Teachers' Perspectives on Artificial Intelligence

Annabel Lindner[1] and Ralf Romeike[2]

[1] Computing Education Research Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany, annabel.lindner@fau.de
[2] Computing Education Research Group, Freie Universität, Berlin, Germany, ralf.romeike@fu-berlin.de

Abstract. The growing importance of artificial intelligence systems in daily life leads to increasing demands for artificial intelligence (AI) as a topic in schools and the necessity to consider what all students in the 21st century should know about the topic. However, the successful integration of topics related to AI into teaching in K-12 requires proper preparation of teachers for this task. Therefore, we have conducted a questionnaire survey to get a first estimation of computer science teachers' knowledge about the subject area. The teachers, who are already interested in AI, are furthermore asked which competences and types of knowledge they would consider as most important for their students in the field of AI. The questionnaire also investigates the challenges of teaching artificial intelligence. The survey shows that the teachers' knowledge about artificial intelligence is broadly influenced by current "hype" topics and media coverage of AI. Teachers place a slightly higher value on socio-cultural and technical knowledge about AI than on pure application-oriented competences. Moreover, teachers perceive a lack of adequate teaching materials as well as best-practice examples and tools in the field of artificial intelligence. Despite these challenges, the integration of the topic into computer science education curricula is welcomed.

Keywords: Teachers' Perspectives · CS Education · Artificial Intelligence.

1 Introduction

With recent advances in technology that become visible in, e.g., the impressive skills of DeepMind's game AI AlphaZero [17], the translator DeepL [4], the development of self-driving cars [3], or smart assistants like Siri and Alexa, the importance of artificial intelligence systems in the modern digital world is rising and starts to affect our daily lives significantly. On account of this development, demands for the integration of artificial intelligence into computer science curricula in K-12 and the fostering of competences in the field of AI have been made by various institutions. For instance, the German government has approved a strategy paper on AI that promotes the extension of artificial intelligence education in Germany [2] and the G7 have committed to a vision on the future of artificial intelligence that also includes the area of education [8]. In response,

material and curricula for teaching AI in K-12 have been developed worldwide (e.g. [22], [23], [15]).

However, besides providing useful teaching material, a central factor for successfully integrating the topic artificial intelligence into teaching is, apart from an appropriate didactic reduction of the subject area's contents, the adequate preparation and qualification of teachers. Diethelm et al. [5] highlight that material for computer science education developed by CS educators is often not used in an actual class. This circumstance is attributed to the disregard of teachers' perspectives in the development of teaching concepts and the assumption that teachers will be able to garner the required knowledge for any topic on their own. Thus, the inclusion of teachers' perspectives, i.e. the teachers' knowledge of the subject area, their explanatory models and their aims and expectations for class, is considered an important aspect for the development of effective teaching concepts and material that corresponds to the teachers' needs. Therefore, it plays an important role in their Model of Educational Reconstruction for Computer Science Education [5]. To get first insights into the teachers' knowledge about AI and to derive measures to support computer science teachers, we have conducted an online questionnaire survey that examines the current situation.

In this context, the following research questions are addressed:

- What general knowledge of artificial intelligence do computer science teachers who are interested in the subject area dispose of?
- Which educational goals are pursued by these teachers in the field of AI and which challenges are they confronted with?

2 Related Work

2.1 Artificial Intelligence

A simple and concise definition of the term artificial intelligence can hardly be found. This is due to the fact that artificial intelligence can have various forms and that the phrase serves as a comprehensive term for different technologies and procedures. Furthermore, the AI community does not even agree upon a concise definition of intelligence as such (c.f. [7]). Therefore, Russell and Norvig [16] assign various definitions of AI to four general approaches of describing artificial intelligence: systems that act humanly, systems that think humanly, systems that act rationally or systems that think rationally. Thus, the central aim of AI is to understand, model and reproduce humanoid or ideal intelligent behavior in artificial systems whereby different techniques are used.

