AI in K–12 education: Empowering teachers through professional development and evidence-based theories from classroom implementation

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Who I am

Franz Jetzinger

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- CS teacher (K-12)
- text book author
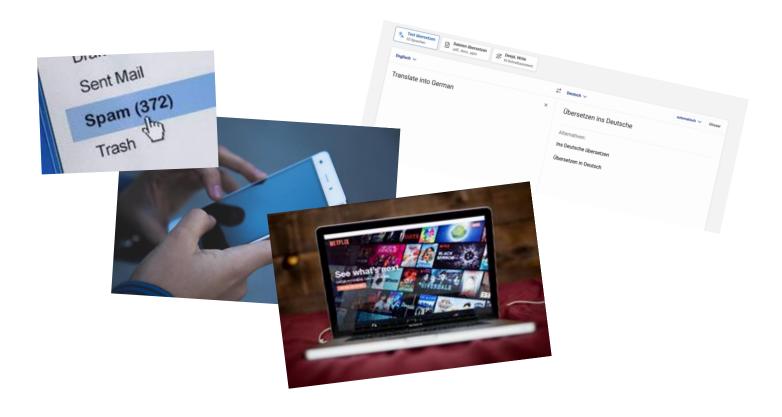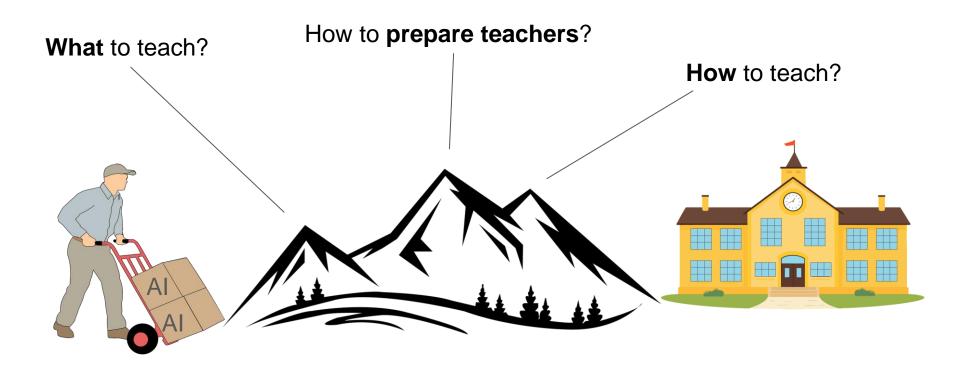- scientist

Improve CS education and teaching

Bringing learning about AI into CS lessons

What to teach?

How to **prepare teachers**?

How to teach?

AI

AI

What to teach?

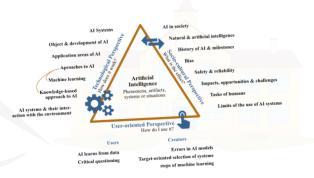# Bringing learning about AI into CS lessons
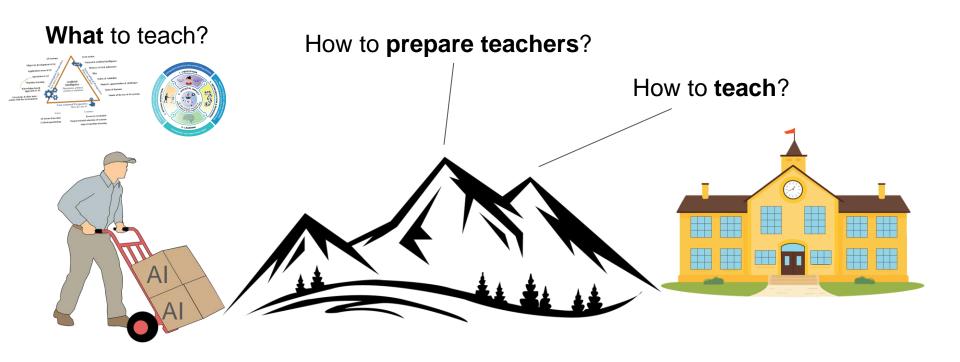

What to teach?

