. It "commits to building sustainable cities and communities, improving the health and well-being of our citizens, improving the quality of education, providing decent work, and fostering innovation-driven economic growth". A robust localised technology sector is planned to be built and a major education reform introduces digital skills in K-12 education. (Jewell, 2018) PWC (2019) forecasts an average annual growth in the contribution of AI between 2018-2030 of 31.3% in the Kingdom of Saudi Arabia and 33.5% in the United Arab Emirates.

The **United Arab Emirates** have put AI at the forefront of the government's strategic plans. The Emirate's strategies include, amongst others a *Smart Dubai Strategy* to promote AI in all fields. The *Dubai 3D Printing Strategy* aims to have 25% of buildings in Dubai constructed using 3D printing technology by 2030. The *Dubai Autonomous Transportation Strategy* has the goal to cut transportation costs by 44%, carbon emissions by 12% and accidents by 12% by transforming 25% of all transportation in the city to autonomous modes by 2030. (PWC, 2019)

4.2 Companies

There are a lot of companies that use AI in their business model[7]. This section introduces a selection of companies which combine *AI and education*, at least partly, in their business model.

Century Tech

The British AI platform *Century Tech* uses AI technology to provide a personalised learning journey to students in several subjects and offer additional insight to educators. (UNESCO, 2019a)

The platform constantly differentiates and adapts paths for learns as it continuously calculates students strengths and weaknesses. This allows tailored, individual learning paths for every student. The interactive dashboard allows teachers and parents to see how a student is progressing in real-time and offers deep actionable insights to the teacher by automatically generated analytics. This allows them to target interventions at both school and at home immediately. (UNESCO, 2019a) Century Tech argues that student understanding is improved by 30% and the teachers workload can be reduced by six hours per week. (Century Tech, n.d.) They have won several awards with the newest ones being *CogX Awards 2019: Best AI Product in Education Winner*, *EdTechXGlobal Awards 2019: Startup Award Winner* and *SOLVE MIT 2018: Education Winner*. (Century Tech, n.d.)

Century Tech recently launched the platform to some public schools in Lebanon, in partnership with the Ministry of Education, to support access to quality learning for Syrian refugee children. (UNESCO, 2019a) The biggest introduction of such a system in recent times is taking place in Belgium where they are negotiating a deal for 700 schools (date of the report: March 21, 2019). (J. Anderson, 2019)

DeepL GmbH

Originally founded as Linguee in 2009, the German company offered the first Internet search engine for translations. They gathered over one billion high-quality translated texts, which was great training material for a neural translation network. (DeepL, 2019)

In August 2017, the company introduced DeepL Translator, a free machine translation system that is produces most accurate and natural-sounding translations, compared to competitors. To understand and translate texts, it uses neural network technology and quickly became the leader in AI translation technology. (DeepL, 2019)

Google

Google is one of the best known companies worldwide and uses AI in a lot of its products.

Google Assistant is a voice-powered assistant who offers hands-free help that you can hear and see using your phone, speakers, smart display, car, TV, laptop, smart watch or similar (Google, n.d.). This service uses artificial intelligence has been powering almost every other smartphone for the past few years. (Chia, 2019)

Google's G Suite which offers several features using artificial intelligence (Stevenedutechers, 2019). It is a productivity suite that includes Google Docs, Sheets, Slides, Gmail, Hangouts Chat and a variety of other business apps (Potter, 2019). It is very suitable for students (Fichter, 2019) and teachers (Ingraham, 2019) More than 40 million teachers and students use this service (Fichter, 2019). **Google Voice** is a cloud telephony service where you have a phone number that works on every device and includes AI-driven features such as voicemail transcription, spam call blocking and text-to-speech capabilities in up to nine languages. (Potter, 2019) **Google Home** is another intelligent service by Google. Altificial intelligence is also used in product like **Chromebooks**, **Deep Mind** and **Maven**.

[7] Some of the most experienced companies are according to Botha (2019): Amazon, Apple, Banjo, DJI, Facebook, Google, HiSilicon, IBM, Intel, Microsoft, Nvidia, OpenAI, Qualcomm, SenseTime, and Twitter.

Gradescope

Solutions of exercises were photographed and stored in a huge database. The application now provides solutions for exercises, allows a uniform distribution of points for partial solutions and thus facilitates the correction process for teachers tremendously. If the same error occurs multiple times, the teacher gets a cluster of solutions where he can select one of the existing correction suggestions. (Turkawka, 2019, 43:50) In this video the platform is presented: https://www.gradescope.com/

Khan Academy

Marogg (2019, 19:35) often uses this free American application which uses machine learning to detect what the student already knows and adapts to students learning behaviour and progress. This can be seen by the teacher immediately in the control center wich allows him individualised supervision. (Marogg, 2019, 23:10)

Turkawka claims there is no company that trains more people than *Khan Academy*. They develop open-source software and employ hundreds of data analysts and programmers, a few psychologists and a few educators. (Turkawka, 2019, 1:12:50)

SenseTime

In April 2018, SenseTime Group Ltd became the world's most valuable AI start-up, having raised $600 million only in 2018 (Wade & Bris, 2018) - in total more than $1,2 billion (Khan, 2019), with a valuation of over $4.5 billion. (Liu, 2019)

In April 2019, around 40 high schools in Shanghai began using "Fundamentals of Artificial Intelligence", a nine-chapter AI textbook compiled by SenseTime. SenseTime today is carrying out a pilot program in more than 100 schools throughout the country in Shanghai, Beijing, Shanxi, Shandong, Guangdong, Jiangsu, and Heilongjiang. Therefore, they are training over 900 teachers to implement its curricula. (Liu, 2019)

Turnitin

The application turnitin is a plagiarism detection software. It identifies content which is analysed for similarities with the world's most comprehensive collection of Internet sources, academic publications and student works. (Turkawka, 2019, 43:45)

VIPKid

The Beijing-based online teaching and education company VIPKid started as a low-tech video conference platform that connected Chinese students with (English) teachers in Canada and the USA. More than 10'000 teachers educate almost 600'000 Chinese students to get additional education each week. The company accumulated and stored user interactions, that allows them personalisation and maximises user happines through better matches, using AI. (Khan, 2019; Liu, 2019)

Some further examples are:

Chatbot (R. Bucher, 2018), Duolingo (R. Bucher, 2018), GETChina (Khan, 2019), Pandai (Jones, 2018), WriteLab (Liu, 2019).

"Ein Tablet ist ein Schweizer Taschenmessen für den Unterricht - du kannst alles damit machen."

Gregory Turkawka

4.3 Tablet Classes in Liechtenstein

In this section an excursion into the *tablet class* of Mathias Marogg, primary teacher in Planken, Liechtenstein is made. Marogg explains; within the next two years, all pupils of primary school in Liechtenstein will be equipped with a tablet (iPad) and all students of secondary school with their own Windows laptop (Kjo, 2019). Marogg and his team of pedagogical media consultants (MIB) is created to support this changeover. (Marogg, 2019, 29:05)

One major advantage in Liechtenstein is it's financial possibilities and the small size which simplifies the changeover (Marogg, 2019, 32:05) is done . Liechtenstein has granted a credit of 10 million Swiss francs for this project (13 million according to (Kjo, 2019)). This includes the costs for track-up, implementation, purchase of equipment and infrastructure. In addition to this amount, there are also contributions from the municipalities. The students do not have to pay anything for their equipment. (Marogg, 2019, 41:15)

Usage of iPads allow a more diverse approach to teaching (MaethiFL, 2019). Marogg numerates multiple advantages, using an iPad as a teacher (see arguments for ICT in classrooms on page 56). The experience gained in Planken is very good. The tablets provide great added value, as they provide new access to content. He states that he won't teach without these gadgets anymore. (Marogg, 2019, 4:25) The tablets are used as a supplement in almost all subjects, including German, English, mathematic, general science and social studies (NMG), music, as well as free work phases. (Marogg, 2019, 5:05) Because it's use is usually voluntary not all students use it. Furthermore, they don't use it for the same length of time, but usually less than 30 minutes per day (Marogg, 2019, 2:35).

The tablets have numerous apps on different topics which can be used to complement the workflow, to search additional information, make music, mind-maps etc. (MaethiFL, 2019) Marogg uses multiple learning apps in his classes. Here's a selection of the apps he uses these the most; *Mathematik Primarschule*, *Khan Academy*, Anton and *Lernwolke* (Marogg, 2019, 19:35). Creative apps are *Puppet Edu*, *Toontastic*, *GarageBand*, *MusicMakerJAM* or *Blocs Wave* (Marogg, 2019, 20:50). Programming skills can be improved using *Tynker* or *Swift Playgrounds* in a playful manner from the kindergarten on. Other apps are *Klexikon*, *Wikipanion*, *Quizlet* and sometimes *Duolingo* (Marogg, 2019, 21:35). The iPads also have games installed, but pupipls are not allowed to play alone. (Marogg, 2019, 5:25)

Marogg assumes that the role of the teacher will change considerably in the coming years due to this trend. The teacher becomes more and more a coach. He gives short input sessions and the kids work more independently and the teacher acts as an advisor. (Marogg, 2019, 22:35) Information about the student's level of knowledge can be evaluated during the learning process and not during the exam. Time, error rate and further information is collected instantly – where to use it depends on the teacher. (Marogg, 2019, 23:50)

Marogg explaines, that he never uses the blackboard during his teaching activity. He usually teaches from the center of the classroms and the tables are arranged in blocks of 4-6 tables ("learning groupwise") around him. This simplifies and supports various other forms of work such as group work, collaborative learning etc. (Marogg, 2019, 9:05)

It took Liechtenstein a very long time to take the step towards digitisation in the field of education. Compared to Swiss schools, Liechtenstein became active much later. It took many years of preparation time, but meanwhile two schools (Ruggell first, then Planken) have dared to push forward and introduced tablet classes. (Marogg, 2019, 27:55)

4.4 Examples in Switzerland and Liechtenstein

These examples don't necessary use articifial intelligence except if it is explicitely said. Nevertheless do they change how education is done and are one of the first impacts seen in the Lehrplan 21 environment. These applications can be assigned in the lower level of the SAMR model seen in Figure 22.

A deeper look is taken at the *Schule am Bildschirm* platform, because I interviewed the founder. Three Swiss organisations and an American organisation offering teaching material are introduced. Below, some applications are presented and listed alphabetically.

EDK

Many tasks doned by the *Conference of Cantonal Ministers of Education* (Erziehungsdirektoren-Konferenz, EDK), require intercantonal cooperation (e.g. curricula) and are handled by the EDK regional conferences which have their own secretariats. A distinction is made between Western Switzerland and German-speaking Switzerland. Western Switzerland includes the *Conférence intercantonale de l'instruction publique de la Suisse romande et du Ticino* (CIIP). Conferences of cantonal ministers of education in German-speaking Switzerland are divided into central Switzerland (BKZ), eastern Switzerland and Liechtenstein (EDK-Ost) and northwestern Switzerland (NW EDK). (EDK, n.d.)

Educa.ch

Educa offers the a digital library (https://biblio.educa.ch/) for additional digital content regarding the Lehrplan 21. Educa is responsible for Switzerland-wide negotiations such as microsoft packages to ensure improved offers for the cantons and schools. They also serve as a contact point for digitisation and also deliver various reports on this topic. (Bucher & Zemp, 2019, 11:30)

In addition to these framework agreements for school matters, various (nationalwide) initiatives such as "Schule ans Netz", Educanet2 (Educa, 2019a) or various recommendations are made by Educa (Turkawka, 2019, 1:04:40). They have for example already issued some recommendations on data protection (Educa, 2019a; Fichter, 2019)

Educa soon launches the project *Fides* (Aufbau der Föderation von Identitätsdiensten für den Bildungsraum Schweiz). The goal is to provide learners and teachers in Switzerland with a single digital identity (ID) for access to the online services they need regarding teaching materials etc. (Bucher & Zemp, 2019, 13:00) Educa is a specialised agency of the EDK. (Bucher & Zemp, 2019, 14:10)

Educational Publishers

There are multiple publishers of teaching aids in Switerland. They offer different teaching materials for most of the school subjects. (Lehrmittelverlag Zürich, n.d.-a)

More and more teaching materials is available online. Their digital platform is www.digital.lmvz.ch and it enriches interaction and offers multiple ways to learn. (Müller, 2019, 34:15) The *Lehrmittelverlag Zürich* offers one part of it's official teaching material in a digital way and therefore it is often used by teachers (Müller, 2019, 38:30).

