Can you explain AI to me? Teachers' pre-concepts about Artificial Intelligence

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***Abstract*—As a starting point for a professional development (PD) program for teachers, this Research Full Paper investigates which ideas and pre-concepts teachers have about artificial intelligence (AI).**

Along with artificial intelligence's increasing relevance in society, it is also finding its way into curricula for K-12. However, in this context, it is not only the students who are confronted with a new topic, but also their teachers. The vast majority of CS teachers have not dealt with AI during their studies and are, therefore, facing a stiff challenge when it comes to teaching it. Consequently, there is an unquestionable need for professional development for teachers in the field of artificial intelligence.

Following the strategy of the *Professional Development for CS Principles (PD4CS)* initiative, a broad characterization of the content knowledge related to the respective topic is necessary as a first step. For this reason, semi-structured interviews were conducted with teachers with different levels of experience and varying previous knowledge of Computer Science to find out what pre-concepts about AI teachers would bring into a PD program. Based on this, together with a body of knowledge gathered from experts and reference books in artificial intelligence, the necessary AI content knowledge of the teachers is defined.

The semi-structured interviews were analyzed using a qualitative approach based on the text analysis of Mayring. To respond to low intercoder-agreement, we used an approach described by Campbell and Quincy.

Investigations of previous knowledge in programming show that this knowledge has a significant impact on misconceptions found with the participants. Bonar and Soloway identified gaps in previous knowledge as one reason for this. Our findings point to a similar effect of previous knowledge in the field of AI. This poses a problem as our participants are teachers who will be AI instructors themselves and who might pass on certain misconceptions to their students. Consequently, the accurate identification and description of the teachers' knowledge gaps is an important starting point for providing a suitable and successful professional development program.

***Index Terms*—Artificial Intelligence, K-12 CS Education, Professional Development for Teachers**

I. Introduction

The increasing relevance of artificial intelligence (AI) in our daily life also leads to increased attention for the topic in (computer science) curricula for K-12. As Wrede [1] points out, "[t]he more artificial intelligence is entering our daily life the more we need to provide people with the ability to use and control it in an adequate way." If the current development continues, AI skills will become life skills before long, and schools are the institutions to mediate them. However, artificial intelligence is not only a new topic for the students, but most teachers also have little or no experience with AI. Consequently, there is a need for intensive teacher training in the field of AI to guarantee successful teaching and the development of competencies in AI.

Following the *Professional Development for CS Principles (PD4CS)* initiative's approach [2], to secure effective teacher training, the teachers' previous knowledge about AI needs to be taken into account. As the Related Work section shows, for successful teaching it is essential to pick up the teachers where they are and make sure they develop an adequate professional concept of AI - concerning both content knowledge and subjective theories or rather pre-concepts. Therefore, it is necessary to determine the teachers' pre-concepts about artificial intelligence, i.e., their everyday theories about AI and its phenomena, including their attitudes and interests[1], and to identify possible misconceptions which might harm their teaching and, thus, need to be cleared up as Denning et al. point out [3]. Consequently, our central research question is: *Which ideas and pre-concepts about artificial intelligence can be observed with teachers?*

To answer this question, we conducted semi-structured interviews using an online questionnaire survey with open questions. The answers were analyzed using the qualitative content analysis approach of Mayring [4].

II. Related Work

A. Relevance of Content Knowledge

Hashweh examined how teachers' subject matter knowledge influences lesson planning and teaching by the example of biology and physics teachers. He found that teachers with well-founded content knowledge are better in enhancing and adapting subject-matter content in textbooks to their needs due to disposing of a detailed overview of the concepts and schemes of the discipline. Furthermore, they use more elaborated explanatory representations, ask higher-order and abstract questions, react more successfully to critical incidents in the classroom, better identify student preconceptions, and

[1] In the literature, this concept is also referred to as subjective theory, belief or preconception.

interact more successfully with students at the content level. In contrast, teachers with little subject matter knowledge tend to stick to teaching materials more closely and use less elaboration. He, furthermore, pointed out that teachers with little content knowledge show more knowledge inaccuracies and preconceptions that play a role in the planning of lessons: preconceptions and knowledge inaccuracies are reflected in the representations the teachers use in class and, in some cases, inaccuracies are pursued although they contradict the textbook. So, detailed content knowledge enables more elaborate teaching and in-depth work with the content in class. Furthermore, the importance of preconceptions as factors that guide the teachers' actions is emphasized. [5]

Chan and Yung also underpin these findings. They stated that the teachers' previous experience impacts lesson planning of new topics and that Subject Matter Knowledge (SMK) could facilitate, but in some cases also hinder the development of pedagogical content knowledge (PCK). The successful use of SMK and previous teaching experiences to develop PCK when teaching new topics are linked to the teachers applying generalized mental frameworks when planning lessons. Therefore, to empower teachers to successfully deal with new topics and curriculum changes in class, besides providing sufficient SMK in teacher training, it is essential to help teachers use such frameworks and form habits for their lesson planning. [6]