Görz et al. [9] identify a series of disciplines of AI but highlight that there are different opinions on how to systematically order them. They establish *search*, *(human) cognition*, *knowledge representation and processing* as well as *inference and logic* as central concepts of AI. These aspects are of high relevance in the field of AI and serve as the basis for more specialized theories and methods. In this context, neural networks, machine learning and data mining, dealing with constraints, planning, dealing with uncertain knowledge (by using e.g. statistical

methods, fuzzy logic and theory of probability), non-monotonic logic[3], case-based reasoning[4], language processing, and multi-agent systems are identified as subfields or rather theories and methods of AI (cf. [9]). These approaches are employed in different applications, e.g. typical ones for machine learning are classification tasks and pattern recognition. Hence, artificial intelligence can not be equated with machine learning as it is currently often done in public discourse. Machine learning is rather one of the sub-domains or paradigms of AI and despite it being highly relevant in AI research and applications at present, considerations of the topic artificial intelligence in educational contexts should not be confined to machine learning but also take the other subfields and, in particular, the central concepts and big ideas of AI into account. This is especially important as the discipline of artificial intelligence is still in constant evolution and significant paradigm shifts cannot be ruled out.

In general, there are two different paradigms of representation in AI. Symbolic and sub-symbolic AI differ in the way in which knowledge is represented in the AI system. Symbolic methods explicitly represent knowledge by describing it symbolically, e.g. by using logic to represent facts and rules in expert systems. The sub-symbolic representation refrains from this explicit representation. Instead of manipulating symbolic representations of knowledge to solve problems, knowledge is stored implicitly. For example, in a neural network it is represented as a pattern of different weights, i.e. indirectly and not as composed of individual parts (cf. [9]). This implicates that often it is not explicitly comprehensible, how a sub-symbolic system determines a solution.

2.2 Perspectives of Teachers

Looking at current literature, research on teachers' perspectives on the topic of artificial intelligence is quite rare. Although there is already plenty of material and curricula dealing with the topic of AI in K-12[5], to our knowledge, there are no studies explicitly regarding teachers' perspectives on AI in secondary education and only some for higher education.

Wollowski et al. [20] carry out a survey with both AI instructors and AI practitioners to evaluate the concordance of current practice and teaching of AI in tertiary education. However, this survey does not focus on the instructors' individual knowledge but rather examines their course concepts. They found that instructed topics and the needs of AI practitioners match largely, both instructors and practitioners emphasize the importance of topics like search, knowledge representation and reasoning as well as machine learning. Differences are found in the practitioners' strong focus on systems engineering while educators tend to rather use more playful approaches to introduce basic AI topics. Further-

[3] Method of deducing new facts from a base of facts and rules in which new facts can contradict old ones. Contradictions lead to the elimination of one of the facts.

[4] The process of solving problems based on solutions of similar past problems.

[5] e.g. [23], [15], https://experiments.withgoogle.com/teachable-machine, https://machinelearningforkids.co.uk/

more, educators take a broader perspective including ethical, philosophical and historical aspects of AI instead of only dealing with AI tools and techniques.

Sulmont et al. [18] explore the pedagogical content knowledge (PCK) necessary for teaching machine learning to university students without a background in CS. In interviews with instructors, they determine preconceptions and barriers the students come across in the field of machine learning and identify the tactics instructors use to face them. The students' preconceptions rather center upon the reputation of machine learning than upon how it works. Consequently, students tend to misconceive AI's abilities or do not consider themselves able to implement machine learning. To overcome these challenges, instructors work through and simulate machine learning algorithms in class. Furthermore, the instructors use specific data sets, real world, open-ended and domain-specific problems as well as extensive visualization. They also find that math and programming are challenges for non-CS students and that, therefore, some instructors tend to omit these aspects when teaching machine learning. They summarize that instructors face a series of challenges when teaching non-CS university students in the field of machine learning, but are able to overcome them by using certain tactics and adequate PCK. Despite that, the results of Wollowski et al. [20] and Sulmont et al. [18] are not transferable to secondary education as the underlying educational goals are not comparable.

Concerning the methodology of gathering teachers' perspectives on CS topics and teaching, a series of different approaches can be found in the literature. Yadav et al. [21] or Gretter et al. [10] are using semi-structured interview protocols to elicit teachers' perspectives. The study of Griffin et al. [11] combines teacher interviews with classroom observations in the form of field notes to analyze teachers' practices and their perspectives on the CS Principles Framework. Another central approach to elicit teachers' perspectives, which is also used in our survey, is conducting questionnaire surveys with closed questions. This method is pursued e.g. by Thompson et al. [19] to assess the adoption of new CS standards by teachers in New Zealand and by Grillenberger and Romeike [12], who have designed a questionnaire to elicit teachers' perspectives on data management – a new field of CS evolving from databases – and find that most teachers possess only a little knowledge about this, like AI, rather new topic of CSE.