There are fewer and fewer publishers of teaching materials. They offer good digital teaching aids, e.g. *Stellwerk* or *Lernpass plus*. Digitisation is a major issue for publishers. Lehrmittelverlag Zürich is the leader in this field. *Schulverlag plus* (Kantone Aargau und Bern) catches up. There are also German teaching aids that are often used here, for example *Westermann Verlag*, which has a much greater scope. (Bucher & Zemp, 2019, 46:25) Also, there is already a teaching material agenda for the coming years to further expand them (Lehrmittelverlag Zürich, n.d.-b).

ISKME

The *Institute for the Study of Knowledge Management in Education* (ISKME) is an independent, education nonprofit organisation. They conduct social science research, develop research-based innovations, and facilitate innovation that improves knowledge sharing in education. (ISKME, n.d.) Established in 2002, and based in Silicon Valley, ISKME supports innovative teaching and learning practices all over the globe, and is well-known for its pioneering open education initiatives. ISKME has various offers like the big ideas fest, OER services, OER training, action collabs, research and evaluation, speaking engagements, and the OER commons. Their theory of action includes three levels of engagement: Study, Open, and Build. (ISKME, n.d.)

These open courseware resources (OER Commons), offered on their on their website are indexed according to the ICT CFT competencies and objectives. The ICT CFT Hub has a search tool that allows developers to search for, and identify, resources that would support teachers to acquire a specific ICT CFT objective (see Figure 21) (UNESCO, 2018). OER Commons offers a lot of different resources. More than 60'000 resources, split into twelve subject areas, three grade levels or twenty-two material types (OER Commons, n.d.):

Zebis

The *zentralschweizer Bildungsserver, Zebis*, is a platform especially for teachers. This platform offers teachers and pupils additional teaching materials on ICT, dealing with new media, risks and opportunities of new media and media competence. The uploaded materials have been reviewed by experts. A curriculum navigation provides information on which materials are available for which learning objective of Lehrplan 21. (BKZ, 2011)

On the website there are lots of additional teaching materials for all subjects and around the classroom. Furthermore, vacancies for teachers are shown. (BKZ Geschäftsstelle, n.d.)

These following list of applications have been mostly recommended by teachers interviewed.

Anton

This learning app offers the most important topics in school for pupils between 1st and 8th grade. These topics include German, maths, general studies (NMG), German as a foreign language (DaZ) and music. According to the website, all offers are free of charge and include over 50'000 tasks, more than 200 exercise types, learning games and interactive explanations. A motivating feature are the built-in stars and trophies that are collected and can be used to play games. (Solocode, n.d.) The Berlin-based company, financed with EU funds, is constructed in a very playful and simply way, as Marogg (2019, 20:05) highlights.

Appolino

The *Lehrmittelverlag St. Gallen* developed multiple applications for pupils between the age of five and ten to learn reading, writing and arithmetic. Each of the six modular appolino apps contains nine modules with six levels.They argue that this step-by-step structure (from left to right and from top to bottom) is central to effective learning. (Appolino, n.d.)

They offer four mathematical and two linguistical applications specially designed for tablets (Appolino, n.d.).

Bettermarks

This platform offers adaptive math books for students in grades 4 to 10. Students can calculate tasks on the tablet, the computer and the smartphone. Each individual and open task is explained with a detailed calculation path and the concrete numerical values of the task. Thus it is exactly comprehensible

how a possible solution could look like and how similar tasks can be solved next time. Bettermarks accompanies every calculation step and supports the student with tips and explanations. In the background, the online learning system finds every knowledge gap. In line with this, bettermarks creates exercises with which forgotten lesson contents can be processed. (Bettermarks, n.d.)

Bettermarks analyses the learning process, identifies problems and offers the approach to the solution. It uses gamification and offers coins for completed tasks which attracts competitive students. It also offers videos and additional theory for explorative students. (Turkawka, 2019, 29:00)

Blocs Wave

Blocs Wave allows you to explore and slice your sounds and improve music education (Marogg, 2019, 20:50) . A huge library offers a lot of melodies to jam. Adding your recorded instruments or voices will further improve the composition. (Apple, n.d.-a)

Edulo

Edulo an application for tablets or can be used using a web browser. It allows teachers to easily create or purchase interactive exercises and distribute them (paperless) to their students. You not only have a simple and clear administration of all worksheets, but also the overview of the learning status of the class and the individual learners at any time. Available for Apple, Google, and Windows. (Edulo, n.d.)

Garage Band

This app for iOS enables students to produce their own music quickly and easily (Marogg, 2019, 20:50). With the help of an audio interface a variety of real instruments can be recorded. It also includes many pre-installed sounds and a large collection of loops. (Apple, n.d.-b)

Hazu

The platform *Hazu* allows teachers to design their lessons. Content can be created, organised, and shared. It allows the teacher to share content with different groups or specific students and pupils can collaborate using this platform. (Bucher & Zemp, 2019, 22:20)

Klexikon

The platform *Klexikon* (Kinder plus Lexikon) provides a child-friendly environment to search for suitable content. It is comparable to Wikipedia or Wikipanion. (Marogg, 2019, 22:00)

Learnify

The Swedish platform Learnify offers students and teachers an optimal learning management system (Bucher & Zemp, 2019, 23:10). The platform describes itself as a combination of the basic functions of Wikipedia, Facebook, WordPress and the Khan Academy meta-structure, adapted for the school sector. It offers easy ways to exchange materials and is hosted in Switzerland. However, the generation of the content might be critical in Switerland. (Köhler, 2016)

Lernwolke

Another Swiss product is the *Lernwolke* platform (Müller, 2019, 37:20; Marogg, 2019, 19:35). This app offers modules like grammar, spelling, vocabulary, tenses, and a module to strengthen the learned content of different primary school levels. The Lehrplan 21 is the foundation of this application and thus the exercises are specially developed for the different competence levels. (Lernwolke, n.d.)

Mathematik Primarschule

This application offers useful exercises for the subject of mathematics developed from *Lehrmittelverlag Zürich* (Marogg, 2019, 19:35).

Music Maker JAM

This music app allows students to easily create songs on a tablet (Marogg, 2019, 20:50). Loops from various genres can be combined, real-time effects and voice or noise recordings can be added and the songs finally can be shared with a global community. (Apple, n.d.-c)

Profax

Profaxonline offers you a variety of programs for lessons which are individually assignable. The subjects on offer include German (various exercises for listening, spelling, certain types of words, basic vocabulary, rules, word stems), mathematics (mathematics training, basic operations), basic skills and perception (perception training, sound training, early support), NMG (Swiss geography, local history, playful offerings). They also offer courses for teachers. (Profax, n.d.)

Quizlet

Quizlet is an online flashcard creator. The American company uses a freemium pricing strategy and is rapidly growing. They allow teachers and students to create flashcards with individualised questions and answers. These flashcards can be used to train spelling, hearing, writing and also allows other forms of exercises. With *Quizlet Live* you have the possibility to invite students into a competitive game where they are working in groups to answer questions. According to Quizlet more than 90% of students who learn with Quizlet report better grades. (Quizlet, n.d.-b) They have more than 50 milion active users from more than 130 countries every month, learning more than 300 milion learning sets on practically any subject (Quizlet, n.d.-a). Marogg (2019, 21:35) uses this in the subject of English.

Schule am Bildschirm

As a hobby, the former developer Christof Müller, programmed the website *www.schabi.ch* to offer his pupils what he thought was lacking in teaching materials and on the Internet. In about 2011, he began with a simple dashboard (similiar as in Figure 24) which he later on shared with his colleagues. On the dasboard, which can be customised for every class, a child-friendly search engine can be found and it is easy for pupils to find relevant links for different subjects (Müller, 2019, 22:15).

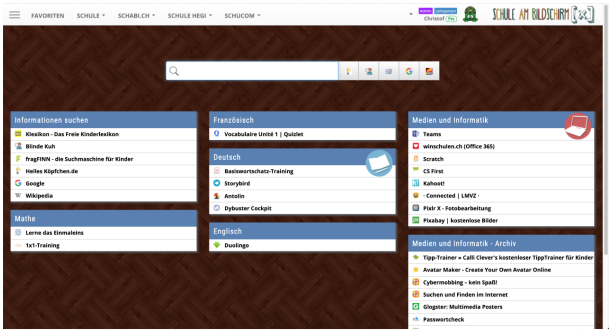

Figure 24: Example dashboard of www.schabi.ch (screenshot by Christof Müller)

Later, he added modules like German, maths and memory training as you can in Figure 25. The *Einmaleins* offers 100 multiplication exercises that must be calculated as quickly as possible (Müller, 2019, 14:50). *Basiswortschatz* offers in each of the 20 levels 50 words which finally contain the 1000 most relevant words for children (Müller, 2019, 18:30). The modules include "listening-exercises", as well (Müller, 2019, 19:10). Different leaderboards have a motivating effect (Müller, 2019, 16:05). These modules are not meant to serve as a substitute for teaching but as supplementary training to strengthen skills (Müller, 2019, 14:00, 17:35).

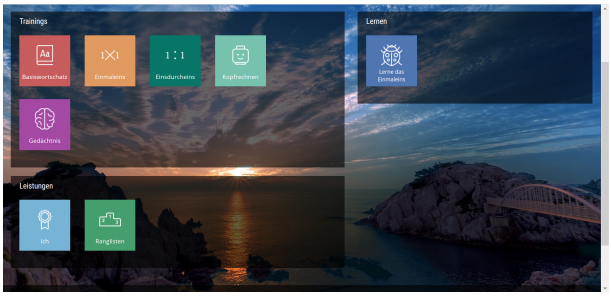

Figure 25: Learning modules in the "Schule" section (screenshot by Christof Müller)

A third part of the platform is the *Lehrerpult* where the teacher can share documents, manage home-

work, chose a random pupil or create groups. One useful tools is the overview of the students activities which makes it easy to identify potential problems. (Müller, 2019, 26:00-30:20).

In this way, the website emerged year by year and it requested additional time. Finally, in November 2018, Müller minimised his teaching enormously (Müller, 2019, 12:55) and founded the Winterthur-based company *Schule am Bildschirm GmbH*. It is a one-man business and is financially, politically and religiously completely independent and 100% free of advertising. There is a free basic licence but also a pay-version for single classes or entire schools. (Müller, n.d.) Currently the platform has over 35'000 users, with a strong upward trend, but these are not active users (Müller, 2019, 35:40).

Shadow Puppet Edu

Shadow Puppet Edu allows students to easily create videos and slideshows in the classroom for students of all levels applicable in different subjects (Marogg, 2019, 20:50). The app helps to prepare a presentation, tell a story or explain a phenomenon. A Self-explanatory tutorial is integrated in the app to make it as easy as possible. In preparation, students write a storyboard, create photos and/or films and write suitable texts. Then select pictures or films in the desired sequence and add any add music, text, recordings, pictures and different animations. (Data Quest, n.d.)

This app can improve student's storytelling skills, demonstrate understanding of a concept, improve speaking skills or practice reading aloud. Furthermore and won two awards in 2014. (Apple, n.d.-d)

On the web page http://get-puppet.co a few instruction scenarios are explained or described.