B. Pre-concepts and Misconceptions

Mesaroş and Diethelm study the subjective theories, i.e., the individual cognitive structures to explain and predict self- and worldviews, of teachers with different CS qualifications on designing CS lessons for the topic networks and the internet. They consider teachers' thinking and preconditions about CS education as relevant aspects for professional development (PD) as the continuous development of the field of CS demands a high degree of flexibility and constantly engaging with new topics. When developing lessons for certain topics, CS teachers have different reasons for teaching a topic, as well as different learning objectives. They, furthermore, highlight different aspects in terms of content and structure. These circumstances are interrelated with the teachers' different perspectives on CS and their subjective theories as well as different levels of education in computer science, whereby some teachers feel a lack of knowledge in CS. Besides pointing towards the importance of teachers' subjective theories and preconceptions, these findings again show the importance of content knowledge for successful teaching. [7], [8]

The importance of subjective theories and emotional processes in teaching is also pointed out by Dann, who highlighted the action regulating function of these theories. "The subjective theories of successful teachers are more complex, more efficiently organized and more consistent with overt behaviour." Consequently, teaching skills can be improved by transforming the teachers' subjective theories in professional development programs. For the teachers to develop appropriate representations, existing knowledge has to be activated, and subjective theories need to be revealed before being supplemented with new knowledge. In this process, it is crucial to eliminate the wrong components and misconceptions in the knowledge system. The use of relevant contexts can support the construction process of more elaborated theories and, additionally, promotes the application of these. [9]

The knowledge that pre-concepts are a source for misconceptions is investigated in different areas. Unfortunately, almost all studies survey students instead of teachers. However, in this papers' context, teachers are seen as learners and, therefore, the findings are comparable except for some slight adaptions. In 1985 Bonar and Soloway investigated the influence of prior knowledge, respectively pre-concepts, on the misconceptions of novice programmers. They stated that the gaps in knowledge that occur during the learning process are filled by patches built from an intuitive understanding of the subject, which is error-prone. The knowledge of the possible errors novice students make, is important to avoid them. These aspects are, of course, also relevant for training teachers in a new field. [10]

Burkhardt et al.s' paper on mental representations of object-orientation constructed by experts and novices points in the same direction. They showed that, based on the level of experience, there are different models built. Again, this is affected by previous knowledge. [11], [12]

C. Educational Background of teachers in the field of AI

There is little related work until now concerning the aspect of K-12 teacher education and pre-concepts in the field of artificial intelligence. Vazhayil et al. described the introduction of an AI curriculum through teacher education programs in India. In this context, they reported a series of challenges like a lack of communication with the CS teachers concerning the introduction of AI in schools and concerns to provide open internet access to the students for this. Furthermore, a considerable interest in applying peer teaching, a game-based approach, and Scratch programming when teaching AI is expressed. However, the teachers do not believe in the potential of AI to be useful for the students' (professional) future. [13]

Lindner and Romeike conducted a questionnaire survey on the teachers' perspective on artificial intelligence. This survey indicates a significant role of the media and the "hype" topics reported there as an informational resource about the subject. In their study, teachers consider socio-cultural and technical knowledge about AI as more important than only application-oriented skills. In general, they are in favor of introducing AI to the curriculum. Furthermore, challenges like insufficient and superficial content knowledge of the teachers in the field of AI, as well as a lack of teaching materials, adequate tools, and examples, are identified. [14]

The related work indicates that the teachers' pre-concepts influence the quality of their teaching performance, both content-wise (e.g., when misconceptions are passed on) and methodologically (e.g., concerning the intensity of knowledge transfer) and, thus, should be addressed in professional development measures. As most teachers presumably do not have extensive content knowledge about AI – this aspect is also

pointed out by [14] – their pre-concepts play a fundamental role when engaging with the topic of artificial intelligence. Consequently, it is crucial to understand the pre-concepts and to use them as a starting point for the teachers' knowledge acquisition process in the field of AI. Only then, they can be transformed into adequate professional concepts.

III. Theoretical Background

As already discussed by Shulman [15], the required knowledge of teachers comprises parts that refer to the subject matter (content), pedagogical content, and curricular issues. In 1987, he refined this model to the following [16]: Content knowledge remained the same, while the other two were split up into general pedagogical knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational surroundings. Carlsen rearranged this system to adapt it to the required knowledge of science teachers [17], dividing Shulman's "curricular knowledge" in a subject-specific and an interdisciplinary component. By this, he was able to separate the three knowledge areas: Pedagogical Knowledge (PK), Subject Matter Knowledge (SMK), and Pedagogical Content Knowledge (PCK).

Mishra and Koehlers' TPACK-model [18] also builds upon Shulman's work by introducing technology as an additional component to the model and by highlighting the importance of technological pedagogical content knowledge (TPCK). For CS education, this integration of technology is particularly significant and represents a major part of the teachers' knowledge as TPCK is considered

> [...] the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge [...].

Ball et al. specified the content knowledge a teacher must gain to teach a subject properly [19]. According to their study, content knowledge can be separated into three types:

- Common content knowledge, which is strongly related to pre-concepts
- Horizon content knowledge, which teachers must have, even if they are not explicitly teaching it
- Specialized content knowledge, which is the knowledge that has to be gained during professional development

The separation is essential for the design of professional development programs. In this paper, we focus on common content knowledge that predominantly has to be taken into account when starting interventions addressing content knowledge. Nevertheless, every PD program has to cover the other two types of knowledge, as well.

