Approaches to Artificial Intelligence as a Subject in School Education

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Abstract. Due to recent developments in the breath-taking field of artificial intelligence (AI) and its impact on almost every area of life, this paper provides an overview of that field focussing on current approaches especially in schools. After a clarification of the particular terminology in a wider context, and after a short journey into the past of AI in schools, current initiatives and AI-related approaches on a school level are described. In the following chapter the disciplinary aspect of AI is stressed. This contribution concludes with some implications for the practice of AI education.

Keywords. Artificial Intelligence, Machine Learning, Deep Learning, Data Science, School Education

1 Introduction

Writing a contribution about artificial intelligence in schools is a challenging task. One reason is the abundance of relevant existing on- and offline resources, and the other is the difficulty to keep an overview of already many studies and initiatives in that field. However, in this paper an attempt is made to give a comprehensive overview of this multifaceted and broad field.

The pace of recent developments in AI has surprised not only insiders, but has also reached the public and schools. If somebody thought that the subject computing in schools is already resting in itself and curricula do not need any major revisions has recently been taught a better lesson.

Although there is a plethora of insightful and valuable books, papers and a vivid blogosphere about AI-terminology (the particular AI-glossary of Wikipedia consists already of more than 300 terms), a compact overview is given in chapter one.

About thirty years ago, when the subject computing was in its infancy, AI played already a certain role in school education. Chapter three gives some insight in this historical episode. The following chapter provides an exemplary overview of recent initiatives and AI-related projects, and is concluded by an illustrative fast run through some approaches to impart AI on various levels. In chapter five the interdisciplinary nature of AI is treated, followed by a short conclusion in which some practical aspects are addressed.

The challenge for providing good practices in AI education and to convey a complete picture of this field is open. It can be expected that AI is no fad and is here to enter school education, and to stay.

Due to the title, this contribution is concerned with “learning about AI”, and does not elaborate on “learning through AI” in the context of educational technologies, except for the following notes on this issue.

AI has the potential to play an important role in educational technology with many potential applications, from the inspiring ones like personalized learning, (automatic) assessment facilitation, assisted language learning and translation etc. to the less favorable ones like advanced cheating. However, we still don’t know how the digitalization of education and the adoption of AI will shape learning in this decade [23].

2 What is it all about?

Let us start with a term sometimes used in an educational context: “Deep learning”. It stands for meaningful learning, in contrast to human surface and rote learning. This will be addressed briefly at the end of this paper.

“Deep learning” with regard to AI is a method that mimics the workings of the human brain in processing big data for use in predictions and decision making. Its results affect our lives already in a way which could not have been foreseen some years ago. It is very likely that most of us have unknowingly been using deep learning models already on a daily basis. Such a deep learning model is used with a high certainty every time we use an internet searching machine, a face recognition system on a social media web-site, a translation system or a speech interface to a smart device. Accordingly, deep learning can be regarded as one of the most powerful and fastest growing applications of artificial intelligence within the sub-field of machine learning.

2.1 From Deep Learning to Artificial Intelligence

Machine learning is one of the primary approaches to artificial intelligence, but by far not the only one as we will see later on. There are many similar definitions around, varying just in the wording, but with the same semantics. It is a sound choice to use Wikipedia’s definition.

“Machine learning (ML) is the scientific study of algorithms and statistical models that computer systems use to perform a specific task without using explicit instructions, relying on patterns and inference instead. It is seen as a subset of artificial intelligence. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task. Machine learning algorithms are used in a wide variety of applications, such as email filtering and computer vision, where it is difficult or infeasible to develop a conventional algorithm for effectively performing the task.” [1]

All three areas, deep learning (DL), machine learning (ML) and artificial intelligence stand in a hierarchical relationship to each other (Fig. 1), although the concept of what

defines AI has changed over time. But at the core there has always been the idea of building machines (computers) which are capable of "thinking" like humans. The field of research - with already impacting and fruitful applications in recent years - has become known as "machine learning". Even more, it has become so integral to contemporary AI that the terms "artificial intelligence" and "machine learning" are sometimes used interchangeably.