Swift Playgrounds

This app for the iPad allows beginners to learn Swift, Apple's programming language (Marogg, 2019, 21:35). The basics are learned by solving different puzzles – using real code to guide a character through a 3D world. : It allows you to write code on the left and immediately see the results on the right as you see in Figure 26.

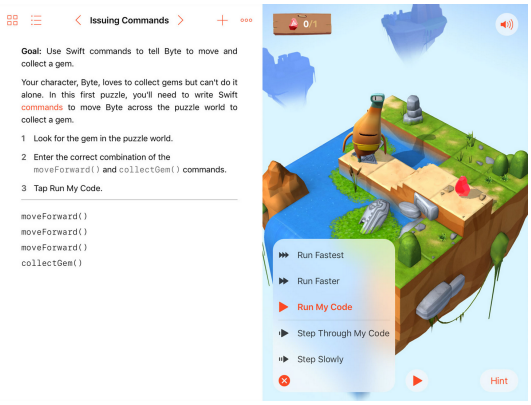

Figure 26: Example from Apple (n.d.-e)

The next step is more challenges and more advanced playgrounds designed by Apple and other leading developers. Concepts like commands, functions, loops, parameters, conditions, variables, operators, types, initialisation, and bug fixing are introduced. (Apple, n.d.-e)

Toontastic 3D

This application by Google allows students to draw, animate, and narrate swashbuckling adventures, breaking news stories, science reports, and a lot of different creative ideas (Toontastic, n.d.). *Toontastic* is similar to *Puppet Edu* and allow you to easily create picture stories including sound for free (Marogg, 2019, 20:50).

Tracce

This application is aimed at Italian language students from level A0 to B2. The app comprises 12 notebooks, which saves space and optimally complements the course. The teaching material includes vocabulary, grammar exercises and games. It refers not only to Italy but also to Italian language areas in Switzerland. It is very new and up-to-date, links again and again to online exercises and is a Zurich teaching aid. (Forciniti, 2019)

Tynker
This is also a application to learn programming for kids Coding for kids (Marogg, 2019, 21:35).

Typewriter
Typewriter is a learning program for practicing the 10-finger system on the computer and winner of the "Learnie Award" (Typewriter, n.d.). According to an internal BKZ investigation, this application is used by several cantons (AI, AR, NW, OW, SG, VS) and licences were purchased (Bucher & Zemp, 2019).

As already mentioned in the introduction, these are just examples and are intended to demonstrate the versatility of apps. There are hundrets of apps available in the regular app markets (e.g. Capterra, 2019; Educational App Store, 2019) but ultimately, it is the content and not the tool that matter (Bucher & Zemp, 2019, 46:25).

4.5 Relevant Aspects

In this subsection I want to summarise trends, show key characteristics, opportunities, and risks of existing tools, and point out certain critical aspects.

The field of artificial intelligence is the fastest growing within the global education market. It adds value in different learning processes, student support and identity/security where the greatest potential for AI is predicted in language learning and assessment. (Davis, 2019; HolonIQ, 2019)

There are already attempts to measure brain signals of children in school (Ye, 2019). If these brain signals were constantly measured and evaluated during lessons, teachers could be provided with enormously important feedback regarding attention, problems etc (Turkawka, 2019, 8:25).

As Marogg explained, resistance often comes from parents regarding safety and health concerns. But this often only concerns the pioneer schools, as there was no resistance in Planken as the second school in Liechtenstein introducing tablets (Marogg, 2019, 28:35). Nevertheless, there are some aspects to keep in mind: The benefits should be obvious as quickly as possible and the handling as simple as possible. Data security and privacy concenrs must be taken seriously. Systems should only receive (and save) as much data as they really need. Often the theory differs from the practice as in the example of G Suite (Fichter, 2019).

It is crucial that systems to not have any bias, therefore important to cluster the data in the right way. Furthermore it is important that different cultures are taken into account. (Turkawka, 2019, 47:55)

It is important that teachers know about how AI and robots work (see TPACK on page 40). They need to be aware of their strengths and weaknesses. Switzerland has a lot of catching up to do here. (Turkawka, 2019, 49:45)

Turkawka is optimistic about the legal situation, as Switzerland is relatively open about regulation. If politically many preventive interventions were to take place, a skill gap would have much more serious effects. Overregulation is problematic. (Turkawka, 2019, 41:15)

Spitzer, a digitisation critic, mentions some harmful trends concerning children using "too much" media and unlearn to think, what he calls *digital dementia* Hanfeld (2012). It is still important to use pen & paper(Logos Lehrerteam, n.d.) for certain tasks. In the end, it is important that the stundent benefits from the technology.

There are enormeous differences how extensively these informatics skills are taught. It depends mainly on the teacher, but another important factor is the access, i.e. the infrastructure. (Marogg, 2019, 17:15) An appropriate interaction is necessary and must be taught.

Dagstuhl Triangle

The *Dagstuhl Triangle* illustrates that digital education must be viewed from three perspectives. There are various digital phenomena that can be explained using this framework. Examples include chatting, computer games, cyberbullying, emojis, fake news, personalised advertising, social networking, and so on can be found on the website from by the Fachkern Medien und Informatik (2019). The framework is explained using *Whatsapp* as an example.

The first perspective is *technological* and answers the question of *how something works*. It questions and evaluates the functioning of the systems that make up the digital networked world. It provides answers to questions about the principles of action of systems and their potential for expansion and design. It explains various phenomena with recurring concepts. Basic problem-solving strategies and methods are taught. In this way, it creates the technological foundations and background knowledge for helping to shape the digital networked world. (Döbeli Honegger, 2017)

Questions regarding eavesdropping security, encryption, cloud and network or other technical aspects are asked here. (Fachkern Medien und Informatik, 2019)

The *socio-cultural perspective* examines *how it affects you* regarding the interactions of the digital networked world with individuals and society. It examines questions, for example: How do digital media affect individuals and society, how can one assess information, develop one's own points of view and influence social and technological developments? How can society and individuals help shape digital culture and cultivation? (Döbeli Honegger, 2017)

This perspective explains how much consumerism is good, how to protect yourself from cyberbullying, how Whatsapp earns money, communication rules and so on. (Fachkern Medien und Informatik, 2019)

The *application-oriented perspective* is concerned with the question of *how to use something*. It focuses on the targeted selection of systems and their effective and efficient use for the implementation of individual and cooperative projects. It investigates questions of how and why tools are selected and used. This requires an orientation with regard to the existing possibilities and functional scope of common tools in the respective application domain and their safe handling." (Döbeli Honegger, 2017)

From the user's point of view it is important to know how to use Whatsapp correctly (privacy, what to say etc), why use Whatsapp and not alternatives (advantages and disadvantages) or similar questions. (Fachkern Medien und Informatik, 2019)

"It's difficult to make predictions, especially about the future."

Mark Twain

5 Scenarios

The future is fundamentally characterised by uncertainty, in the light of the increasing complexity and insecurity of social and natural conditions. The aim of scenarios is to generate an orientation with regard to future developments by considering certain relevant key factors. (Kosow & Gassner, 2008)

The term *scenario* is a fuzzy concept sometimes used differently. Thereby, the majority of field-related authors can identify an implicitly shared basic understanding of what a scenario is. A scenario is defined by many authors as the "presentation of a possible future situation including the development paths leading to the future situation". (Kosow & Gassner, 2008, p.9)

This thesis uses the methodology developed by Kosow and Gassner (2008) in one of the most comprehensive studies describing the scenario technique as a way to project the future.

Three aspects have to be considered: Scenarios do not represent a comprehensive picture of the future, because the focus is directed at one or more specific, defined sections of reality. It is also a matter of design work with regard to the selection and combination of key factors. Certain factors and events are deliberately regarded as (partly subjective) relevant or neglected. Third, scenarios are based on assumptions and hypotheses. Furthermore, there are three ways of looking at the future. The future can be evolutionary, predictable or shapable. (Kosow & Gassner, 2008) All of the following statements and statements are based on the findings of the previous chapters and the insights gained from the expert interviews.

"Like e-commerce solves the problem of shopping, new energy vehicles solve pollution problems, and AI can realise the fairness and modernisation of educational resources. And internationalisation, and most importantly, it can help children get the ultimate personalised education."

Xiaoping Xu

5.1 Expert Discussions

This subsection explains why I chose these experts. The entire audio recordings of the interviews can be found on the CD which was handed in with this work.

Several interviews were conducted in the scope of this work. Each interviewee is an expert in his field. The goal was to get an overview from different perspectives. The most obvious is the pedagocial, therefore i chose to select two teachers; Christof Müller and Mathias Marogg. It was very crucial for me to chose at least two teachers, because it was clear to me, that this is the most important factor of influence. Luckily i could choose these teachers, which had also very interesting additional functions. Secondly, I wanted to interview a person with educational-political background. I was happy to find Benedict Zemp and Monika Bucher, both scientific assistants at the BKZ. Both are experts in their field and Monika was involved in the whole development process of the Lehrplan 21. Gregory Turkawka is scientific assistant at the PHZH and has worked with several organisations on multiple projects in the field of education. This allows a further perspective, from a more scientific point of view.

Monika Bucher: Scientific Assistant at Lehrplan 21/BKZ
Monika Bucher is a scientific assistant at the *BKZ Geschäftsstelle*, which is a successor organisation of the D-EDK. Since the beginning of the development of the Lehrplan 21 she has been involved in the project management of several subjects. Among others in the subject media and informatics (MI). She is managing director at the Swiss-German level for languages and resposible for external evaluation of schools (Interkantonale Arbeitsgemeinschaft Externe Evaluation von Schulen, argev). Furthermore, she also manages the central Swiss education server, *Zebis*, and the *Netzwerk Lehrmittel*. The interview was taken in Lucerne, on Oct. 14, 2019.

Tommaso Forciniti: Teacher
The secondary school teacher Tommaso Forciniti is teacher in a short-term gymnasium in Aargau.

Mathias Marogg: Young Teacher and Future Head Teacher, Member of MIB
Mathias Marogg is a teacher at the primary school in Planken, Liechtenstein since four years. Planken is the second primary school in Liechtenstein which offers all its pupils a tablet. This has been introduced more than two years ago, after the primary school Ruggell did this as the first school in Liechtenstein. Because he already has experience using tablets in school he was asked to become a member of the MIB, as a pedagogical media consultant. The MIB was founded in Summer, 2019. What also makes him interesting as an interview partner is the fact that he is in education to become a school director, what allows an additional perspective on everyday school life. The interview was taken in Planken, Liechtenstein, on Sept. 26, 2019.

Christof Müller: Founder of schabi.com, Member of SCHU::COM, and Teacher
This interviewee was chosen because of multiple reasons. First, Christof Müller created the website www.schabi.ch (Schabi is an abbreviation for *Schule am Bildschirm*) which aims to teach pupils additional content next to the curriculum. Second, he works in the school and computer department (SCHU::COM) for the city of Winterthur. And third, since 2010 he is a primary school teacher. The interview was taken in Winterhur, on Sept. 11, 2019.

Gregory Turkawka: Scientific Assistant at PHZH
Gregory Turkawka is a scientific assistant at the Zurich University of Teacher Education (PHZH). He works in the field of digital learning and is responsible for digital learning environments where he is working in several projects with the *Institute for Projects in Education* (Institut für internationale Bildungsentwicklung, IB). He is a former teacher, mayor of the municipality Regensberg and studying Game Design at ZHDK Zurich University of the Arts in its Master program which allows him a versatile view on this topic. The interview was taken in Zurich, on Oct. 9, 2019.

Benedict Zemp: Scientific Assistant at Lehrplan 21/BKZ
Benedict Zemp is scientific assistant at the *BKZ Geschäftsstelle*. He is the contact person for the cantons and has drawn up the cantonal curricula for the Lehrplan 21 in collaboration with the cantonal representatives. He is responsible for enquiries, communication and media regarding the Lehrplan 21. He is also managing director of the Northwestern Swiss Conference of Cantonal Ministers of Education (NW-EDK). The interview was taken in Lucerne, on Oct. 14, 2019.