3 Methodology

In order to evaluate the teachers' perspectives on artificial intelligence, a questionnaire survey was developed that aims to get a first impression of the teachers' content knowledge about AI as well as their experiences, expected challenges and objectives when teaching the topic. With this structure, the questionnaire focuses on content knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge of teachers according to the TPACK Model [14], which is a conceptual framework to structure professional knowledge of teachers. These components of the teachers' professional knowledge influence the teachers' views on certain CS topics

and their teaching and are, hence, important for the successful development of material and for teacher training. General pedagogical and technological knowledge, which are also part of TPACK, are not subject or topic specific and are, therefore, not explicitly considered in the questionnaire.

The survey was conducted with 37 German secondary school computer science teachers from Bavaria, Berlin, and Brandenburg before they participated in a workshop about unplugged activities on artificial intelligence[6]. Thus, all participants are holding some kind of CS degree, are already interested in AI and are looking for possibilities to deal with the topic in class. However, this does not mean that all teachers have already taught AI or possess content knowledge about AI, the group of participants is rather heterogeneous. Consequently, the teachers have probably dealt with the contents of the subject area in varying degrees of intensity and have different levels of knowledge. This circumstance can help to assess how training material for teachers as well as teaching materials about AI should be arranged to build upon the teachers' previous knowledge.

As this survey (cf. Table 1) has the clear objective to gain a first general overview of the teachers' perspectives on AI, the questionnaire was kept short and consists of only five questions. To assess the teachers' content knowledge on AI, teachers were asked to evaluate certain keywords on their relevance for the subject area artificial intelligence. The keywords were selected based on the contents of widely-accepted reference books for the field of AI ([16], [6], [13], [7], [9]) and their examination of the subject area. The topics identified in the literature by structuring and matching the books' contents were summarized and partly reworded for the benefit of unambiguous comprehensibility. The keywords focus on methods and applications of AI, specific technologies like neural networks are therefore subsumed under these categories (neural networks are considered as one aspect of machine learning). This approach led to the following list of keywords that can also be assigned to the principles of AI identified in the Related Work section ([9], [20]): *Knowledge Representation, Search, Statistical Methods and Theory of Probability, Ethics, Classification, Machine Learning, Reasoning, Robotics, Algorithms, Natural Language Processing, Pattern Recognition, Approximation, Data Analysis*. Furthermore, distractors were added to identify random answers: *Sorting Algorithms, Simulation, Cloud Computing, Turing Machines*. These aspects are not associated with AI in any of the reference books that were taken into account. However, this approach can only give a first indication of the teachers' knowledge of AI and does not provide insights into details or explanatory models, further evaluation of this aspect is, therefore, necessary.

Furthermore, the questionnaire examines if the teachers have already taught artificial intelligence and evaluates educational goals and challenges of AI in class. Adapted to the three perspectives established in the Dagstuhl triangle [1], the educational goals included in the questionnaire can be attributed to either a structural, application-oriented or socio-cultural perspective on the topic of artificial intelligence. These perspectives contribute to a holistic view of the topic. In terms of challenges and difficulties of teaching AI, a series of central factors were

[6] See https://ddi.cs.fau.de/schule/ai-unplugged/ for details about these activities.

Table 1. The specific questions of the survey. All questions except question 2 are designed as Likert items.