Concerning pre-concepts, Westermann et al. [20] stated that taking up pre-concepts (of students) leads to significantly better learning outcomes concerning conceptual knowledge. Furthermore, learners do not only profit from including their pre-concepts in the learning process, but also from the ideas and pre-concepts of others. Consequently, determining the pre-concepts of teachers about artificial intelligence can improve their learning process about the field.

According to Bender et al. [21] there is no consistent definition of teachers' beliefs. They present a literature review that shows two separate areas. On the one hand, beliefs comprise of general teaching aspects, including structures of interactions with students and attitudes towards teaching. On the other hand, beliefs are related to a pre-conceptual understanding of a specific subject (e.g., understanding and assumptions about phenomena). The fact that these beliefs are highly dependent led to the instrument's multifaceted questions presented in the following section. In [22] beliefs are described as "the lens through which incoming information is interpreted." Consequently, the teachers' learning about a new field is already influenced by their existing pre-concepts.

IV. Methodology

To investigate which ideas and pre-concepts teachers have about AI, we asked 23 teachers, who are currently being trained as computer science teachers in an in-service study program, to participate in a semi-structured interview, which we realized as an online questionnaire with open questions. The teachers, who did not have any previous experience teaching AI, were asked to explain certain aspects of artificial intelligence to determine their subjective explanatory models. In this context, the central questions were:

- Where does your current knowledge of AI come from?
- When thinking of artificial intelligence, what feelings do you associate with it? Why do you feel this way?
- What is your definition of AI?
- How do you think machine learning works?
- How do you envision neural networks?
- What applications of AI have you encountered so far in your daily life?
- What do you think will be possible with artificial intelligence in the future?
- Which other aspects of artificial intelligence not mentioned above come to your mind?

Furthermore, the participants' demographic background and their teaching, CS, and overall AI experience were surveyed. The survey was conducted in German; the authors have translated all items and the answers used as examples.

All answers were analyzed using an adaption of Mayring's qualitative content analysis approach [4]. The category system was developed from the content by isolating meaningful chunks from the responses (minimal coding unit: individual nouns), which were then abstractly summarized under suitable categories. After coding 20% of the material, the categories were revised and partly subsumed under more general terms. Due to the low sample size of 23 participants in total, a further

refinement of the category system was carried out after coding the entire data set. This approach was necessary as some additional categories developed as part of coding the remaining 80% of the data. Furthermore, it was aimed at an unambiguous description of the categories. Subsequently, the whole data set was coded again. To ensure coding reliability, 20% of the data were independently encoded by a second researcher following the approach by [23]. As the basic assumptions (i.e., the categories are independent, mutually exclusive, and exhaustive) for calculating intercoder reliability or agreement coefficients [24] are not met, we chose to follow a qualitative approach to face differences in coding the interviews [25]. For that purpose, the differences between the codings were thoroughly discussed between the two coders. Additionally, reasons for the discrepancies were identified, and several steps were undertaken to achieve higher agreement, depending on the reason. The following reasons were found while revisiting the first coding steps:

- Missing context: Some of the codings were too short to find an unambiguous classification. For example, some of the answers were just given in keywords. Here, adding the context of the question made it possible to assign the codings that differed to the proper code.
- Different Focus: Some of the codings could be interpreted in different ways by focusing on one of two aspects mentioned within the coding. Here, a more detailed definition of the categories and a clear description of how to proceed through the coding categories helped to resolve these differences. For instance, a description of a phenomenon was prioritized to the description of an artifact.
- Expansion of the coding system: Ethical aspects were not part of the central questions but only brought up by the interviewees. Thus, the coding of the ethical aspects only developed during the coding process. This lead to ambiguous initial categories that had to be refined. In the end, after revisiting the codings and elaborating on the code descriptions, the agreement increased.

In general, most of the remaining differences could be made up by re-coding following the exact steps of Mayring proposed in [4]. The resulting final version of the coding system (displayed in Table I) was applied to the whole data set again.

TABLE I
CODING SYSTEM

Category	Example	Group
AI is Equivalent to Machine Learning	*[Complete the following sentence: For me, the term artificial intelligence means...] machine learning based on large amounts of information being processed by neural networks.*	(1) Attributions/Features of AI
Complexity and Unpredictability	*complex in real applications, because it often is a "blackbox"*	
Network/ Layer Structures	*Data processing networks that have a similar structure to the neural network of living beings (synapses + nerve cords).*	
Humanoid/ Mimicking Humans	*Information processing systems that imitate human thought processes, including perception and processing.*	
Autonomy	*robots and machines learn to "think" independently*	
Reference to Biological Concept	*Neural networks are human brain network structures*	(2) Explanations of AI Phenomena
Behavior Modification/ Optimization through Experience	*For example, by recognizing usage behavior over time and being able to adapt itself, or by calculating different approaches and incorporating the best ones into its program code.*	
Creation of Logical Links	*through logically linking the information provided ("input")*	
Information Processing	*By processing and evaluating information and learning something by means of programmed algorithms, something like that...*	
Programs/ Algorithms	*Using skills/methods provided by humans through programming.*	
Data Processing	*intelligent evaluation of large amounts of data*	
Efficiency and Optimization of Processes	*Optimization in the distribution of resources (energy, goods, services).*	(3) Expectations towards AI
Unpredictability and Uncontrollability/ Risk	*Processes influenced by AI become/are no longer comprehensible/verifiable and therefore less transparent.*	
Change	*Big change is certain. Change has winners and losers.*	
Assistance Function and Support	*Care assistance for elderly people (also with personal communication and conversations)*	
Automation/ Human Replacement	*automation of tasks*	
Autonomous Agents	*Autonomous action of robots/ machines/ cars, e.g. road traffic, other planetary probes*	(4) Everyday Perception of AI
Smart Agents	*Language assistants (Siri, Alexa etc.)*	
AI as Creator	*Google's attempt to invent pieces of music in the style of Johann Sebastian Bach, based on Johann Sebastian Bach's chorales*	
Mixed Feelings	*Mainly fascination, but also fears of abuse/ mistakes*	(5) Feelings towards AI
Positive	*Very interested and eager to see what the changes associated with these technologies will bring.*	
Negative	*Horror of the fact that the control of the operation is not fully thought through and the consequences are incalculable.*	
Ethical Control of AI	*The society in liberal democracies must be very vigilant, legal regulations are needed for the use of AI.*	(6) Ethical Issues of AI
Man-Machine Relationship	*By examining artificial intelligence, it also becomes clear what it means to be human.*	