"I refuse to make predictions."

Berthold Horn

5.2 Scenario Set Up

Like R. Bucher (2018), I will limit the observation period for the scenarios to a maximum of five years. This observation period is chosen because it is assumed that for scenarios that lie further in the future, the spread would be too great and it would make it more difficult to assess and make a recommendation. The procedure for generating the scenarios is based on five phases, illustrated in the next figure (Kosow & Gassner, 2008).

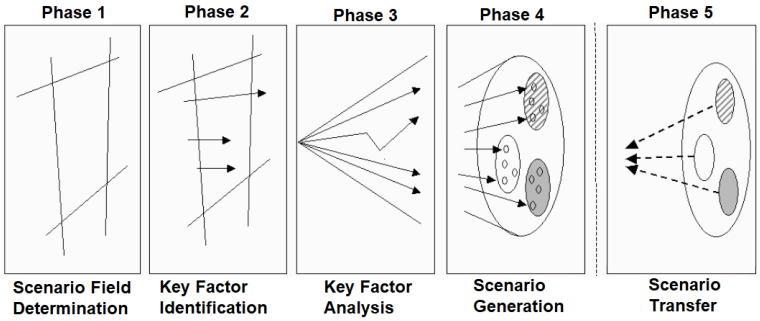

Figure 27: General scenario process, illustration translated from Kosow and Gassner (2008, p.20)

In a first phase, the subject of the scenario is defined. In this paper, an impact assessment of AI on the field of education is presented. In particular, primary schools in the Lehrplan 21 area are to be examined. The future is seen as shapeable, as it is in Bucher's work. This work is in line with Bucher (2018) in his opinion that the development and application of AI is open and can be influenced by the actions of various stakeholders and decision-makers in education, development, politics, and the users.

Second, the *key factors* (KF) are identified. For the following scenarios, the same key factors as R. Bucher (2018) are chosen and his *influencing factors* (IF) were used as an orientation. KF_1 is called *development of AI* and KF_2 deals with the *framework conditions* of AI. Multiple influencing factors are combined to one key factor as illustrated in Figure 28. These key factors are analysed in phase three. Two influencing factors have been identified for KF_1, namely *history of AI* and *technological developments*. For KF_2, five influencing factors on the the following levels were identified: *Individual*, *school*, *educational system*, *economy*, and *legal*. Thereby information from literature and from experts are considered, where KF_1 is influenced globally and KF_2 is influenced by Swiss framework conditions.

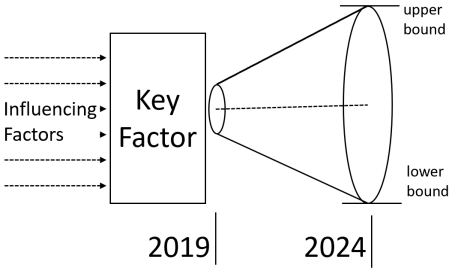

Figure 28: General scenario structure, own illustration, derived from R. Bucher (2018)

In a fourth step, the scenarios are created. This is done by creating upper and lower bounds of both key factors (A_1 and A_2 for KF_1, and B_1 and B_2 for KF_2). These *extreme futures* are combined and individually analysed in chapter 5.2.3. It is assumed that the scenario process is explorative and qualitative (Kosow & Gassner, 2008). The scenario process in the strict sense ends after these four phases and the scenario transfer is optional (Kosow & Gassner, 2008, p.22p).

Phase 5 describes the use of the scenarios. There is a wide range of analysis options (Kosow & Gassner, 2008).

The following key and influencing factors will be discussed:

- **KF_1: Development of AI**
  - IF 1.1: History of AI
  - IF 1.2: Technological Developments
- **KF_2: Framework Conditions**
  - IF 2.1: Individual
  - IF 2.2: School
  - IF 2.3: Education System
  - IF 2.4: Economy
  - IF 2.5: Legal

5.2.1 Key Factor 1: Development of AI

This subsection examines the influences on and development of AI. This is conducted using two influencing factors, *history of AI* on one hand and *technological developments* on the other. A scenario analysis with a time horizon of five years shall be executed and will provide two future states named A_1 and A_2, as seen in Figure 29. Following, the author will refer to these two extremes as *A_1: Best development* in which one might perceive AI as a "cure-all" and *A_2: Worst development* where the perceived benefit of AI is stagnating and even perceived as demonising.

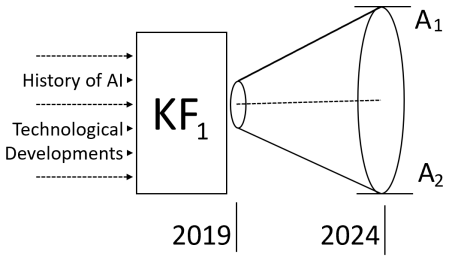

Figure 29: Scenario structure, own illustration, derived from R. Bucher (2018)

IF 1.1: History of AI

As described in chapter 2.2, there have been several hypes around AI, but also there have been AI winters. A trend towards higher usage of technology in teaching continues and the distances between the milestones that are reached in association with AI, are shortened as indicated in the list of milestones in computer history on page 21pp. But the opinions regarding predictions based on the past vary (Bostrom & Yudkowsky, 2014; Crevier, 1993).

> "Let's not forget, though, that the other most common mistake in technological forecasting is to underestimate long-term achievements. The onlookers at Kitty Hawk never imagined today's airliners. Marie Curie never thought of Nagasaki. Believing today in the failure of AI would be like deciding, after the Vanguard flops in the 1950s, that space travel was impossible." (Crevier, 1993, p.7)

> "Technology first removed much of the dirt, sweat, and dangers from physical work. Then it took away many of the dull mental tasks that could be automated, and now it threatens to even displace some tasks that require expert decision-making."
>
> *Fadel et al. (2015)*

IF 1.2: Technological Developments

The author assumes, that computing technology develops in a way that Ray Kurzweil predicts. That includes the exponential growth of computing, which is also illustrated in Figure 30. When a certain point in an exponential development is reached, the output value will explode. Then it should be possible to build an artificial neural network that is faster than a human brain, which is physically possible already, today (Bostrom & Yudkowsky, 2014). This point is expected after the time horizon of the scenarios.

As shown in chapter 4.2, leading developers in the field of AI are mostly private. This thesis agrees with other authors (Liu, 2019) and the experts interviewed (Turkawka, 2019, 1:12:30, Müller, 2019, 59:05), which assume that private companies will have the lead in technological developments regarding education. Private companies are economically motivated by default and research depends on some other aspects as well which discussed in the following chapter 5.2.2.

"An important point to underscore here is that we may not be able to stop the accelerating progress of invention and technology, but we can carefully manage how they are used in our lives."

Fadel et al. (2015)

Evaluation of Key Factor 1

This subsection examines the influences on and development of AI. Best case development in terms of possibilities is a double-edged sword. According to Bostrom (2002), superintelligence (ASI) is one of several *existential risks* meaning "where an adverse outcome would either annihilate Earth-originating intelligent life or permanently and drastically curtail its potential." The scenario outcome on the upper bound A_1 could turn out as a distopian future where the the superintelligent AI turns agains human kind. This scenario, however, cannot be taken into account, due to it's contradictive nature. Furthermore, it can be assumed, that such a state would be further in the future than five years.

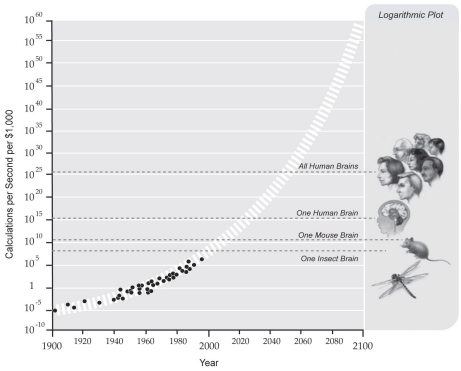

Figure 30: Exponential growth of computing in 20th and 21st Century, derived from Kurzweil (n.d.)

On the other hand, "a positive outcome for superintelligence could preserve Earth-originating intelligent life and fulfill its potential" (Bostrom & Yudkowsky, 2014). This prediction would include education systems that are relevant for this thesis.

In scenario $\mathbf{A_1}$, which predicts the **best technological development**, progress proves to be faster than predicted. In this case, AI will also affect and improve more spheres of human life.

Therefore the **worst technological development $\mathbf{A_2}$**, would be stagnation in AI technology development and application. A complete loss of knowledge (negative development) in the field of technology is highly unlikely and can therefore be neglected.

5.2.2 Key Factor 2: Framework Conditions

In addition to the rate of technological advancements of AI, which have been analysed in the previous subsection, there is a range of other considerations.

As indicated in Figure 31, multiple factors influence KF_2. The author choses *individual*, *school*, *education system* , *economy* and *legal* in agreement with other authors. It must be noted that these factors are in some cases overlapping.

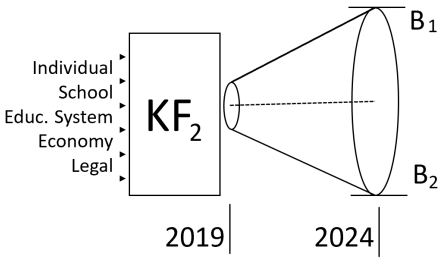

Figure 31: Scenario structure, own illustration, derived from R. Bucher (2018)

The output of this scenario creation will provide two future points of extreme nature titled B_1 and B_2, as illustrated in Figure 31. The author will refer to them as *B_1: Best framework conditions* where optimistic assumptions are made and *B_2: Worst framework conditions* where a version of the future is predicted.

IF 2.1: Individual Acceptance and Trust

Döbeli Honegger (2016) identified three influencing factors of which the *individual level* is one. The factor has been complemented with the IF *Acceptance / Trust* found by R. Bucher (2018). In a similar way *public adoption* was identified as one key influencing factor by a study of the World Economic Forum (2018, p.7).

The desciption of this factor takes into account the perspective of parents, children and teachers.

The acceptance of AI is strongly dependent on concerns about biases (Bucher2018) concerns of data protection and privacy (J. Anderson, 2019), uncertainty concerning the value added (Bucher & Zemp, 2019, 44:15), dependency on technology providers (J. Anderson, 2019), the ease of implementation, personal preferences, experiences and competencies of teachers, students and parents (Döbeli Honegger, 2016). Furthermore, trust is dependent on the handling and ease of commercialisation plays (World Economic Forum, 2018, p.7).

Turkawka clarifies that parents are often overwhelmed and unfamiliar with today's technology based practices. Oftentimes the optimum for the children is not fully overlapping with the parents' point of view. The preference of teachers for new methods is not taken as the truth by parents, as it was the case in the past. (Turkawka, 2019, 13:05)

Döbeli Honegger (2016, p.105) still identifies the teacher as the most important factor in the equasion. Marogg understands certain insecurities and fears (Marogg, 2019, 37:40). Turkawka adds that it can be particularly difficult for teachers to accept that a machine performs a tasks better than they do. It certainly helps if relevant case studies and examples are presented. (Turkawka, 2019, 58:50) Turkawka adds that students usually are the least skeptic compared to teachers, school management and parents (Turkawka, 2019, 35:45).

Gerald Knezek et al. have found three factors which provide surprisingly accurate predictions as to whether and to what extent teachers will use digital media in their teaching. This model is called *Will-Skill-Tool Model* and can be found on page 51 (Döbeli Honegger, 2016, p.105).