1. How strongly do you associate the following aspects with artificial intelligence? Knowledge Representation, Search, Statistical Methods and Theory of Probability, Ethics, Classification, Machine Learning, Sorting Algorithms, Simulation, Reasoning, Robotics, Algorithms, Cloud Computing, Natural Language Processing, Pattern Recognition, Turing Machines, Approximation, Data Analysis Scale: 1-Very strongly — 2 — 3 — 4 — 5 — 6-Not at all — I cannot assess this.
2. Have you already given lessons on artificial intelligence? No. Yes, in regular class. Yes, in a special seminar. Yes, as part of extracurricular activities. Other.
3. I would like to see an explicit curricular integration of the topic AI. Scale: 1-Very strongly agree— 2 — 3 — 4 — 5 — 6-Very strongly disagree
4. When it comes to artificial intelligence (AI), I consider it important that all students... ...are able to assess ethical implications of AI systems, especially chances and risks for society. ...are able to identify the technical limitations of AI systems. ...develop a reflected personal attitude towards the use of AI systems. ...can use AI libraries (e.g. Tensorflow, Scikit-Learn) in their own programs. ...effectively utilize AI systems. ...are able to explain the functioning of machine learning processes. ...are able to assess the intelligence of AI systems. ...compare different methods that are used in AI systems. ...are able to identify use cases for AI systems. Scale: 1-Very strongly agree— 2 — 3 — 4 — 5 — 6-Very strongly disagree
5. What challenges and difficulties do you perceive when it comes to teaching artificial intelligence? I do not have the required expertise in this field. There is a lack of suitable teaching materials. There are no good best practice examples. There is a lack of appropriate tools. The subject is too complex. There is little or no time to deal with extra-curricular content in class. Scale: 1-Very true of me— 2 — 3 — 4 — 5 — 6-Very untrue of me — I cannot assess this.

integrated into the questionnaire. They include the teachers themselves, teaching materials available and the topic itself. The survey questions are designed as Likert items and have to be answered on six-level Likert scales (cf. Table 1).

4 Results

The questionnaire does not indicate how much content knowledge the teachers possess in the individual sub-domains of artificial intelligence, but only gathers if the teachers generally have an idea of the field. Consequently, it cannot be determined if teachers who have already taught AI possess a more detailed knowledge about the field. For this reason, the results for teachers with (7 teachers) and without teaching experience (29 teachers) in the field of AI are not considered separately. The following aspects were found:

1. The teachers' content knowledge of AI is largely influenced by social discourses about AI. In terms of content knowledge on artificial intelligence, the survey indicates that AI-buzzwords frequently used in the media influence the teachers' idea of the field. Both median and mode values for the keywords *Classification, Machine Learning, Natural Language Processing, Pattern Recognition, and Data Analysis* show that these keywords are associated with the subject area very strongly (cf. Table 2). The other keywords obtain lower rates with median values between 2 and 3.

Table 2. Association of keywords with the subject area artificial intelligence, 1 - Very strongly, 6 - Not at all. When the No. of Answers is less then 37, participants have either not answered at all or indicated that they cannot assess the item.

Keyword	No. of Answers	Median	Mode	$\overline{d}_{0.5}$
Knowledge Representation	34	3	3	0.94
Search	36	2	2	0.72
Statistical Methods and Theory of Probability	37	2	1	0.76
Ethics	36	2	1	1.22
Classification	37	1	1	0.78
Machine Learning	37	1	1	0.46
Sorting Algorithms	33	3	1	1.52
Simulation	36	2	1	1.06
Reasoning	35	2	1	1.06
Robotics	37	2	1	1.00
Algorithms	37	2	1	0.97
Cloud Computing	36	2	1	1.25
Natural Language Processing	37	1	1	0.65
Pattern Recognition	37	1	1	0.22
Turing Machines	31	4	3	1.19
Approximation	35	2	2	0.97
Data Analysis	37	1	1	0.38

2. The teachers' ideas of artificial intelligence diverge significantly. The absolute deviation from the median $\overline{d}_{0.5}$ shows clearly that the association of the keywords with artificial intelligence differs widely among the participants. Seven out of seventeen keywords have a deviation of $\overline{d}_{0.5} \geq 1$. Still, all buzzword-keywords have a deviation of $\overline{d}_{0.5} < 0.8$. Such deviation values also indicate that the teachers' ideas of what artificial intelligence comprises diverge significantly. These results cannot be brought in to draw detailed conclusions on the teachers' knowledge about the subject area, but the prominent assessment of the buzzwords indicates that teachers have only a rough idea of the subject area and its sub-topics, which is shaped by current hype topics.

This conclusion is also supported by the fact that the distractors, i.e. *Simulation*, *Cloud Computing*, *Sorting Algorithms* and *Turing Machines*, are not clearly perceived as rather not belonging to the field of AI. Except for *Turing Machines*, the median and mode values for the distractors do not stand out from the other keywords (cf. Table 2) and they are just as much associated with AI as the other keywords used in the survey.