V. RESULTS

A. Demographic Data and Previous Experience

The interview-survey was completed by 23 teachers, 18 men and five women (21.7%), who are participating in an in-service study program for the qualification of CS teachers. All participants are qualified grammar school teachers in Germany with different backgrounds. Twelve teachers are teaching mathematical and technical subjects, eleven teach foreign languages and social sciences, four are teaching music. Considering the age spectrum, 16 teachers are aged 35-50, while the rest is even younger (25-34).

The majority of teachers have more than ten years of general teaching experience (56.5%), only five teachers are teaching for less than five years and are, therefore, rather inexperienced. Concerning their CS education background, ten teachers have already taught 1-5 years of CS, two even 6-10 years, despite not having a university degree in Computer Science Education. The teachers' previous knowledge of computer science differs based on these teaching experiences and the participants' private interests. For example, some participants are novice programmers who were introduced to programming only during their studies, while others have several years of programming experience. The teachers' self-concept in the field of artificial intelligence is low: Based on their current knowledge about the topic, only two teachers consider themselves able to teach AI. However, nine teachers state that they have already actively informed themselves about artificial intelligence.

As resources for what they have heard about AI, the teachers almost exclusively name popular scientific sources like the media or (web-)articles. Only four participants additionally list reference books and lectures.

B. Pre-concepts of AI

The categories found as part of the qualitative content analysis can be subsumed under six different aspects, which largely reflect the structure of the questionnaire: *(1) Attributions/ Features of AI (Systems), (2) Explanations for AI Phenomena, (3) Expectations towards AI, (4) Everyday Perception of AI, (5) Feelings towards AI, (6) Ethical Issues of AI* (see Table I). Only the consideration of AI from an ethical point of view has not been explicitly represented in the questionnaire and was added based on the teachers' responses. These six aspects can be considered as different facets of the teachers' pre-concept about artificial intelligence.

1) Attributions/ Features of AI: The features the participants attribute to AI can be subsumed under five central characteristics. First of all, artificial intelligence systems are considered to be humanoid or to be mimicking humans. In this context, it is the imitation of human thought-processes that is described most frequently. However, participants also expect AI systems to show traits of creativity and problem-solving:

> *[Complete the following sentence: For me, the term artificial intelligence means...]*
> *a computer which, using complex algorithms, is able to imitate human (i.e., creative, problem-oriented and independent) thinking to the best possible extent. Especially the combination of enormous computing power with this ability to think humanly is what I consider as the main appeal of AI.*

The perception of AI as humanoid is closely linked to the attribution of autonomy. Autonomy is most strongly perceived for the way AI systems learn, but independent thinking, acting, and decision-making are also often mentioned. Furthermore, the idea that AI systems could independently change and extend their program code is also found. Based on these pre-concepts, AI is considered technically complex and unpredictable in terms of its results.

From a technical perspective, AI systems are associated with network or layer structures that process data. However, these descriptions remain vague and superficial; there are no detailed technical descriptions of how these technologies work. The network-association, as well as the fact that several participants define AI as machine learning, shows that the term artificial intelligence is connected to specific technologies and approaches, representing one part of this broad sub-field of computer science. This narrow perspective is also reflected in the teachers' definitions of AI in general.

> *[Complete the following sentence: For me, the term artificial intelligence means...]*
> *machine learning and thereby acquired knowledge applied to new situations.*

The participants primarily mentioned these features when defining AI, but they also characterized artificial intelligence in other parts of the interview. The definitions of AI, in particular, included the aspects autonomy, humanoid behavior, and the description of AI as a program or algorithm, which, however, is considered an explanation for AI phenomena.