In the 1962 book *Diffusion of Innovations* Rogers described a model on how people react to innovations. He differentiates between innovators, early adopters, early majority, late majority, and laggards. (Döbeli Honegger, 2016)

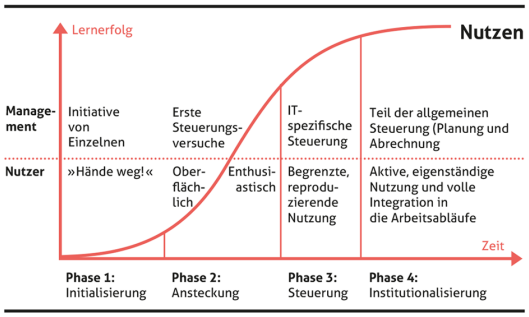

Figure 32: Breiter's phase model of the organisational learning curve in embedding ICT in schools, illustration from Döbeli Honegger (2016, p.109)

The model presented in Figure 32 is comparable. The first of the four phases is *Initialisation*, where individual enthusiasts use the new technology. During the *Contagion* phase, the technology is spread rapidly and superficially among users, and the first attempts are made to control it. The third phase, *Control*, finds repeated and more targeted use with simultaneous massive, technology-specific control attempts by the decision makers. In *Institutionalisation*, the organisation returns to its actual goals, turning away from technological objectives and fully integrating technology into workflows. (Döbeli Honegger, 2016)

This model shows, that technology will be adapted over time under the condition that a certain added benefit is realised.

IF 2.2: Teaching and Education Surroundings

R. Bucher (2018) named this factor *Teaching / Teaching forms* and it can be aligned with one of three influencing factors identified by Döbeli Honegger (2016). Cultural differences amog schools and the requirements for further education influence the adaption of ICT. As Turkawka (2019, 6:15) explains, school administration has a huge impact on the school's daily teaching routines. Supportive school management, needs-based infrastructure, and both technological and pedagogical support have been identified as crucial drivers for an adequate realisation of ICT and AI implementation.

Private schools are innovation-friendlier and more flexible as Turkawka (2019) states. Furthermore, private schools often have higher budgets than public schools which enables an successful realisation.

The curriculum, however, makes no recommendations for tools to teachers. They are free to use any tool they see fit for use (Bucher & Zemp, 2019, 19:40).

IF 2.3: Education Policies

R. Bucher (2018), as well as Döbeli Honegger (2016) identify a factor called *Education Policy* as relevant in this system. This view is supported by Marogg.

Most decisions regarding changes have to be taken at the political level. (Marogg, 2019, 16:10) Policies are associated with an inherent level of instability regarding elections and changes of leadership occurring every few years. There are educational policy guidelines and curricula defined and financial resources allocated. Oftentimes cantons and schools and not teachers decide about appropriate digital teaching materials. Apart from acceptance and trust, Turkawka sees one of the biggest challenges regarding the development of AI in the school environment in the budget allocated for it. This has been identified as the most limiting factor by Liu (2019), as well. Investments in infrastructure are very costly, and often recurring every semester. Currently, in most cases such costs for technology are not included in the budget planning. (Turkawka, 2019, 1:01:50) Bucher considers costs to be the first and most important factor in this system (Bucher & Zemp, 2019, 43:30).

It is important to have appropriate syllabi on one hand, but also that the appropriate funds are made available.

Turkawka adds, it is important that smart solutions are offered, and no hasty decisions without expertise are made. Often, these initiatives have no positive effect on education and money is squandered. Unfortunately, Turkawka observes this phenomenon and perceives it as a hindrance for beneficial education policies. (Turkawka, 2019, 1:06:15) It would be desirable that politicians are advised by more experts when making decisions about such complex topics as AI in combination with education (Turkawka, 2019, 1:05:45).

Furthermore, it seems important to collaborate within a respective canton in initiating such programs as oposed to the implementation in every school district on its own (Turkawka, 2019, 1:04:00).

Switzerland having 8 million inhabitants is rather flexible compaired to bigger countries and in addition rather prosperous. Nevertheless, bureaucratic processes can slow down policy changes compared to international peers. Oftentimes it is difficult to find a consensus on a political level (Fadel et al., 2015) but the Swiss system is consensus seeking by design which helps a great deal.

IF 2.4: Economical Goals

This IF is a combination of two factors identified by R. Bucher (2018), called *Economy* and *Entrepreneurial Goals*. Furthermore, it has also been selected by the World Economic Forum (2018, p.7).

Budgetary limitations have been identified as one of the major influences in the education system. This insight is true of the IFs. The higher the demand for AI, the higher the economic activity in the field.

A second economical angle concerns the job market. Depending on the needs of the future job market

the requirements for education varies. That means for example AI may not be relevant for education, because the economy is fully automated and other (creative) jobs are needed or opposingly the market needs a lot of AI experts to develop and maintain the technology.

IF 2.5: Legal Perspective

Influences from the *legal* perspective were highlighted by R. Bucher (2018) and the World Economic Forum (2018, p.7).

As long as the data is protected, which is possible on a technical level, monitoring applications are a possibility. Today, Turkawka explains, exams are taken and students are evaluated, too and this data is protected, as well. (Turkawka, 2019, 58:20) Through more targeted support of AI, the students' cognitive abilities can be significantly enhanced. This is only possible when sufficient data about students can be collected and evaluated. (Turkawka, 2019, 37:40) It is crucial that in the field of data collection and analysis, suitable laws are created or adapted. A balance between usability and data security must be achieved (Müller, 2019, 31:55). There are further concerns about how to handle the results generated by AI.

Compared to America or China, the EU has stict regulations on data protection and privacy. This might be a disadvantage in the application of AI. It is assumed, that more liberal data protection laws promote the development of AI.

As mentioned before, the research, funding and development can be promoted or prevented by laws.

Evaluation of Key Factor 2

Unwillingness from teachers, a lack of budget and a lack of understanding around benefits have been identified as the biggest barriers to using ICT and AI in the classroom (Rogers, 2019, p.10). Further, unwillingness as a barrier has even increased since last year, according to the same report. The identification of these IFs can be supported in this work, as well.

In general, Turkawka states Switzerland has great framework conditions. One factor is outstanding universities like ETH and EPFL which are highly connected to the market. Good conditions are also reflected in the high number of international (tech-)companies located in Switzerland. However, even more integration between the universities and the rest of the education area would be desirable. (Turkawka, 2019, 51:30) However, Turkawka stresses the importance of remaining liberal in respect to policies (Turkawka, 2019, 54:05). In the end, one of the most important elemts in the system is the teacher.

In the **best framework conditions $\mathbf{B_1}$**, schools fully adapt the technology and all levels support the implementation. Intelligent tutoring systems and interactive learning environments are are established and well used in the education environment. Technology-based applications enhance the individualization of learning.

The popularity, acceptance and trust of AI is high in this case. Information technology is utilised in order to engage society, politics and governments. The legal framework conditions are being optimised to ensure that privacy and data protection benefits the entire population.

$\mathbf{B_2}$ describes the **worst framework conditions**, where acceptance is low, people do not trust the technology and even try to avoid it. At school, technology is kept to a minimum. Policymakers do not even think about getting involved in technology-based methods and tools. Economic interest is low, no startups are founded and no funding is allocated. Laws, as well prevent or limit the possibilities of AI. In this case, a *AI winter* prevails.

5.2.3 Scenario Generation

A probability analysis for the scenarios cannot be performed in the boundaries. The scenario transfer includes assessments of the scenarios and their possible influence on the education system. In this paragraph, the different alternative futures A_1, A_2, B_1, and B_2, defined in the previous subsection delivered, are juxtaposed. Special attention will be paid to the two extremes.

Best Development of AI (A_1) and Best Framework Conditions (B_1)

In this version of the future, the technology is developed into a useful product. All the advantages listed in chapter 3.4.3 (page 56p) can be fully exploited.

Technology adaptation allows for individual support. It is therefore imaginable, what Turkawka says, that in the future classes are not grouped by age anymore but by performance per subject (age-mixed classes). Each individual level can be addressed with dynamic goals and variable times for each individual subject. (Turkawka, 2019, 32:55)

In an already technology-friendly environment where everybody is using it much more than today, it is conceivable that technology around teaching will gain enormously in popularity. Again, this advancement stems mainly from private companies.

Intelligent tutoring systems will be commonly applied. Technologies such as VR/AR allow students to experience learning using multiple senses. Bucher hopes for an even more diversified school life in the future. Individualised instruction as well as technology will increase the possibilities to improve personalisation. It remains important to teach children non-digital skills and competences and not only skills for the digital life. (Bucher & Zemp, 2019, 36:35)

The economy is as well encouraging the development of AI and a variety of applications is made available. Most aspects of an *Industry 4.0* became reality.

In an international comparison AI-based education in China is flurishing and intelligent tutoring systems are well-used. Technological breakthroughts can be achieved.

Best Development of AI (A_1) and Worst Framework Conditions (B_2)

This scenario describes a future where in principle there is the technological possibility, but it is enormously restrained by the surrounding conditions. Acceptance and trust is on a very low level, individuals fear the technology and avoid it. Politics block policy changes to avoid technological progress or even prohibit the use of AI. Schools are required to use as little technology as possible. The technologically advanced means can only be used in selected circles.

Worst Development of AI (A_2) and Best Framework Conditions (B_1)

If the technological development and especially the development of AI does not meet expectations set by individuals, school, politics and the economy, but the framework conditions which are good now, increase to an even better level, school education is not changing very much. Some new concepts like gamification will be applied. Switzerland is in a good international position and countries that have invested in AI cannot exploit the hoped-for advantage. In the field of technology not a lot innovations happen, thus Switzerland is at the forefront.

Worst Development of AI (A_2) and Worst Framework Conditions (B_2)

In this scenario, the technological progress is stagnating and the framework conditions regarding AI are unfavourable from a individual, school, political, economic and legal point of view.

The worst case scenario would be the misuse of the technology, as Zemp articulates it. This would be the case, if students only used their tools in isolation. The importance of and focus on interaction between pupils and teachers should prevail in the future school life. (Bucher & Zemp, 2019, 35:55)

Another critical trend called "Zuboff's Laws" states firstly, that everything that can be automated will be automated, secondly that everything that can be informated will be informated and thirdly, every digital application that can be used for surveillance and control will be used for surveillance and control (Dehaye, 2018, min: 15:13). This can be a reason for the worst case scenario.

For Marogg, one worst case scenario would be to stick to current conditions for a long time to come. Infinite possibilities arise from technology and it would be negligent to withhold them from the students. It would be a great pity if teachers refused to train themselves further. It would be unacceptable if the education system would not reflect the reality in for example the job market. (Marogg, 2019, 36:40)

Switzerland is losing its leading position in the comparison of international education systems. An *AI winter* is in town.

Finally, I would not like to deprive you of one subsection called *The Impact on Learning* in Ray Kurweil's book *The Singularity Is Near - When Humans Transcend Biology*. This subchapter, in which the inventor and futurist Kurzweil deals with the effects of singularity on education, can be found in the appendix on page 106.

"AI will be the best or worst thing ever for humanity."

Elon Musk

6 Discussion

This chapter first briefly answers the research questions posed. These are then interpreted and a conclusion is drawn. Limitations and uncertainties are outlined and finally further thoughts are formulated.

6.1 Summary

This chapter shall summarise the previously defined research questions:

RQ 1: What skills and competences are learned in school today?

On primary level education, the *Lehrplan 21* recommends the following allocation of subjects over six years, as shown in Table 2 on page 33:

- The reference value (RV) for *German* is 19%, while the actual taught average is 20%.
- The RV and the actual taught average for the *First Foreign Language* is 6%.
- The RV and the actual taught average for the *Second Foreign Language* is 3%.
- The RV for *Mathematics* is 18%, while the actual taught average is 19%.
- The RV for *General Science and Social Studies* is 21%, while the actual taught average is 19%.
- The RV for *Artistic, Textile and Technical Design* is 14%, while the actual taught average is 16%.
- The RV and the actual taught average for *Music* is 7%.
- The RV and while the actual taught average for *Exercise and Sports* is 11%.
- The RV and the actual taught average for *Media and Informatics* is 1%.
- In total a RV of 168 lessons (45min) is proposed and the actual taught average is 167 (100%).