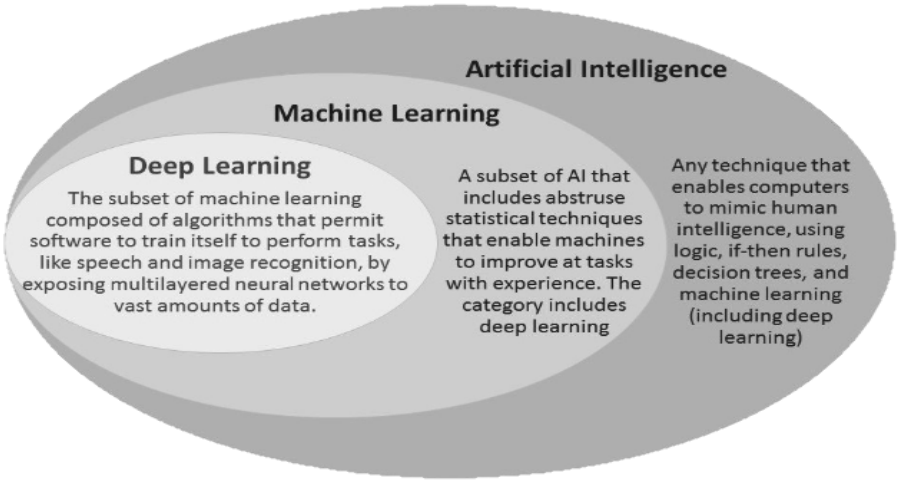

Fig. 1: Relationship between DL, ML and AI [2]

Used to solve problems which were previously considered too complex, and using the model of neural networks involving huge amounts of data and rapidly growing computational power, AI has revolutionized the quality of speech recognition, language processing and computer vision, vehicle identification driver assistance and other domains.

Generally, AI comprises advanced algorithms based on advanced mathematics, which can handle higher processes similar to humans. Examples include visual perception, speech recognition, decision making, and translations between languages.

Among other trends in information technology as the internet of things, robotics, 3D printing, big data, blockchain technology, virtual and augmented reality, AI is one of the leading topics of our digitally penetrated world. AI is often accompanied by misleading stories and thus causing diverging feelings in the general public, ranging from utopian enthusiasm to dystopian fear. Accordingly, there is a huge challenge for education and schools to provide all pupils with a solid understanding in that field.

As every new technological achievement, deep learning as the main application of machine learning, has its dystopial implications. It is potentially worrying that the trail of data and metadata, we are leaving and delivering voluntarily and largely unnoticed when moving through the online world, is also being processed and analyzed using deep learning models. This is why it is so important to at least understand what artificial intelligence is, how smart technologies work, and what they are capable of, and what their current limitations are [3].

It is important to recognize once more that AI is a constantly moving target. Things that were once considered within the domain of artificial intelligence - optical character recognition and computer chess, for example - are now perceived as routine computing. Today, robotics, image recognition, natural language processing, real-time analytics tools and various connected systems within the Internet of Things (IoT) are all increasingly using AI in order to be augmented with more advanced features and capabilities.

Deep learning and/with neural networks, meanwhile, get the most attention because they are particularly well-suited for tasks involving image, video, and audio data ("All the cool stuff is happening in AI right now" [4]). For text and numerical information, though, the older methods can still be more suitable.

Its transformative effects on technology will increase over the coming decades, with the development and adoption of deep learning continuing to be driven by extremely growing datasets, the development of new algorithms, and improved hardware. These trends are not stopping.

2.2 Artificial Intelligence in a Wider Context

We cannot discuss AI without the highly related and overlapping wide area of data science (Fig. 2). Simply put, data science is the study of data, involving developing methods of recording, storing, and analyzing data to effectively extract useful information. The goal of data science is to gain insights and knowledge from structured and unstructured data. It is the science which brings the saying "data is the new oil" to life.

Data is worth very little if there are no highly skilled professionals who can derive actionable insights from it. Undoubtedly, the competence to understand, use, process and inteprete data has become indispensable and a requirement for an expanding range of jobs and careers. (Big) Data is ubiquitous. It is estimated that about ninety percent of the world's data has been created in the last two years [6].