3. Most teachers do not have experiences with teaching AI yet. The diverging ideas of artificial intelligence are directly related to the fact that 80.56 % of the teachers questioned have not taught artificial intelligence until now and thus had no need to take a closer look at the topic. Furthermore, AI is not a compulsory part of teacher training programs in Brandenburg, Berlin, and Bavaria where this survey was conducted. Nevertheless, the majority of the teachers is in favor of a curricular integration of the topic, only 8.33 % of the participants have a rather negative opinion on the curricular integration of AI as Table 3 indicates.

However, due to this result, the outcome of the subsequent items must be reviewed critically: with little content knowledge about the topic and no teaching experience, it is rather difficult to assess educational goals and challenges of teaching it. Therefore, for comparison, the results of the teachers who have already taught AI and should thus be more confident in assessing the goals and challenges were reviewed again separately. These results show the same tendencies concerning the importance of certain educational goals (e.g. 85.71 % and 89.66 % of the teachers with and without experience agree that students should be able to assess the intelligence of AI systems; socio-cultural aspects are considered most important in both groups). Nevertheless, those with teaching experience in AI generally consider the challenges of teaching AI less high although they still perceive the same kind of difficulties (e.g. only 85.71 % perceive a lack of suitable teaching materials, compared to 94.29 % in the entire group).

4. Teaching concepts for AI should address a variety of educational goals. The educational goals of teachers in the field of AI are not confined to one of the Dagstuhl-perspectives [1] but comprise each of the three aspects mentioned in the methodology section. However, socio-cultural aspects like the development of a critical personal attitude towards AI systems (100 % agreement[7]) or the eval-

[7] In this section, agreement refers to the response options *1-Very strongly agree, 2* and *3* on the Likert-scale.

Table 3. I would like to see an explicit curricular integration of the topic AI.

Response Option	%
1 - Very strongly agree	36.11 %
2	30.55 %
3	25.00 %
4	8.33 %
5 & 6-Very strongly disagree	-

uation of social chances and risks of AI technologies reach the highest approval rates (94.44 % agreement). The ability to actually utilize AI systems (77.78 % agreement) and libraries (63.89 % agreement) is considered least relevant by the teachers, being able to identify technical limitations of artificial intelligence (88.89 % agreement) or to explain the functioning of machine learning processes (86.11 % agreement) is regarded as more important.

The challenges of teaching artificial intelligence perceived by the teachers are diverse. 91.67 % of the teachers agree that they lack profound knowledge about artificial intelligence, 94.29 % consider it as a problem to find suitable teaching materials or best-practice examples (87.88 %). The high complexity of the topic is considered a problem by 64.52 % of the teachers and can therefore also be seen as a central challenge for integrating the topic in K-12 education. Furthermore, 71.43 % of those questioned indicate that they do not have enough time to deal with extracurricular contents like AI in class.

5 Discussion

Even though the sample size is too small to permit general conclusions and reasonable statements about statistical significance, the results of the questionnaire survey show that even most teachers interested in the topic only have a rough idea about the subject area of AI. Their knowledge seems to be shaped by the latest (media) topics and developments in the field of artificial intelligence, topics of AI which are currently less popular, e. g. search, are less strongly associated with AI. In the teachers' perception, the subject of artificial intelligence seems, above all, to be linked with aspects of machine learning and typical application areas of AI such as language processing and data analysis. This might indicate that teachers are often not aware of the full scope of the topic and the aspects forming the basic principles of AI. Yet, it is these basic principles that are highlighted by AI instructors and practitioners on the university level, as the findings of Wollowski et al. [20] show, and which, therefore, should also be familiar to teachers and play a role in class. Nevertheless, this thesis should be verified with a more detailed investigation of the teachers content knowledge on AI. This could be done by using open questions which were not part of this questionnaire.

The strong focus on AI buzzwords also indicates that, for class, AI is not only relevant as a mere subject content but also serves to educate and inform about

current public discourses and, therefore, is of high value for general education. Consequently, teaching AI should not only consider either a technological or a socio-cultural or an application-oriented perspective, as it is done by many of the concepts that already exist[8], but follow a holistic approach that integrates computer science contents, media-ethical perspectives and aspects of practical and socio-cultural relevance. As the educational goals of the teachers questioned are not confined to one of the Dagstuhl-perspectives [1], such a wide perspective is clearly aimed for by them. With this in mind, teacher training should cover this new topic in various facets to allow for a holistic teaching.