In addition, *education for sustainable development* and *transversal competences* are two modules that are integrated into other subjects and deal with cross-disciplinary topics The curriculum is mainly adapted and harmonised.

RQ 2: What skills and competences are needed in future?

The traditional subjects have hardly lost their importance but knowledge has lost importance. Today, understanding is promoted more.

A focus should be set on skills and competences which cannot be replaced by the computer.

Next to the skills and competenced aquired in the *traditional subjects*, a focus should be set on the competences introduced in the *4C model*. The *Four-Dimensional Education Model* supplemented this skills dimension by three further dimensions, namely character, knowledge and meta-learning.

The following new competences have been identified: creativity, critical thinking, communication, collaboration (4C), computional thinking, digital literacy, networked thinking, self-mindfulness, resilience, environmental literacy, lifelong learning, courage, ethics, and leadership.

RQ 3: Is there a skill gap?

There has always been and always will be a gap in skills and competences. The Swiss curriculum is very progressive and adaptive compared to international standards. The World Economic Forum (2018, p.22) reveales Switzerland as the country with the least required reskilling days for the year 2022.

This work was able to reveal a progressive picture of Switzerland's education system, particularly in the digital field. Also the *4C model* was considered in the new curriculum.

RQ 4: Future scenarios

The first key factor *KF_1: Development of AI* is influenced by the *History of AI* and *Technological Developments*. The second key factor *KF_2: Framework Conditions* is affected by several levels: *Individual Acceptance and Trust*, *Teaching and Education Surroundings*, *Education Policies*, *Economical Goals* and the *Legal Perspective*.

For each KF two extreme futures have been created and these have each been juxtaposed. This results in four scenarios (best-best, worst-best, best-worst, worst-worst) which can be found on page 82. Special attention should be paid to the two extremes.

RQ 5: What considerations have to be taken into account?

Artificial intelligence is a complex topic of which the impact should not be underestimated. As R. Bucher (2018) has concluded with some opportunities and risks. It's of imense importance to keep the curriculum updated and educate people, especially teachers. This is only possible through appropriate allocation of budgets.

"Ein Computer in der Hand von Lernenden ist ein effektiveres Werkzeug als ein Computer in der Hand von Lehrerinnen und Lehrern."

Dominik Petko

6.2 Conclusion

School is a highly complex system where children learn about themselves and the whole world. We live in a world characterised by change at an unprecedented pace. Digititalisation contributes to that enormously and AI is a driving force behind this development. The economy and society are making new demands in a much more interconnected world.

Contrary to expectations of the author, there have been comprehensive changes in education in the Lehrplan 21 area, as well. Four new subjects and almost infinitely many new methods and tools have been adopted. Technology improves individual, inclusive and equitable quality education. Individual teaching promotes many of the skills and competencies identified as important (see chapter 3.3.3). This is made possible by technology, which influences more and more areas in schools. More individual teaching means that children can learn according to their level of expertise and interest. A move away from age-based classes towards level-based classes will further encourage this. However, there are also critical voices (Weibel, 2016). The fact that the teacher serves only as a coach and helping each other becomes more of a focus for students has advantages – but it can also be a dilemma. Further challenges must be identified while moving further in a digital direction.

Switzerland and Liechtenstein are well positioned for the future and offer suitable framework conditions (KF2). There are several initiatives that are driving the successful implementation of technology and STEM-related skills and competences (Das Schweizer Parlament, 2017; Schwendener, 2019). The skills and competences taught in the Swiss education system correspond to the demands of the economy very well. Further, Switzerland is among the most competitive countries in the 2018 IMD World Talent Ranking. (IMD, 2018) Some gaps were identified, but development of the education system lags per definition behind the demands of the market.

A harmonisation between (at least) the German-speaking cantons is desirable. Since, this could improve the quality and lower the costs of teaching materials, simplifies the mobility of families with childern within Switzerland (D-EDK, 2017).

Further training for teachers has been identified as a key factor in harvesting the benefits of technology (Döbeli Honegger, 2016; Lozza, 2015), as they need to know models like *4C*, *TPACK* and *SAMR*. School is paramount in our society and therefore the discussion should be as inclusive as possible. As a consequence of that, the allocation of appropriate budgets must be ensured.

However, there are major differences in the implementation of methods and tools depending on geography and teacher. It can be assumed, that AI will find its way into the classroms. However, this will happen slowly and partially hidden in the long term. Technological evolution takes its time and needs it for everybody and everything to adapt properly. Flexible curricula where subjects are adapted are important, too. The world is getting more complex and interconnected and the subjects should mirror that fact.

It is of crucial importance not to chose the easiest way (e.g. "give everybody an iPad"), but the best, from the student's point of view (e.g. "teach media competence combined with tools"). Technology should be used carefully and proven subjects should be kept in the scedule. Subjects surrounding physical wellness, manual work, and creativity for instance.

As already mentioned several times, the proper implementation of ICT in the classrom is heavily dependent on the teacher. How technology shapes the future of our schools in a positive way, is decided

by how well teachers are prepaired for the digital future. No matter how advanced technology will become, AI cannot, at least in the forethinkable future, replace the role of a teacher completely.

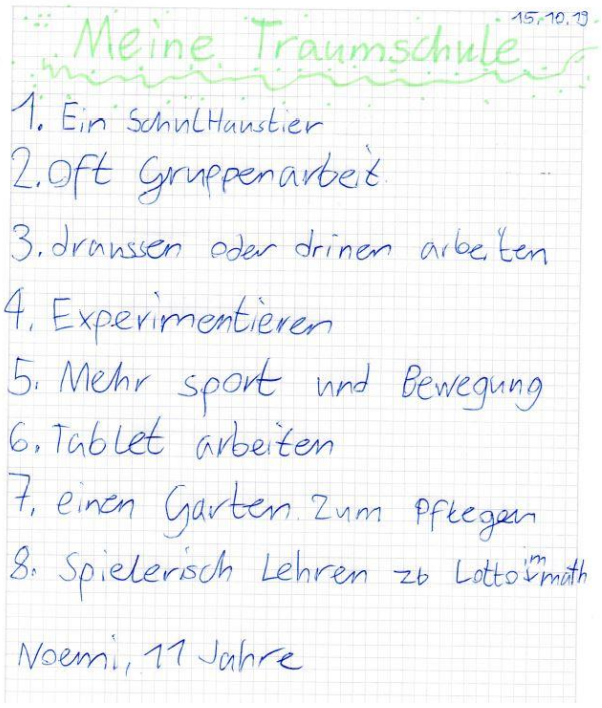

Figure 33: A pupil describes her dream school, found on Linkedin (16.10.19)

"Artificial intelligence is destroying the traditional world of work."

Beppe Grillo

6.3 Limitations and Uncertainties

There are certain limitations to the creation of scenarios. On the one hand, it is a closed system in which only the selected influencing factors have an impact. Some factors may have been forgotten. In addition, interactions can arise that are very difficult to predict and only extreme future effects were generated with the method chosen here.

The selection of experts interviewed for this thesis is based upon availability and not professional status per se.

The object of investigation of AI-based education is enormously broad, strongly growing and rather volatile. The companies and products presented here serve only as examples and should reflect the diversity. In general the methods chosen are of qualitative nature further studies could quantify the effects.

All these limitations stem from the limited time and resources available for a master thesis.

A distinct definition of skills and competences could be of further interest.

Most of the skills identified in subsection 3.3.3 are rather soft skills. It is difficult to define them, to teach them and even more difficult to measure them. Thus an imense responsibility lies with the teacher. Again. They are mainly taught in the minor subjects *education for sustainable development* and *transversal competences*.

"Those who can imagine anything,
can create the impossible."

Alan Turing

6.4 Further Thoughts

There are a lot of technological breakthroughs that lead to rapid shifts of the frontiers between the work tasks performed by humans and those performed by machines and algorithms (World Economic Forum, 2018, p.3). The future is increasingly challenging, as economy and society change. Children are becoming more diverse as Marogg (2019) elucidates, there are more and more differences amog them. However, precisely these differences must be promoted. In the course of this work a few further thoughts were discovered and are mentioned here:

- There are some things that can be questioned in the current education system, in revealing the full potential of the students. As Turkawka (2019, 34:40) mentions, grading as it is done today must be questioned critically. Furger and Burri (2018) elaborate that grading leads to an improvement of students weaknesses rather than their strengts, which might be more interesting for society.
- To what extent will school be needed in the future? Are there other (better) possibilities for education? Is school a place to teach the children or is it a place of care so parents can work and children are socialised?
- The experts do not agree on the duration of compulsory schooling. It is proposesed to prolong the school time so that the learned knowledge can be internalised more sustainable (Furger & Burri, 2018). Turkawka, on the other hand, proposes for it to be shortened (Turkawka, 2019, 1:08:40).
- AI is gaining attention and needs a lot of policies. For example, what happens if an intelligent machine makes an error. Who is responsible in that case?
- As World Economic Forum (2018) reveals, new technologies and labour augmentation will boost productivity, incomes and wealth. It is important that "governments may find that increased tax revenues provide scope to enhance social safety nets to better support those who may need support to adjust to the new labour market. This could be achieved through reforming and extending existing social protection schemes, or through moving to a wholly new model such as the idea of basic income and basic services." (World Economic Forum, 2018, p.22)
- It is important to take people's fear of technology and especially AI serious. This is achieved through training and education and should start at a young age.
- The author likes the idea of Turkawka of a "Swiss Label" in the context of AI that ensures a certain quality based on the latest technology and privacy standards, including ethically acceptable guidelines. (Turkawka, 2019, 54:15) This would help to counteract skepticism.
- It is important to have some screen-free time, how this fact is taken into account, needs further research.

"Don't cry because it's over,
smile because it happened."

Dr. Seuss (Theodor Seuss Geisel)

7 Appendix

7.1 List of Abbreviations

This subsection shows two lists of abbreviations. The first list represents general abbreviations with reference to the topic of this work. Generally, the abbreviation is written in the language the abbreviation comes from and then translated into German, respectively English. The second list records all the Swiss cantons and their abbreviation.

ADL	Altersdurchmischtes Lernen	
ADM	Automated Decision Making	
AGI	Artificial General Intelligence	
AI	Artificial Intelligence	(Künstliche Intelligenz)
ANI	Artificial Narrow Intelligence	
ANN	Artificial Neural Network	
App	Application to download for smartphone or tablet (Anwendungsprogramm für Smartphone / Tablet)	
ASI	Artificial Super Intelligence	
BKZ	Bildungsdirektoren-Konferenz Zentralschweiz	
BNE	Bildug für nachhaltige Entwicklung	(Education for sustainable developlemt)
BYOD	Bring Your Own Device	("Bring dein eigenes Gerät mit")
CAI	Computer-Assisted Instruction	
CCR	Center for Curriculum Redesign	
CNN	Convolutional Neural Network	("faltendes neuronales Netzwerk")
DaZ	Deutsch als Zweitsprache	("German as a foreign language")
DNN	Deep Neural Network	
e.g.	exempli gratia [lat.]	(for example)
EDK	Erziehungsdirektoren-Konferenz ("Conference of Cantonal Ministers of Education")	
etc.	et cetera [lat.]	("und die übrigen Dinge")
GDPR	General Data Protection Regulation	(Datenschutz-Grundverordnung)
GNR	Genetik, Nanotechnik und Robotik	(Genetics, Nanotechnology, and Robotics)