2) Explanations for AI Phenomena: Participants used a series of explanatory models to explain AI phenomena like machine learning and neural networks. An important explanation arising in this context is the concept of behavioral modification and optimization based on the experiences made. Some teachers even describe this idea on a more detailed level by referring to pattern recognition, modification of parameters and adjustment of weights, statistical methods, and trial and error procedures. However, a large part of the responses remain rather unspecific:

> *A machine runs through various scenarios and is able to store and, most importantly, evaluate them. From this, new behaviors are developed, which, when the scenarios are processed again, lead to optimization.*

Teachers also assume that the functioning of artificial intelligence is based on the creation of logical links or information processing. These categories were distinguished based on the different focus, which is either on the creation of something new (*"Machines scan their environment, evaluate it and try to link new data with the existing information."*) or on simple processing operations (*"That information is passed on, and thus several places (synapses?) can receive the same information and then use it."*).

The identification of AI systems as programs and algorithms forms another important explanatory model. However, the aspect of self-learning is being added as a distinctive feature of AI algorithms by several participants. Codings attributed to this category underline the fact that AI systems are algorithms/ programs compared to those that only describe information processing.

> *In any case, information is collected and stored according to a predefined algorithm (which can, of course, be designed on different levels of specificity).*

Another frequently mentioned explanation for AI phenomena is data processing. The participants describe, on a rather superficial level, that data is used to identify patterns or rules and to develop the machines' behavior based on these. In doing so, the teachers are aware of the relevance of large amounts of data in these procedures.

> *Using many (the more, the better) data examples + given results to identify patterns and then apply these patterns to new data.*

Besides the aspect of data processing, the idea of behavioral modification based on experience and the use of trial and error procedures to acquire these experiences are the central elements of the teachers' explanations of how machine learning works. The ideas of a neural network often refer to networks and humanoid (brain) structures, associations that are already evoked by the term itself. In this context, some participants only took the biological concept of a neural network into account and described biochemical processes. That implies that these teachers do not have a pre-concept of neural networks in computer science, but only draw upon its biological model. Furthermore, some teachers did not give any explanation. However, it is not clear whether this is due to an actual lack of explanatory models for machine learning and neural networks or due to other factors, e.g., of motivational nature.

In general, the explanations remain rather superficial; technical terms are either not used confidently or not applied at all. Partly, misconceptions of processes can be found, and there is no awareness of different methods.

3) Expectations towards AI: The teachers described a series of different expectations towards AI in the interview survey. On the one hand, they expect greater efficiency and the optimization of processes and actions both in different areas of society and the business sector by using artificial intelligence, e.g., *"better workforce planning, more effective adaptation of search algorithms."* Besides optimization due to AI, the teachers also expect AI technologies to take over significant assistance and support function in everyday life, which leads to relief for the individual.

> *I would like to have some relief when correcting. However, I think it is more realistic that we will have technical reliefs, e.g., when driving a car.*

In this context, hope is being expressed that AI could be an effective problem solver in some areas: *"Chance to get the nursing shortage under control with robots."* This is closely connected to the expectation of automation and a replacement of the human workforce caused by artificial intelligence systems: *"many jobs, especially in large-scale industry, but also in the service sector are likely to be replaced by AI."* The evaluation of this process is ambivalent, depending on the concrete situation. The respective categories "Assistance Function and Support" and "Automation/ Human Replacement" were distinguished based on the focus of the respective statement on assistance and support or independence and replacement.

AI is furthermore expected to lead to a general social change, although this impact is often not specified by the participants (*"AI can offer a lot of new possibilities"*). When more detailed aspects are given, the fields of medicine, traffic, and technology stand out:

> *Great medical benefit, e.g., better diagnosis of skin cancer, detection of genetic factors for diseases*

On the other hand, the participants anticipate that the increasing use of artificial intelligence will also carry many risks and have unpredictable and uncontrollable consequences: *"For sure, AI leads to some unmanageable or rather not foreseeable risks."* However, these fears also remain unspecific and are not limited to concrete applications of artificial intelligence.

4) Everyday Perception of AI: Some categories already presented in the context of expectations towards AI are also arising in the field of everyday perception of AI. Separate categories were established for both contexts due to the different perspective on already existent AI technologies versus future developments.

In daily life, artificial intelligence is predominantly perceived in the form of smart agents of all types. The participants have already interacted with detection systems like speech and image recognition, are advised by proposal systems, and have used machine translation.

> *Speech assistants on mobile phones and computers or company websites - including pure speech recognition; the software usually reacts to keywords and provides the appropriate answers to problems (similar to FAQ).*

Besides smart agents, the teachers also describe autonomous agents present in their everyday life:

> *An automated subway, for example. No driver is necessary anymore, because all driving processes including exit/ entry, "doors open" etc. are automated.*

> *Lawnmowers, vacuum cleaners or rather cleaning robots that independently explore and "learn" the (spatial) plan of the area to be cleaned instead of being limited by hardware (by "beacons", light barriers and so on).*

Interestingly, self-driving cars are also mentioned in this context, which might be due to the media presence of this topic or the fact that assistance systems that seem to be intelligent are already present in many modern cars.

However, although not being common in day-to-day applications, participants also mention attempts to use artificial intelligence to make creative artifacts, e.g. of music and art, which might also be attributed to a special media presence of these applications due to their artistic and cultural

value. Furthermore, some participants indicate that they are not aware of any AI applications being present in their daily lives.