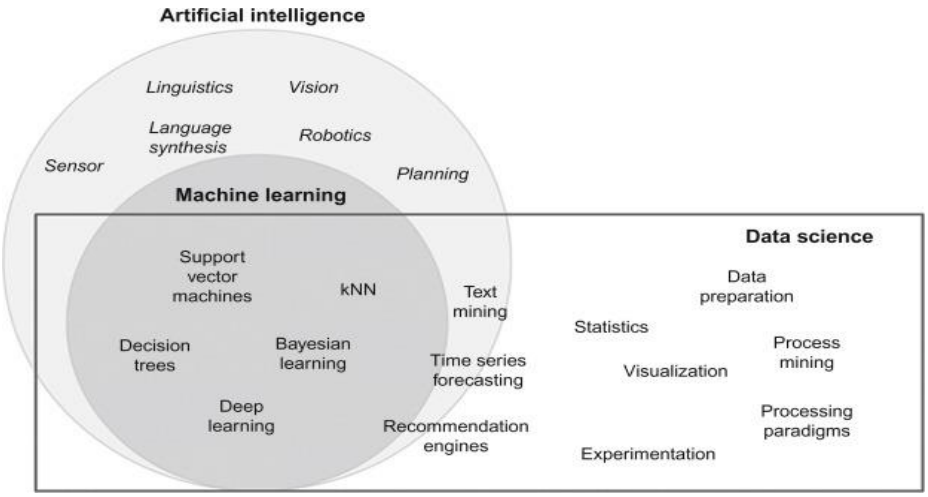

Fig. 2: Relationship between Data Science and AI [5]

Mastering data science and harnessing data, means a solid grounding in Mathematics for processing and structuring (big) data, in statistics, programming not only in one specific programming language, and last but not least analytical and computational thinking, including problem solving and logical reasoning.

The new data-driven world requires individuals to be constantly separating fact from fiction. In short, the need to analyze and interpret data is no longer confined to engineering or computer programming; it has become an essential life skill. Yet, the K-12 education landscape is lagging behind. Schools have not recognized till today the changes the data explosion has made to society. Curricula we teach currently, should be revised and provide more practical utility for the 21st century. There is a widening gap between competencies students need in life and what is taught in schools. Data science including AI should be building blocks of a modern school education.

Obviously, machine learning is one of the primary approaches to artificial intelligence, but it has to be seen in the wider context of data science which encompasses such important areas as the often underestimated and arduous data preparation on one hand, and the fascinating field of data visualization on the other.

Before learning machines and machine learning provide us with suggestions and predictions in (still) particular situations (contrary to "general artificial intelligence" with super intelligent robots exceeding the abilities of human beings), they have to be trained with (big) data sets which can be accomplished through "supervised", "unsupervised" or through "reinforced learning". In short, supervised learning requires the supply of training data and correct answers, unsupervised learning occurs when machines learn from a dataset on their own, and reinforcement learning is based on permanent feedback from the environment.

Machine learning uses algorithms to learn from data and data patterns, and the knowlegde aquired can be used to make predictions and decisions.

Apropos data! Whereas AI is just at the beginning to be included in curricula and lessons, data have been already for a long time a building block of computing education. In some countries the term "Electronic Data Processing" was the predecessor for the later subject "Informatics". Accordingly, AI is naturally embedded in all aspects and fields around data, that is data literacy and data management. Recently, a comprehensive model of data key concepts and a competence model of data literacy have been published [8][9]. This holistic view on data shows convincingly that data driven computing education is very broad, with AI playing an increasingly important role in it.

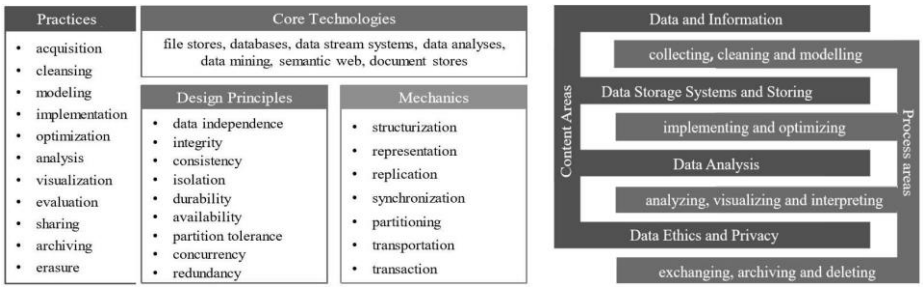

Fig. 3. Key concepts of Data Management, Data Literacy Competence Model

3 Historical Context

Although AI may be regarded as the hot topic of the moment in (digital) technologies, and the driving force behind many technological breakthroughs of recent years, at least the term is not all that new. During the last decades, AI has moved out of the domain of science fiction and into the real world, and the theory and the fundamental computer science which makes it possible has been around for decades.

There are many very useful resources on the web which describe this timeline in general and the amazing AI milestones in special [7]. These valuable content on the web can be harnessed and discussed by pupils in a historical, interdisciplinary context.