GOFAI	Good Old-Fashioned Artificial Intelligence	
GUI	Graphical User Interface	(Grafische Benutzeroberfläche/-schnittstelle)
i.e.	id est [lat.]	("in other words")
ICT	Information and Communications Technology (Informations- und Kommunikationstechnik)	
ICT CFT	ICT Competency Framework for Teachers	(IKT Kompetenzrahmen für LehrerInnen)
IF	Influencing Factor	(Einflussfaktor)
ILE	Interactive Learning Environment	
iOS	Apple's Mobile Operating System	(Apple's mobiles Betriebssystem)
IQ	Intelligence Quotient	(Intelligenzquotient)
ITS	Intelligent Tutoring System	
K-12	Prim. und sek. Bildungsbereich, Abk. für "Kindergarten bis 12. Schuljahr" (Kindergarten to 12th grade, primary and secondary education)	
KF	Key Factor	(Schlüsselfaktor)
KI	Künstliche Intelligenz	(Artificial Intelligence)
LCH	Dachverband Lehrerinnen und Lehrer Schweiz (Swiss Association of Teachers)	
LLL	Lifelong Learning	(Lebenslanges Lernen)
LMS	Learning Management System	(Lernplattform)
LOL	Learning out Loud	
MI	Medien und Informatik	(Media and Informatics)
MIB	Medien und Informatik Berater	(Media and Informatics Consultant)
MINT	Mathematik, Informatik, Naturwissenschaft und Technik, MINT-Fächer (STEM fields)	
ML	Machine Learning	(Maschinelles Lernen)
MLP	Multilayer Perceptron	(Mehrlagiges Perzeptron)
MOOC	Massive Open Online Courses	("offener Massen-Online-Kurs")
NLG	Natural Language Generation	
NLP	Natural Language Processing	(natürliche Sprachverarbeitung)
NMG	Natur, Mensch, Gesellschaft	(General Science and Social Studies)
OCR	Optical Character Recognition	
ODL	Open and Distance Learning	

OECD	Organisation for Economic Co-operation and Development (Organisation für wirtschaftliche Zusammenarbeit und Entwicklung)	
OER	Open Educational Resources ("freie Lern- und Lehrmaterialien mit einer offenen Lizenz")	
PBL	Project-Based Learning (Projektbasiertes Lernen, Projektunterricht, Projektarbeit)	
PDF	Portable Document Format (datatype) ((trans)portables Dokumentenformat, Dateiformat)	
PH	Pädagogische Hochschule	(University of Teacher Education)
PLN	Personal Learning Network	(Persönliches Lernnetzwerk)
RNN	Recurrent Neural Network	("rückgekoppeltes neuronales Netzwerk")
RPL	Recognition of Prior Learning	
RV	Reference Value	(Referenzwert)
SCHILF	Schulinterne Lehrerinnen- und Lehrer Fortbildungskurse	
SCHILW	Schulinterne Weiterbildung	
SDG	Sustainable Development Goals	(Ziele für nachhaltige Entwicklung)
STEM	Science, Technology Engineering, and Mathematics, STEM fields (MINT-Fächer)	
UDL	Universal Design for Learning	
UN(O)	United Nations (Organisation)	(Vereinte Nationen)
UZH	University of Zurich	(Universität Zürich)
VLE	Virtual Learning Environment	
VUCA	Acronym to describe the future that will consist of greater volatility, uncertainty, complexity, and ambiguity (Zukunft geprägt von: Volatilität, Unsicherheit, Komplexität und Mehrdeutigkeit)	
WTO	World Trade Organisation	(Welthandelsorganisation, WHO)

This list shows the abbreviations of the 26 Swiss cantons and Liechtenstein, the translations to English are from Pöhland (n.d.).

AG	Aargau	(Aargau)
AI	Appenzell Innerrhoden	(Appenzell Inner-Rhodes)
AR	Appenzell Ausserrhoden	(Appenzell Outer-Rhodes)
BE	Bern	(Bern)
BL	Basel-Landschaft	(Basel District)
BS	Basel-Stadt	(Basel)
FL	Fürstentum Liechtenstein	(Principality of Liechtenstein)
FR	Freiburg	(Fribourg)
GE	Genf	(Geneva)
GL	Glarus	(Glarus)
GR	Graubünden	(Grisons)
JU	Jura	(Jura)
LU	Luzern	(Lucerne)
NE	Neuenburg	(Neuchâtel)
NW	Nidwalden	(Nidwalden)
OW	Obwalden	(Obwalden)
SG	St. Gallen	(St Gallen)
SH	Schaffhausen	(Schaffhausen)
SO	Solothurn	(Solothurn)
SZ	Schwyz	(Schwyz)
TG	Thurgau	(Thurgau)
TI	Tessin	(Ticino)
UR	Uri	(Uri)
VD	Waadt	(Vaud)
VS	Wallis	(Valais)
ZG	Zug	(Zug)
ZH	Zürich	(Zurich)

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7.3 List of Interviews

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7.4 List of Figures

7.5 List of Tables

7.6 Additional Information

This is a subchapter in chapter six of Raymond Kurweil's book *The Singularity Is Near - When Humans Transcend Biology* called *The Impact on Learning*:

> "Most education in the world today, including in the wealthier communities, is not much changed from the model offered by the monastic schools of fourteenth-century Europe. Schools remain highly centralized institutions built upon the scarce resources of buildings and teachers. The quality of education also varies enormously, depending on the wealth of the local community (the American tradition of funding education from property taxes clearly exacerbates this inequality), thus contributing to the have/have not divide.
>
> As with all of our other institutions we will ultimately move toward a decentralized educational system in which every person will have ready access to the highest-quality knowledge and instruction. We are now in the early stages of this transformation, but already the advent of the availability of vast knowledge on the Web, useful search engines, high-quality open Web courseware, and increasingly effective computer-assisted instruction are providing widespread and inexpensive access to education.
>
> Most major universities now provide extensive courses online, many of which are free. MIT's OpenCourseWare (OCW) initiative has been a leader in this effort. MIT offers nine hundred of its courses—half of all its course offerings—for free on the Web. These have already had a major impact on education around the world. For example, Brigitte Bouissou writes, "As a math teacher in France, I want to thank MIT ... for [these] very lucid lectures, which are a great help for preparing my own classes." Sajid Latif, an educator in Pakistan, has integrated the MIT OCW courses into his own curriculum. His Pakistani students regularly attend virtually-MIT classes as a substantial part of their education. MIT intends to have everyone of its courses online and open source (that is, free of charge for noncommercial use) by 2007.
>
> The U.S. Army already conducts all of its nonphysical training using Web-based instruction. The accessible, inexpensive, and increasingly high-quality courseware available on the Web is also fueling a trend toward homeschooling.
>
> The cost of the infrastructure for high-quality audiovisual Internet-based communication is continuing to fall rapidly, at a rate of about 50 percent per year, as we discussed in chapter 2. By the end of the decade it will be feasible for underdeveloped regions of the world to provide very inexpensive access to high-quality instruction for all grade levels from preschool to doctoral studies. Access to education will no longer be restricted by the lack of availability of trained teachers in each town and village.
>
> As computer-assisted instruction (CAl) becomes more intelligent the ability to individualize the learning experience for each student will greatly improve. New generations of educational software are capable of modeling thestrengths and weaknesses of each student and developing strategies to focus on the problem area of each learner. A company that I founded, Kurzweil Educational Systems, provides software that is used in tens of thousands of schools by students with reading disabilities to access ordinary printed materials and improve their reading skills.
>
> Because of current bandwidth limitations and the lack of effective three-dimensional displays, the virtual environment provided today through routine Web access does not yet fully compete with "being there," but that will change. In the early part of the second decade of this century visual-auditory virtual-reality environments will be full im-

mersion, very high resolution, and very convincing. Most colleges will follow MIT's lead, and students will increasingly attend classes virtually. Virtual environments will provide high-quality virtual laboratories where experiments can be conducted in chemistry, nuclear physics, or any other scientific field. Students will be able to interact with a virtual Thomas Jefferson or Thomas Edison or even to become a virtual Thomas Jefferson. Classes will be available for all grade levels in many languages. The devices needed to enter these high-quality, high-resolution virtual classrooms will be ubiquitous and affordable even in third world countries. Students at any age, from toddlers to adults, will be able to access the best education in the world at any time and from any place.

The nature of education will change once again when we merge with nonbiological intelligence. We will then have the ability to download knowledge and skills, at least into the nonbiological portion of our intelligence. Our machines do this routinely today. If you want to give your laptop state-of-the-art skills in speech or character recognition, language translation, or Internet searching, your computer has only to quickly download the right patterns (the software). We don't yet have comparable communication ports in our biological brains to quickly download the interneuronal connection and neurotransmitter patterns that represent our learning. That is one of many profound limitations of the biological paradigm we now use for our thinking, a limitation we will overcome in the Singularity." (Kurzweil, 2005)

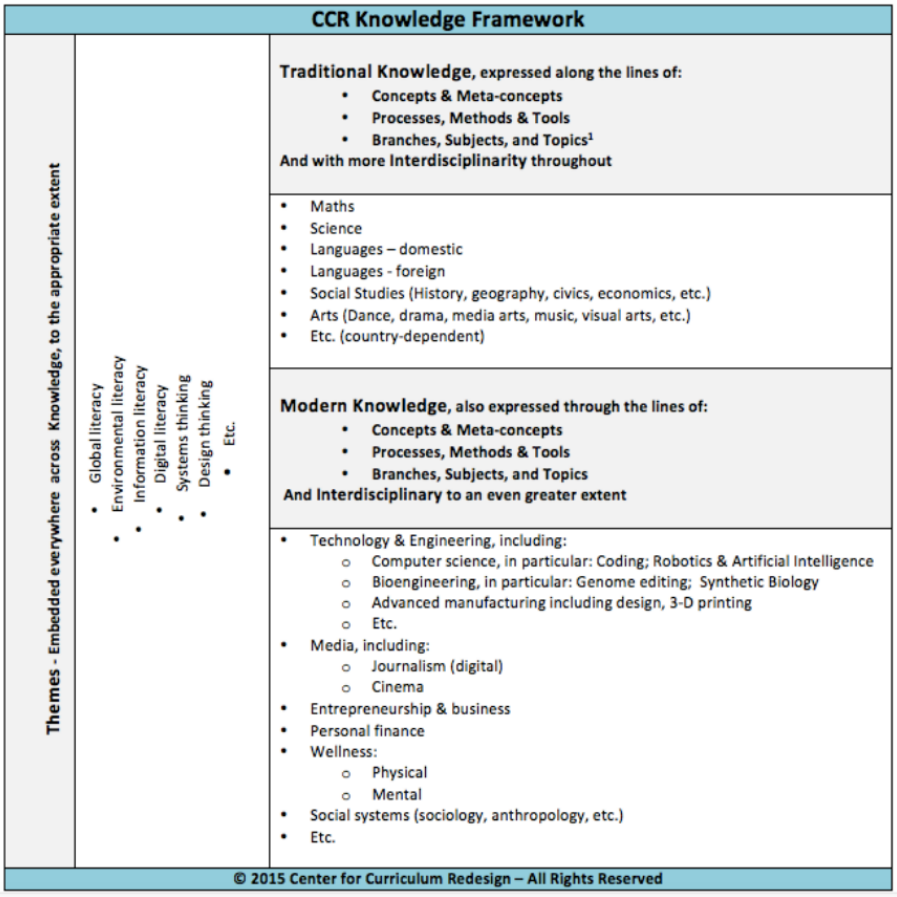

Figure 34: CCR Framework: Summary of the knowledge areas, from Fadel et al. (2015, p.68)