Thus, the aspects mentioned need to be taken into account in the development of workshops, teaching materials and concepts for teacher training. To meet the teachers' needs, it is important to adapt the material to the teachers' prior knowledge about AI [5]. As, according to the survey, the teachers have only basic content knowledge about AI, the buzzwords already familiar from social discourses can form adequate starting points to introduce and discuss topics of AI. This approach also makes it possible to explore the existing explanatory models of teachers for certain AI phenomena[9] and, if necessary, to modify them. By clarifying and deepening terms like machine learning, referring to AI applications familiar from everyday life, as well as by establishing connections to AI sub-topics or principles which are already part of CS curricula, e.g. search or expert systems, familiarizing with the topic is facilitated. For example, as problem-solving by search is a fundamental concept of AI, teachers can be made aware that search strategies can also be mediated in the context of AI. This is equally possible with data structures like graphs and (decision) trees.

Moreover, to respond to the challenges perceived by the teachers questioned, it is necessary to develop innovative and creative material that offers low initial hurdles but also appeals to teachers who are already experienced in the field of AI. This can be achieved by providing detailed material which serves both to extend the teachers' content knowledge and to show suitable and innovative teaching approaches for different and complex topics from the subject area, as the findings of Sulmont et al. [18] show that instructors face a series of topic-specific challenges when teaching about AI. The curricular integration of the topic would have to be accompanied by such actions to reduce the hurdles of teaching artificial intelligence and to guarantee an effective, competence-oriented alignment of AI education.

Nonetheless, to achieve this, the teachers' perspectives need to be examined in more detail (e.g. by conducting qualitative interviews) and teaching materials for AI should be developed in close cooperation with teachers to effectively meet their needs. This survey, which gives first insights into the teachers' perspectives on AI and whose general findings correspond to those of Grillenberger and Romeike [12] for the field of data management – an equally new topic for CS class –, can serve as a basis for further research on these aspects.

[8] e.g. http://moralmachine.mit.edu/, https://machinelearningforkids.co.uk

[9] A further general investigation of these explanatory models in the field of AI is necessary as they were omitted in this rather general survey.

6 Conclusion

In sum, we found that even computer science teachers who are already interested in AI predominantly draw upon content knowledge about the topic that is largely influenced by the current social discussion about AI. Nevertheless, most teachers are in favor of introducing artificial intelligence into computer science curricula and have diverse educational goals that focus on technical as well as socio-cultural and application-oriented aspects. Furthermore, the teachers questioned perceive a number of challenges ranging from content knowledge deficits in the subject area to high thematic complexity and a lack of adequate teaching materials and time in class. All of these aspects need to be taken into account when developing AI training materials for teachers and teaching concepts. Thus, the following recommendations can be made: to connect to the teachers' prior knowledge, which is influenced by the media and social discourse, materials about AI should start with familiar buzzwords and then go deeper. Furthermore, the central principles of AI should be highlighted with varied examples and be linked to existing curricular topics in training materials. Finally, to ensure sustainable teaching about AI, teachers should be encouraged to take a holistic perspective on the topic and be supported in mastering the complex technical aspects of AI and its subfields with extensive training and teaching materials. Such starting points can simultaneously provide teachers with ideas on how to introduce the topic to students without being overwhelmed by the complexity of the field.

However, the results of the questionnaire also lead to subsequent research questions that need further investigation: Can the present results be transferred to a larger sample size? Moreover, it needs to be determined how the teachers acquired their knowledge about AI and to which extent the media really is important in this process of knowledge acquisition.

References

1. Brinda, T., Diethelm, I.: Education in the digital networked world. In: Tatnall, A., Webb, M. (eds.) Tomorrow's Learning: Involving Everyone. Learning with and about Technologies and Computing. pp. 653–657. Springer International (2017)
2. Bundesregierung: Strategie Künstliche Intelligenz der Bundesregierung [Artificial intelligence strategy] (2018), https://www.bmbf.de/files/Nationale_KI-Strategie.pdf. Last accessed June 15, 2019
3. Conner-Simons, A., Gordon, R.: Self-driving cars for country roads (2018), http://news.mit.edu/2018/self-driving-cars-for-country-roads-mit-csail-0507. Last accessed May 23, 2019
4. DeepL GmbH: Deepl translator, https://www.deepl.com/translator. Last accessed May 22, 2019
5. Diethelm, I., Dörge, C., Mesaros, A.M., Dünnebier, M.: Die Didaktische Rekonstruktion für den Informatikunterricht [Educational reconstruction for computer science education]. In: Informatik in Bildung und Beruf–INFOS 2011–14. GI-Fachtagung Informatik und Schule. pp. 77–86. Lecture Notes in Informatics (LNI) - Proceedings, Gesellschaft für Informatik e.V. (2011)
6. Ertel, W.: Introduction to Artificial Intelligence. Springer International (2018)