Long before robots have been dominating utopian and dystopian arenas in science fiction, in the 17th century scientist and philosopher Rene Descartes thought of thinking and decision making machines. While he was wrong in stating that they would never be able to talk like humans, he already distinguished between machines which might one day learn about performing one specific task, and those which might be able to adapt to any job. Today, these two fields are known as specialized and general AI.

The origin of the term "artificial intelligence" goes back to a conference at Dartmouth College (USA) in 1956, years before the subject computing (computer science, informatics, information technology) came into play into the curricula of timetables in some countries, and accordingly into textbooks about computing/informatics.

We know very little about what really has been taught in computing/informatics lessons in the eighties of the last decade, but some textbooks indicate that artificial intelligence was at least part of curricula and recommendation at that time.

In their seminal and modern introduction of computer science Goldschlager and Lister [10] artificial intelligence is located in the chapter "Algorithms in action: some computer applications", subdivided to "Can machine think?", computer games, understanding language, visual perception, knowledge representation and expert systems. The book ends with the (philosophical) question "Superfluous human?". With their comforting assertion that human beings with their creative capabilities, innovation power and originality will never be superfluous, the authors were right. But were they right with the statement "Computers carry out (only) repetitive tasks"?

The year 1987 is insofar remarkable as one of the authors of this paper carried out a new curriculum at K-12 level in which AI was one explicit topic. It could be chosen among other themes: Statistical and prognostic procedures, programming languages and software products, applications of microelectronics in economy, and finally *artificial intelligence*, expert systems, authoring systems and complex simulations.

1987 was also the year and hype of (DOS) Turbo Prolog (Fig. 4), taking place of Turbo Pascal, and disappearing quickly due to revolutionary graphical user interfaces, standard software applications, other programming languages and integrated development environments as Visual Basic and Delphi, the MS-Windows based successor of Turbo Pascal.

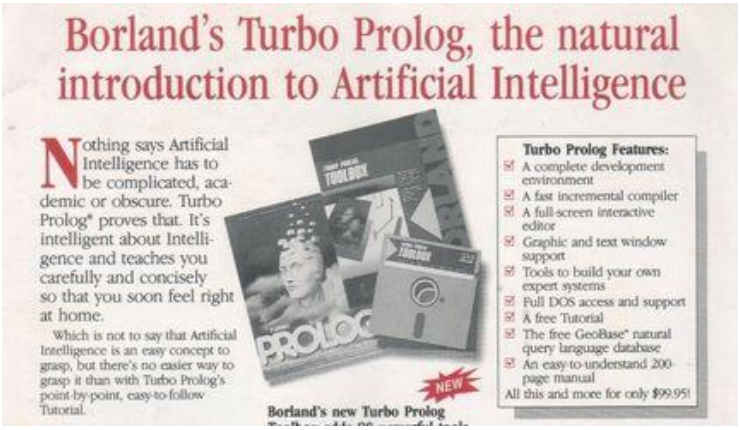

Fig. 4: Memories of a time about years ago [13]

About ten years later, the first German comprehensive textbook on "Didaktik der Informatik" contained a full chapter about "artificial intelligence" [13], referring to AI as an academic discipline with its subsections natural language systems, expert systems, robotics, computer vision, followed by a short historical summary and vague explanations about cognitive science, including a skeptical view on neural networks. Herein, the author Baumann dismissed statements (from his students) such as "neuronal networks can learn" as an improper use of language.

A similar misjudgement can be read in Rechenberg's "Was ist Informatik" [11], where neuronal networks are denoted as an offspring, and not really belonging to artificial intelligence. "It looks like this idea is doomed to failure. […] Neuronal networks have proven some applicability, but its performance should be estimated very carefully. There are many examples for which much more efficient solutions have been found with other mathematically trustworthy processes."

What followed was an "AI winter" also in schools, up until recently. Currently we are witnesses of an "AI springtime", not only in research and business, but slowly in schools either. However, there is much evidence that AI in schools is still in its infancy.

4 Current AI-Initiatives and Approaches in K-12 education

After the AI-hype in the eighties in form of a classical rule-based approach, expert systems and the programming language Prolog, we observe currently a regaining momentum in this field, fueled by some promising approaches. The signs are good that AI will be introduced in curricula and computing lessons in an appropriate and sustainable manner.