5) Feelings towards AI: The participants' general attitude toward artificial intelligence is mixed. Twelve participants indicate that they have ambiguous feelings towards AI and assume that this technology will offer both chances and risks. However, as already mentioned, when describing expectations towards AI, the examples given for these are rather general:

> *The idea that "machines" can think for themselves is, for one thing, very exciting and offers many possibilities that make our lives easier and, furthermore, enables new technical achievements. Then again, the idea of what could happen if machines could think and act independently is also scary.*

On the other hand, seven participants indicate positive feelings towards AI and are open to how it will influence society. They express interest, curiosity, fascination, and excitement towards AI. Those that perceive AI rather negatively express respect, concern, discomfort, but also fear and a feeling of being threatened by artificial intelligence.

6) Ethical Issues of AI: Ethical issues arising in the context of AI were mentioned by the participants in connection to their feelings towards AI as well as when being asked for other aspects of AI coming to their mind; there was no specific question concerning this topic. This indicates the high personal relevance of these aspects for the teachers. The technology is perceived as worthy of ethical debate, and regulation with laws, rules, and ethical guidelines is demanded explicitly.

> *You don't have to do everything just because you can. AI should not have final decision-making power in cases of "life and death"[...].*

> *I think that AI should not be used uncontrolled in all areas of human life, because a robot, for example, cannot decide everything ethically correct.*

The participants request that machines taking over control in society and the discrimination of specific population groups caused by AI systems are actively prevented. In this context, the relation between humans and machines is also brought up as AI serves to mimic humanoid structures and simultaneously reveals what it means to be human.

VI. Discussion

A. Structure of the Pre-concept

The findings of the qualitative content analysis, in general, confirm our preceding assumption that teachers currently only have superficial knowledge about artificial intelligence and that their pre-concepts are of rather general nature. Following [5], this indicates that teachers need to acquire more detailed content knowledge about the topic to successfully teach it, which can only be achieved with professional development measures. The teachers' pre-concepts comprise several facets and contain characteristics of AI, explanations for AI phenomena, expectations and feelings towards AI, as well as a keen awareness of the ethical relevance artificial intelligence has in modern society. Moreover, teachers are aware of AI being present in their daily lives. This structure of the teachers' pre-concepts is, of course, shaped by the interview's structure. However, all aspects addressed in the questionnaire were taken up by the participants and, being asked for further AI-related aspects that come to their minds, only the ethical aspect was added and stressed by the participants. In short, the teachers' pre-concept about AI and its facets can be described as follows:

The teachers do not dispose of a concrete technical idea of artificial intelligence. The pre-concepts remain on a rather abstract level. The participants consider artificial intelligence as the attempt to imitate human thought or behavior with machines by copying human biological structures and behavioral patterns like learning. By this process, machines achieve autonomy and technical inexplicability or at least complexity. Despite this being a quite detailed definition of AI, when explaining AI, the teachers only refer to some of the Big Ideas of AI, which are introduced by Touretzky et al. [26] (in particular *Learning* and *Social Impact*). This circumstance indicates that their concept of the topic of AI is not extensive.

Teachers explain the functioning of artificial intelligence systems with different procedures. On the one hand, the modification of behavior based on preceding experiences is described with different approaches, and the importance of data processing is highlighted. On the other hand, general computer science principles like algorithms, are mentioned, or technical explanations are entirely missing. The different aspects mentioned here, reflect the observation of Mesaroş and Diethelm [7], [8] that teachers highlight different aspects of one topic in terms of content and structure, which also impacts their teaching. Moreover, less content-related knowledge leads to more general explanatory approaches, as [5] observes.

The teachers expect AI to lead to social change with both positive effects like more efficiency and automation in different areas of society (e.g., traffic and medicine) and negative consequences and risks like uncontrollability of AI technologies. Currently, the teachers already interact with intelligent assistants and autonomous agents using AI in their daily lives and, overall, have ambiguous feelings towards the technology. Both the potential and the risks of AI are perceived, and open-mindedness and curiosity are equally present as a preoccupation. To face the risks of AI, the teachers strongly demand ethical control and critical reflection concerning the use of AI technologies.

B. Shortcomings of the Pre-concept

The results of our survey reveal misconceptions in the sense of Bonar and Soloway [10]. Several answers show the use of misleading analogies as well as a clear over-generalization [27] that leads to wrong, but consistent explanations of AI: *"You have to provide the machine with information over*

information which is then linked up by the machine, e.g., by using something like foreign keys."

At least, the results indicate that analogies have to be chosen carefully, and explanations have to deal with over-generalizations to provide a knowledge base for the teachers that allows them to interact appropriately in class as, according to [9] and [5], subjective theories and knowledge inaccuracies lead their actions. Further investigations have to examine those misconceptions and their origin. Although the study asked for the teachers' feelings about AI, it remains unclear whether knowledge inaccuracies come from missing learning opportunities or misleading resources, fostering teachers' feelings.

Popular scientific reports and the media mainly influence the participants' ideas, and only about 40% of the teachers have actively informed themselves about AI. Lindner [14] also observes these aspects. Similar results were found for teachers' preparation of general CS classes [28]. On the other hand, professional development programs' curricula contain classes dealing with scientific literature, even on urgent topics [29]. However, the use of popular sources requires a critical and reflective positioning towards the contents mediated. When using popular scientific sources as an informational resource, teachers need to be aware that, in this context, knowledge is often represented in a reduced form - similar to the reductions made in teaching - and relevant details are omitted in favor of general comprehensibility. Teachers, however, need to reach a much more elaborated knowledge than their students to be able to present a topic in class adequately. Therefore, there is a need to dig deeper and use a wide variety of different resources. Moreover, adequate preparation of teachers can only be guaranteed by extensive, high-quality teacher training led by experts in the respective fields.