7. Frankish, K., Ramsey, W.M.: The Cambridge Handbook of Artificial Intelligence. Cambridge University Press (2014)
8. G7: Charlevoix common vision for the future of artificial intelligence (2018), https://www.bundesregierung.de/resource/blob/975254/1142208/9fdd8014296e52270d56d70df98ce7e0/2018-06-09-g7-kanada-artificial-intelligence-en-data.pdf?download=1. Last accessed June 17, 2019
9. Görz, G., Schneeberger, J.: Handbuch der künstlichen Intelligenz [Handbook of Artificial Intelligence]. Oldenbourg (2014)
10. Gretter, S., Yadav, A., Sands, P., Hambrusch, S.: Equitable learning environments in K-12 computing: Teachers' views on barriers to diversity. ACM Transactions on Computing Education **19**, 1–16 (01 2019). https://doi.org/10.1145/3282939
11. Griffin, J., Pirmann, T., Gray, B.: Two teachers, two perspectives on CS principles. In: Proceedings of the 47th ACM Technical Symposium on Computing Science Education. pp. 461–466. SIGCSE '16, ACM, New York, NY, USA (2016). https://doi.org/10.1145/2839509.2844630
12. Grillenberger, A., Romeike, R.: What teachers and students know about data management. In: Tatnall, A., Webb, M. (eds.) Tomorrow's Learning: Involving Everyone. Learning with and about Technologies and Computing. pp. 557–566. Springer International (2017)
13. Lämmel, U., Cleve, J.: Künstliche Intelligenz [Artificial Intelligence]. Hanser (2012)
14. Mishra, P., Koehler, M.: Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record **108**, 1017–1054 (06 2006). https://doi.org/10.1111/j.1467-9620.2006.00684.x
15. ReadyAI: ReadyAI Curriculum (2019), https://www.readyai.org/curriculum/. Last accessed August 20, 2019
16. Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Prentice Hall (2009)
17. Silver, D., Hubert, T., Schrittwieser, J., Hassabis, D.: Alphazero: Shedding new light on the grand games of chess, shogi and Go (2018), https://deepmind.com/blog/alphazero-shedding-new-light-grand-games-chess-shogi-and-go/. Last accessed May 27, 2019
18. Sulmont, E., Patitsas, E., Cooperstock, J.R.: Can you teach me to machine learn? In: Proceedings of the 50th ACM Technical Symposium on Computer Science Education. pp. 948–954. SIGCSE '19, ACM, New York, NY, USA (2019). https://doi.org/10.1145/3287324.3287392
19. Thompson, D., Bell, T., Andreae, P., Robins, A.: The role of teachers in implementing curriculum changes. In: Proceeding of the 44th ACM Technical Symposium on Computer Science Education. pp. 245–250. SIGCSE '13, ACM, New York, NY, USA (2013). https://doi.org/10.1145/2445196.2445272
20. Wollowski, M., Selkowitz, R., Brown, L.E., Goel, A., Luger, G., Marshall, J., Neel, A., Neller, T., Norvig, P.: A survey of current practice and teaching of AI. In: Proceedings of the Sixth Symposium on Educational Advances in Artificial Intelligence (EAAI-16). pp. 4119–4124 (2016)
21. Yadav, A., Gretter, S., Hambrusch, S.: Challenges of a computer science classroom: Initial perspectives from teachers. In: Proceedings of the Workshop in Primary and Secondary Computing Education. pp. 136–137. WiPSCE '15, ACM, New York, NY, USA (2015). https://doi.org/10.1145/2818314.2818322
22. Yu, Y., Chen, Y.: Design and development of high school artificial intelligence textbook based on computational thinking. Open Access Library Journal **5**(09), 1–14 (2018). https://doi.org/10.4236/oalib.1104898
23. Zimmerman, M.: Teaching AI. Exploring New Frontiers for Learning. ISTE (2018)