Perhaps the most advanced development in implementing AI in K-12 education can be found in China, where a textbook on AI based on computational thinking has been rewritten and published. The old textbook in that field mainly included knowledge representation, reasoning, expert system, search, etc. whereas the core concepts of the new textbook encompass intelligent systems, artificial neural networks, and machine

learning. The shift from focussing on expert systems to the analysis and design of intelligent systems incorporating state of the art AI concepts has been put on the right track [14].

In England, the initiative "Computer Science for fun", an (online) magazine where "the digital world meets the real world" offers many ideas and teaching materials for machine learning (http://www.cs4fn.org/machinelearning), with the so called "Sweet learning computer (a simplified chess game) as one example [15].

Looking to Germany, there are various initiatives on the way to pilot AI-related projects and studies in schools. These range from unplugged activities in that field [16], an activity based explanation how neurons work and learn in robot controlling [17], to machine learning in the context of data science [18].

Fig. 5. From Phenomenological AI to "Deep Learning of Deep Learning"

Computer vision, perhaps for pupils the most striking and impressing aspect of AI, can be treated and discussed in a phenomenological way already for an early age-group, with Google's Autodraw as an example. The question if and how a computer recognizes animals (as the fat giraffe in Fig. 5) can be a starting point for interesting lessons. So do captchas as the "incarnation" of the historical Turing test, including the question how long it takes until deep learning will solve also these puzzles. The upper right face in Fig. 5. is fake, it does not exist in reality and is AI-generated. The website, provided by a software team of a well-known company (© Nvidia, "thispersonthatdoesnotexist.com") can trigger inspiring and demanding AI lessons, especially when recognizing unobtrusively displayed notes at the lower right corner (Fig. 6).

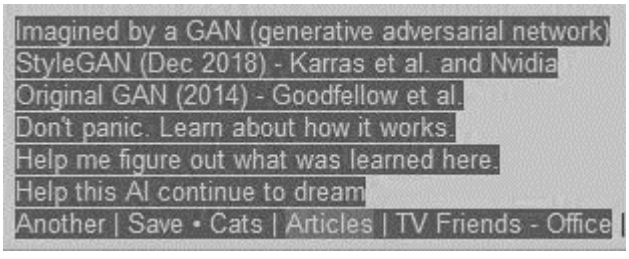

Fig. 6. A starting point for meaningful "deep learning"

Due to deep learning, character recognition has made great progress. This aspect of AI is almost daily practice of all internet users and therefore suited for computing lessons, addressing (un)supervised and reinforcement learning through training with data, underpinned by theoretical foundations.

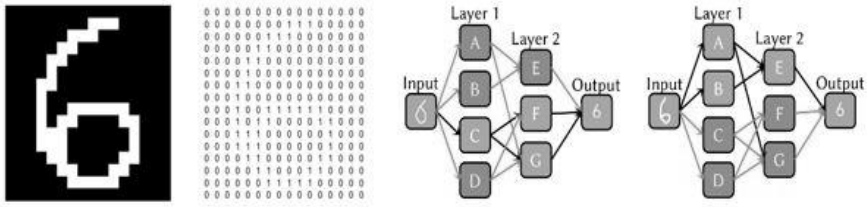

Fig. 7. Character recognition and "deep learning" with a neuronal network [21]

5 AI is interdisciplinary

Like hardly any other science, AI is interdisciplinary. It uses many interesting results from such diverse fields as mathematics, logic, operations research, statistics, control engineering, image processing, linguistics, philosophy, psychology and neurobiology. In addition, in many AI-projects the field of the respective application has to be taken into account. To successfully work on AI projects is therefore not always easy, but almost always exciting and challenging [24].

The challenge is at least as great when thinking of introducing AI into school curricula, as interdisciplinary aspects are rather the exception than the rule.

In Germany, a nationwide initiative about imparting a holistic view on artificial intelligence within the "Science Year" has been launched [16]. Its ambitious goals aiming at the target group from 12-18 years old pupils comprise

- a sound explanation how AI works
- stimulation of a social discourse on AI
- a reduction of existing misconceptions

The course consists of (up to) six modules, containing teaching material, arranged around the following modules.

- *Module 1: Introduction - students' everyday experiences with AI*
  This module is intended to activate and systematize existing experience with artificial intelligence. It also should help to make the students aware of their existing attitudes.
- *Module 2: How does Machine Learning work?*
  This part consists of the simulation game named "Man, Machine!" and helps students to understand how machine learning and/within AI work. They simulate a learning machine and observe the learning process. The particular material contains worksheets to reflect the experiences.
- *Module 3: What's the difference between man and machine?*
  This module systemizes the differences between man and machine, and the concepts of intelligence and learning in particular are examined more closely.