The observation that the pre-concepts of those teachers who indicated that they have already informed themselves about AI are not more elaborated than the ideas of those who have not taken action themselves also shows that the popular scientific resources are not a sufficient informational resource. There is a slight tendency for explanations and ideas to become more specific, but they remain on a superficial level. For example, even in this group, almost no technical terms are used. This rudimentary level of knowledge and the very general shaping of the teachers' pre-concept of AI is not sufficient for teaching.

C. Implications

Gaps in the teachers' knowledge about artificial intelligence might lead to the (further) formation of misconceptions they might pass on to their students [5]. The interviews have shown that the teachers' knowledge gap comprises technical aspects of AI in general - there seems to be almost no knowledge and even no concrete pre-concepts concerning technical aspects of AI - as well as general functional principles of artificial intelligence and its different methods. In contrast, ethical issues coming up with intelligent machines are already more familiar, although concrete examples are also missing in this field. Based on this, teacher training initiatives in the field of AI should start with these basic functional principles and then approach technical details as well as their social and ethical consequences. A low threshold provides the opportunity to clear up all misconceptions about the field and guarantees a thorough training of all teachers.

VII. Conclusion

The study shows that the pre-concepts of teachers in the field of AI already contain several fundamental concepts and ideas of AI, but show no technical depth. The explanations for AI phenomena mostly originate from computer science in general or other disciplines; the central approaches of artificial intelligence like learning are often perceived in a non-technical or non-AI-typical sense, an aspect which [5] also observed with less knowledgeable teachers. Ethical aspects of AI, which are an important social factor, are perceived as particularly relevant. This can be explained by the interdisciplinary nature of this aspect and the school's concern to provide general education. Although some misconceptions could be identified on the part of the teachers, they were less widespread than could be expected with the broad "Science Fiction background" of AI. However, gaps in knowledge entail the risk of creating further misconceptions, even though in total, the potential of artificial intelligence was assessed realistically, and there is a particular awareness for problems that could arise with AI systems.

When establishing a teacher training for AI, it is helpful that teachers already have a reflected attitude towards AI and are open-minded towards this new technology and the change it might bring without considering it as a "magic bullet." Based on this, teachers will be able to consider artificial intelligence form a critical perspective and identify the central aspects and controversial points worth of ethical discussion. This perspective is particularly relevant for mediating a reflected attitude towards AI to the students, who need to know the limits and problems of these systems in order to be able to use and control artificial intelligence in the future adequately.

As the teachers we questioned are still being trained to be CS teachers, a further investigation will examine the pre-concepts of fully trained computer science teachers to determine if there are differences between these groups. This investigation will be conducted with personal semi-structured interviews to have the possibility to make further inquiries and to gain more detailed answers, which is not possible in the online questionnaires. Additionally, international comparison offers interesting perspectives. Replenished with a body of knowledge about artificial intelligence, which is gathered from experts and reference books in further research and can help to determine the necessary AI content knowledge for teachers, the results of this survey will be taken into account for the development of a teacher training workshop on artificial intelligence. This workshop is supposed to introduce the principles of AI and provide the teachers with everything they need to teach artificial intelligence successfully in K-12.

References

[1] B. Wrede, "Explaining AI: Are we ready for it?" *KI - Künstliche Intelligenz [AI - Artificial Intelligence]*, vol. 34, no. 1, pp. 1–3, 2020.

[2] Y. Qian, S. Hambrusch, A. Yadav, and S. Gretter, "Who needs what: Recommendations for designing effective online professional development for computer science teachers," *Journal of Research on Technology in Education*, vol. 50, no. 2, pp. 164–181, 2018.

[3] P. J. Denning, M. Tedre, and P. Yongpradit, "Misconceptions about computer science," *Commun. ACM*, vol. 60, no. 3, p. 31–33, 2017.

[4] P. Mayring, *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. SSOAR, 2014. [Online]. Available: http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173

[5] M. Z. Hashweh, "Effects of subject-matter knowledge in the teaching of biology and physics," *Teaching and Teacher Education*, vol. 3, no. 2, pp. 109–120, 1987.

[6] K. Chan and B. Yung, "Developing pedagogical content knowledge for teaching a new topic: More than teaching experience and subject matter knowledge," *Research in Science Education*, vol. 48, pp. 233–265, 2017.

[7] A.-M. Mesaroş and I. Diethelm, "Exploring computer science teachers' subjective theories on designing their lessons," in *Informatics in Schools: Situation, Evolution and Perspectives, Proceedings of the 5th International Conference ISSEP 2011*, 2011, pp. 158–168.

[8] ——, "Ways of planning lessons on the topic of networks and the internet," in *Proceedings of the 7th Workshop in Primary and Secondary Computing Education*, ser. WiPSCE '12. New York, USA: ACM, 2012, p. 70–73.

[9] H.-D. Dann, *Subjective theories and their social foundation in education*. Hogrefe & Huber, 1992, pp. 161–168.