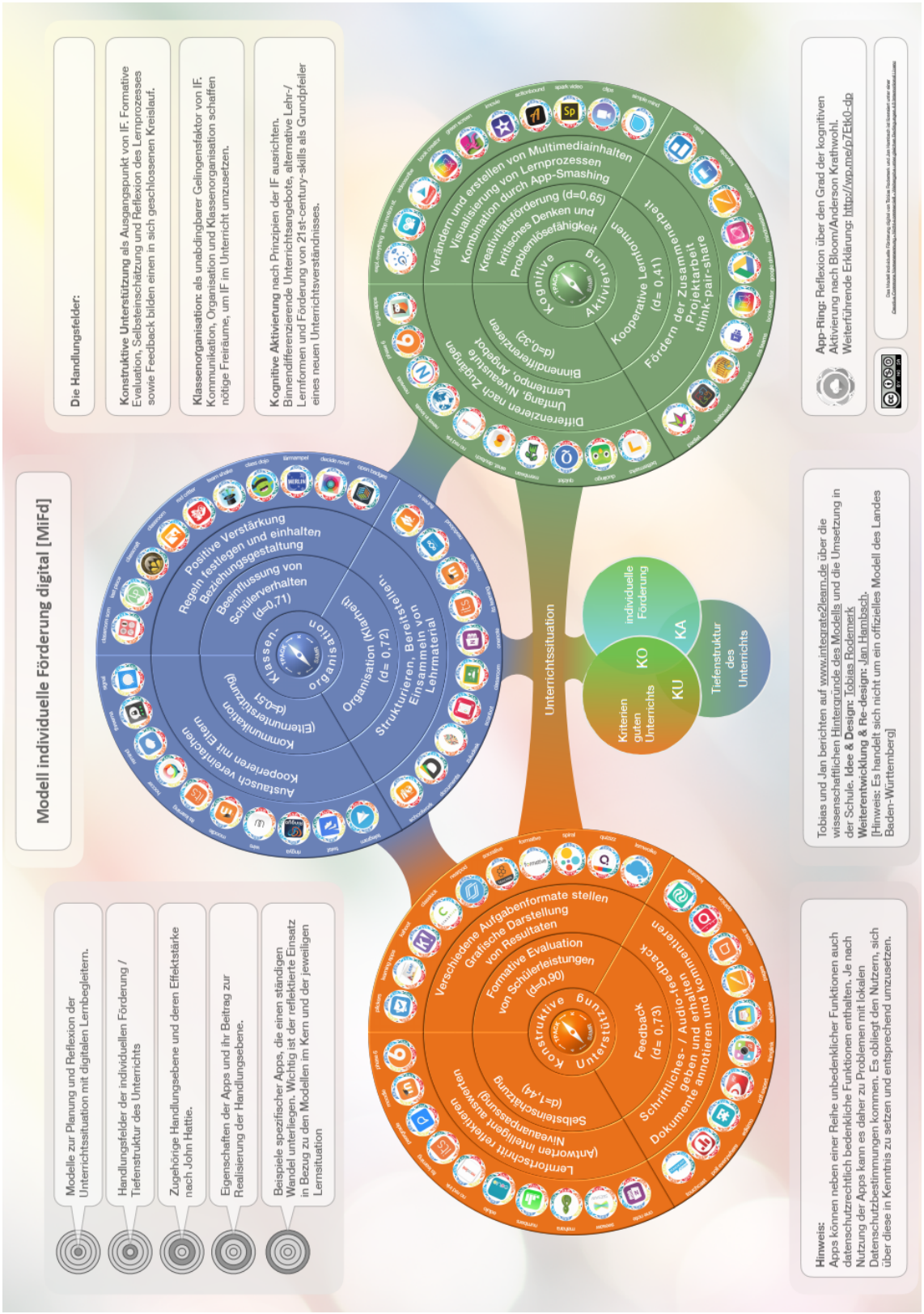

Figure 35: German version 4.0 of the model *Supporting Students Individual Advancement via Tech*, from Rodemerk (n.d.)

Table 5: Lehrplan 21: Subject area **German** divided into competence areas (content divided; 1-6) and corresponding aspects of action (divided according to activities; A-G), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Hören	A - Grundfertigkeiten B - Verstehen in monologischen Hörsituationen C - Verstehen in dialogischen Hörsituationen D - Reflexion über das Hörverhalten
2 - Lesen	A - Grundfertigkeiten B - Verstehen von Sachtexten C - Verstehen literarischer Texte D - Reflexion über das Leseverhalten
3 - Sprechen	A - Grundfertigkeiten B - Monologisches Sprechen C - Dialogisches Sprechen D - Reflexion über das Sprech-, Präsentations- und Gesprächsverhalten
4 - Schreiben	A - Grundfertigkeiten B - Schreibprodukte C - Schreibprozess: Ideen finden und planen D - Schreibprozess: formulieren E - Schreibprozess: inhaltlich überarbeiten F - Schreibprozess: sprachformal überarbeiten G - Reflexion über den Schreibprozess und eigene Schreibprodukte
5 - Sprache(n) im Fokus	A - Verfahren und Proben B - Sprachgebrauch untersuchen C - Sprachformales untersuchen D - Grammatikbegriffe E - Rechtschreibregeln
6 - Literatur im Fokus	A - Auseinandersetzung mit literarischen Texten B - Auseinandersetzung mit verschiedenen Autor/innen und verschiedenen Kulturen C - Literarische Texte: Beschaffenheit und Wirkung

Table 6: Lehrplan 21: Subject areas **English**, **French** (it depends on the canton which is the 1st and which is the 2nd foreign language), and **Italian** (not until the 3rd cycle) divided into competence areas (content divided; 1-6) and corresponding aspects of action (divided according to activities; A-F), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Hören	A - Monologische und dialogische Texte hören und verstehen B - Strategien C - Sprachmittlung
2 - Lesen	A - Texte lesen und verstehen B - Strategien C - Sprachmittlung
3 - Sprechen	A - Dialogisches Sprechen B - Monologisches Sprechen C - Strategien D - Sprachmittlung
4 - Schreiben	A - Schriftliche Texte verfassen B - Strategien C - Sprachmittlung
5 - Sprache(n) im Fokus	A - Bewusstheit für Sprache B - Wortschatz C - Aussprache D - Grammatik E - Rechtschreibung F - Sprachlernreflexion und -planung
6 - Kulturen im Fokus	A - Kenntnisse B - Haltungen C - Handlungen

Table 7: Lehrplan 21: Subject area **Latin** (not until the 3rd cycle) divided into competence areas (content divided; 1-6) and corresponding aspects of action (divided according to activities; A-D), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Lesen	A - Texte lesen und verstehen B - Strategien
2 - Übersetzen und Interpretieren	A - Texte erschliessen B - Texte übertragen C - Texte interpretieren D - Strategien
3 - Hören	A - Verstehen von Hörtexten B - Strategien
4 - Sprechen	A - Texte vortragen
5 - Sprache(n) im Fokus	A - Bewusstheit für Sprache B - Wortschatz C - Grammatik
6 - Kulturen im Fokus	A - Kenntnisse B - Haltungen C - Handlungen D - Literatur und ästhetische Bildung

Table 8: Lehrplan 21: Subject area **Mathematics** divided into competence areas (content divided; 1-3) and corresponding aspects of action (divided according to activities; A-C), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Zahl und Variable	A - Operieren und Benennen B - Erforschen und Argumentieren C - Mathematisieren und Darstellen
2 - Form und Raum	A - Operieren und Benennen B - Erforschen und Argumentieren C - Mathematisieren und Darstellen
3 - Grössen, Funktionen, Daten und Zufall	A - Operieren und Benennen B - Erforschen und Argumentieren C - Mathematisieren und Darstellen

Table 9: Lehrplan 21: Subject area **General Science and Social Studies** divided into competence areas (content divided; 1-12), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich
1 - Identität, Körper, Gesundheit - sich kennen und sich Sorge tragen
2 - Tiere, Pflanzen und Lebensräume erkunden und erhalten
3 - Stoffe, Energie und Bewegungen beschreiben, untersuchen und nutzen
4 - Phänomene der belebten und unbelebten Natur erforschen und erklären
5 - Technische Entwicklungen und Umsetzungen erschliessen, einschätzen und anwenden
6 - Arbeit, Produktion und Konsum - Situationen erschliessen
7 - Lebensweisen und Lebensräume von Menschen erschliessen und vergleichen
8 - Menschen nutzen Räume - sich orientieren und mitgestalten
9 - Zeit, Dauer und Wandel verstehen - Geschichte und Geschichten unterscheiden
10 - Gemeinschaft und Gesellschaft - Zusammenleben gestalten und sich engagieren
11 - Grunderfahrungen, Werte und Normen erkunden und reflektieren
12 - Religion und Weltsichten begegnen

Table 10: Lehrplan 21: Subject area **Visual Arts** divided into competence areas (content divided; 1-3) and corresponding aspects of action (divided according to activities; A-D), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Wahrnehmung und Kommunikation	A - Wahrnehmung und Reflexion B - Präsentation und Dokumentation
2 - Prozesse und Produkte	A - Bildnerischer Prozess B - Bildnerische Grundelemente C - Bildnerische Verfahren und kunstorientierte Methoden D - Materialien und Werkzeuge
3 - Kontexte und Orientierung	A - Kultur und Geschichte B - Kunst- und Bildverständnis

Table 11: Lehrplan 21: Subject area **Textile and Technical Crafts** divided into competence areas (content divided; 1-3) and corresponding aspects of action (divided according to activities; A-E), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Wahrnehmung und Kommunikation	A - Wahrnehmung und Reflexion B - Kommunikation und Dokumentation
2 - Prozesse und Produkte	A - Gestaltungs- bzw. Designprozess B - Funktion und Konstruktion C - Gestaltungselemente D - Verfahren E - Material, Werkzeuge und Maschinen
3 - Kontexte und Orientierung	A - Kultur und Geschichte B - Design- und Technikverständnis

Table 12: Lehrplan 21: Subject area **Music** divided into competence areas (content divided; 1-6) and corresponding aspects of action (divided according to activities; A-C), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Singen und Sprechen	A - Stimme im Ensemble B - Stimme als Ausdrucksmittel C - Liedrepertoire
2 - Hören und Sich-Orientieren	A - Akustische Orientierung B - Begegnung mit Musik in Geschichte und Gegenwart C - Bedeutung und Funktion von Musik
3 - Bewegen und Tanzen	A - Sensomotorische Schulung B - Köperausdruck zu Musik C - Bewegungsanpassung an Musik und Tanzrepertoire
4 - Musizieren	A - Musizieren im Ensemble B - Instrument als Ausdrucksmittel C - Instrumentenkunde
5 - Gestaltungsprozesse	A - Themen musikalisch erkunden und darstellen B - Gestalten zu bestehender Musik C - Musikalische Auftrittskompetenz
6 - Praxis des musikalischen Wissens	A - Rythmus, Melodie, Harmonie B - Notation

Table 13: Lehrplan 21: Subject area **Physical Education** divided into competence areas (content divided; 1-6) and corresponding aspects of action (divided according to activities; A-C), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich	Handlungsaspekte
1 - Laufen, Springen, Werfen	A - Laufen B - Springen C - Werfen
2 - Bewegen an Geräten	A - Grundbewegungen an Geräten B - Beweglichkeit, Kraft und Körperspannung
3 - Darstellen und Tanzen	A - Körperwahrnehmung B - Darstellen und Gestalten C - Tanzen
4 - Spielen	A - Bewegungsspiele B - Sportspiele C - Kampfspiele
5 - Gleiten, Rollen, Fahren	
6 - Bewegung im Wasser	A - Schwimmen B - Ins Wasser springen und Tauchen C - Sicherheit im Wasser

Table 14: Lehrplan 21: Subject area **Media and Informatics** divided into competence areas (content divided; 1-2), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich
1 - Medien
2 - Informatik

Table 15: Lehrplan 21: Subject area **Vocational Orientation** divided into competence areas (content divided; 1-4), retrieved from D-EDK (2016d) (in German)

Kompetenzbereich
1 - Persönlichkeitsprofil
2 - Bildungswege, Berufs- und Arbeitswelt
3 - Entscheidung und Umgang mit Schwierigkeiten
4 - Planung, Umsetzung und Dokumentation

7.7 Content of the CD

Zusfsg.txt	Zusammenfassung
Abstract.txt	Abstract
Masterarbeit.pdf	The whole master thesis
Interview_recording	This folder contains the recordings from the interviews (only in digital format)