- *Module 4: Historical Overview of the Development of Artificial Intelligence*
  In this module, various aspects from the other chapters are linked and classified through the historical approach.
- *Module 5: The distribution of roles of man and machine - ethical and societal aspects*
  This part examines the roles between man and machine more closely, including not only the role of the developers, but also the role of the users. Users also contribute to the further development of AI systems through their data input or data traces.
- *Module 6: In which AI world do we want to live?*
  The students develop scenarios and ideas about an AI-driven world they want to live in and how they think the future of AI should be shaped.

Contemporary computer lessons (should) make use of contextualized teaching concepts such as IniK which means „Informatik in Kontext“ [19]. IniK is based on the assumption that solely technical computing competences do not suffice to understand the digital world of IT systems and digital media. Pupils should be able to use them in a self-determined way. To this end, questions are placed at the center of computing that go beyond technical issues, and include the social context, aspects of economics, culture, politics or law [20]. Answering these questions, make it possible to develop IT content in a cross-disciplinary way and can lead to sustainable computing competences. Aspects of AI are almost predestined to supplement this interesting approach of IniK with already recommended and elaborated topics, such as “E-mail only(?) for you.”, “My computer is talking to me!”, “Smart and rich through apps”, “Social networks”, and “Don't trust a picture!”.

Lessons according to "Computing in Context" are per se interdisciplinary and subject-linking. Assuming a real-life context, there are manifold references to different subjects. But most likely, there are only a few teachers who are able to deal with multidisciplinary challenges with professional competence. Maybe, appropriate interdisciplinary teacher training in which colleagues from the relevant subjects join together to form a team may be the key to remedy this situation. However, the challenge of a sound teacher education in AI is ahead of us.

6 Implications and Final Remarks

From a theorical point of view, some studies indicate that many seemingly "intelligent" systems and AI can be demystified in computing lessons, and sooner or later, this much-discussed area of digital technologies will reach school informatics on a broader basis. However, we have to be so honest to realize that a constructive and meaningful approach to teach the (currently) hot topic AI in depth, requiring a deep understanding of the field, represents a big pedagogical challenge for a teachers and teacher trainers, and of course, a cognitive one for many pupils.

Obviously, it makes a big difference to approach this topic in schools (comprehensively)

- from a social and philosophical viewpoint (talking and reasoning about AI)
- by conscious awareness of AI applications on a phenomenological level (knowing about AI and using AI applications in a reflective way)
- by applying a grey box model of AI, requiring a basic knowledge of its key concepts and programming languages and environments (applying AI)
- through putting the mathematical and computational perspective into the foreground (understanding the foundations of AI and constructing AI)

From a practical point of view and with the focus on learning outcomes it is useful to have the seminal (revised) Bloom's taxonomy in mind, which starts from mere recalling and basic understanding up to the creation of AI-applications. Referring to the "Tale of Three Learning Outcomes" [21] with three categories "No learning", "Rote Learning" and "Meaningful Learning" the question arises, how much time can be allocated to AI in (always) overcrowded curricula. "Meaningful Learning" is recognized as an important general educational goal and occurs when pupils build their knowledge and cognitive processes needed for successful problem solving. This begins with an appropriate mental representation of the problem and ends with the problem solution, in which the pupils devise and carry out a plan for solving the problem.

With regard to didactical aspects of AI-education, it is a key question how to deal with the plethora of its possible approaches. The spectrum begins with a discipline Artificial Intelligence in its own right, providing a holistic picture of the field with sequenced und structured lessons, and ranges from fragmented approaches within subjects such as computing, Mathematics or philosophy [16]. These include singular bottom-up initiatives as the simulation of a neuron with the programming environment Scratch [17], and unplugged activities in form of a role playing simplified chess-game to demonstrate reinforcement learning [18]. All these approaches in schools are worldwide still in its infancy and in an experimental stage lacking empirical results.

Finally, the rise of big data, the huge progress of machine learning and the impact on all of us suggest to implement AI-education in school edcuation on a broader basis. It has the potential to extend and enrich not only the subject computing in schools, but education in general.

However, there is still a long way to go and to find the right approaches for particular age-groups with reasonable levels and requirements. Above all, it needs curious educators, teachers and teacher trainers who are able to incorporate this important and prospective field into general, specific and vocational education.

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