[10] J. Bonar and E. Soloway, "Preprogramming knowledge: a major source of misconceptions in novice programmers," *Human-Computer Interaction*, vol. 1, no. 2, pp. 133–161, 1985.

[11] J.-M. Burkhardt, F. Détienne, and S. Wiedenbeck, "Mental representations constructed by experts and novices in object-oriented program comprehension," in *Proceedings of the IFIP TC13 Interantional Conference on Human-Computer Interaction*, ser. INTERACT '97. Chapman & Hall, Ltd, 1997, pp. 339–346.

[12] ——, "Object-oriented program comprehension: Effect of expertise, task and phase," *Empirical Software Engineering.*, vol. 7, no. 2, pp. 115–156, 2002.

[13] A. Vazhayil, R. Shetty, R. R. Bhavani, and N. Akshay, "Focusing on teacher education to introduce ai in schools: Perspectives and illustrative findings," in *2019 IEEE Tenth International Conference on Technology for Education (T4E)*, 2019, pp. 71–77.

[14] A. Lindner and R. Romeike, "Teachers' perspectives on artificial intelligence," in *ISSEP 2019 - 12th International conference on informatics in schools: Situation, evaluation and perspectives, Local Proceedings*, E. Jasutė and S. Pozdniakov, Eds., 2019, pp. 22 – 29.

[15] L. S. Shulman, "Those who understand: Knowledge growth in teaching," *Educational Researcher*, vol. 15, no. 2, pp. 4–14, 1986.

[16] ——, "Knowledge and teaching: Foundations of the new reform," *Harvard Educational Review*, no. Feb., pp. 1–22, 1987.

[17] W. Carlsen, "Domains of teacher knowledge," in *Examining Pedagogical Content Knowledge*, ser. Science & Technology Education Library, J. Gess-Newsome and N. Lederman, Eds. Springer Netherlands, 2002, vol. 6, pp. 133–144.

[18] P. Mishra and M. J. Koehler, "Technological pedagogical content knowledge: A framework for teacher knowledge," *Teachers College Record*, vol. 108, no. 6, pp. 1017–1054, 2006.

[19] D. L. Ball, M. H. Thames, and G. Phelps, "Content knowledge for teaching: What makes it special?" *Journal of Teacher Education*, vol. 59, no. 5, pp. 389–407, 2008.

[20] K. Westermann, N. Rummel, and L. Holzäpfel, "Präkonzepte aufgreifen fördert den Verständniserwerb. [Taking up pre-concepts promotes understanding]," in *Beiträge zum Mathematikunterricht 2012 Digital. Vorträge auf der 46. Tagung für Didaktik der Mathematik. [Contributions to teaching mathematics 2012 digital. Lectures of the 46th conference for mathematics education]*, 2012.

[21] E. Bender, N. Schaper, M. E. Caspersen, M. Margaritis, and P. Hubwieser, "Identifying and formulating teachers' beliefs and motivational orientations for computer science teacher education," *Studies in Higher Education*, vol. 41, no. 11, pp. 1958–1973, 2015.

[22] E. Bender, P. Hubwieser, N. Schaper, M. Margaritis, M. Berges, L. Ohrndorf, J. Magenheim, and S. Schubert, "Towards a competency model for teaching computer science," *Peabody Journal of Education*, vol. 90, no. 4, pp. 519–532, 2015.

[23] J. L. Campbell, C. Quincy, J. Osserman, and O. K. Pedersen, "Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement," *Sociological Methods & Research*, vol. 42, no. 3, pp. 294–320, 2013.

[24] R. L. Brennan and D. J. Prediger, "Coefficient kappa: Some uses, misuses, and alternatives," *Educational and Psychological Measurement*, vol. 41, no. 3, pp. 687–699, 1981.

[25] P. Hubwieser, M. N. Giannakos, M. Berges, T. Brinda, I. Diethelm, J. Magenheim, Y. Pal, J. Jackova, and E. Jasute, "A global snapshot of computer science education in K-12 schools," in *Proceedings of the 2015 ITiCSE on Working Group Reports*, N. Ragonis and P. Kinnunen, Eds. ACM Press, 2015, pp. 65–83.

[26] D. Touretzky, C. Gardner-McCune, F. Martin, and D. Seehorn, "How should K-12 students experience AI?" in *Presentation at AIAED 2019 (extended abstract)*, 2019.

[27] M. Clancy, "Misconceptions and attitudes that interfere with learning to program," in *Computer Science Education Research*, S. Fincher and M. Petre, Eds. London: Taylor & Francis, 2004, pp. 85–100.

[28] P. Hubwieser, J. Magenheim, A. Mühling, and A. Ruf, "Towards a conceptualization of pedagogical content knowledge for computer science," in *Proceedings of the ninth annual international ACM conference on International computing education research*. ACM Press, 2013, pp. 1–8.

[29] P. Hubwieser, M. Berges, J. Magenheim, N. Schaper, K. Bröker, M. Margaritis, S. Schubert, and L. Ohrndorf, "Pedagogical content knowledge for computer science in german teacher education curricula," in *Proceedings of the 8th Workshop in Primary and Secondary Computing Education*. ACM, 2013, pp. 95–103.