- **Approaches** to defining overall **AI competencies**
  (Long & Magerko, 2020; Touretzky et al., 2019; Michaeli et al., 2023; UNESCO. 2024)

- **National guidelines**
  (c.f. UNESCO, 2022; AAAI, 2018; Standards for CS education in Germany, 2025)

- **Curricula** design
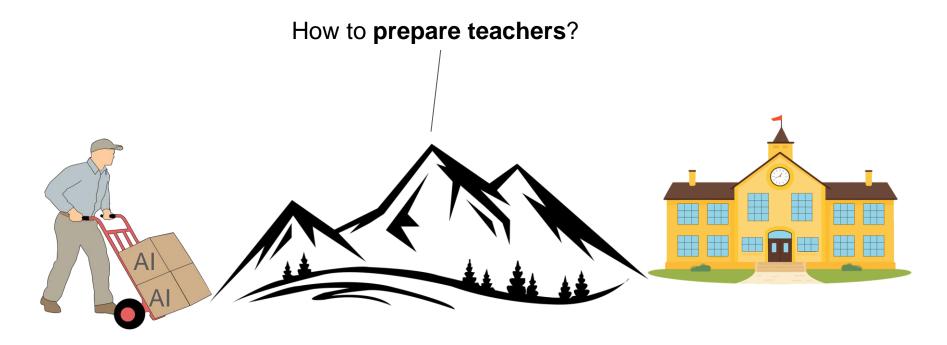 (Lin & Brummelen, 2021; Han et al., 2018; Chiu et al., 2021, …)

Bringing learning about AI into CS lessons

What to teach?

How to **prepare teachers**?

How to **teach**?

Bringing learning about AI into CS lessons

How to **prepare teachers**?

Bringing learning about AI into CS lessons
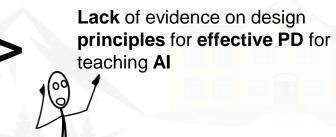
How to **prepare teachers**?
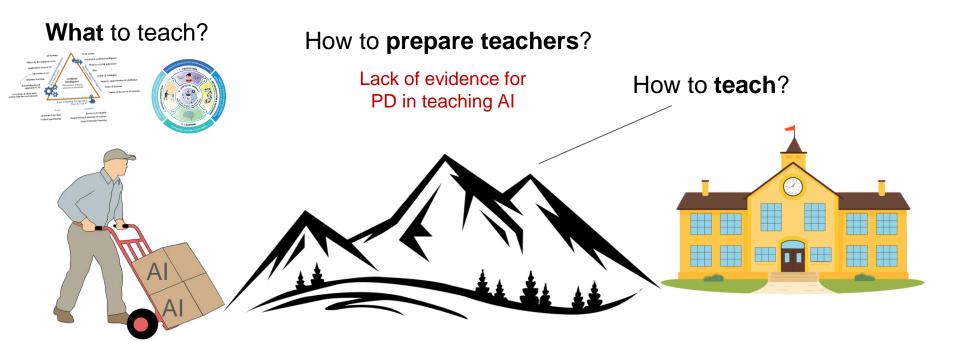
- professional development (PD) is a **key factor**
  (Good et al., 2014, UNESCO, 2025)

- **principles of effective** PD
  (e.g. Darling-Hammond et al., 2017, Qian et al., 2018)

- PD is very much **dependent on** the **content**
  (Lipowsky & Rzejak, 2015)

- very **few reports** of PD related to teaching about AI
  (Sanusi et al., 2023)

=> **Lack** of evidence on design **principles** for **effective PD** for teaching **AI**

Bringing learning about AI into CS lessons

What to teach?

How to **prepare teachers**?

Lack of evidence for
PD in teaching AI

How to **teach**?

Bringing learning about AI into CS lessons

How to **teach**?

Bringing learning about AI into CS lessons

How to **teach**?
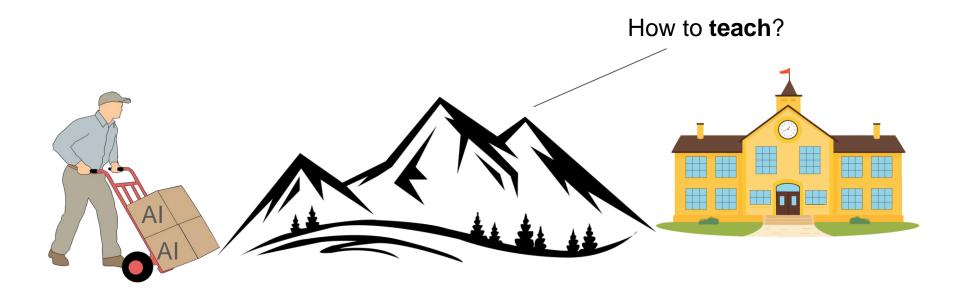
- **many** experience reports on **materials** and **tools**
  (see e.g. Marques et al., 2010; Tedre et al. 2021, Martins & Wagenheim, 2023)

- **few** reports on **measuring** the effectiveness of learning
  (e.g. Zhu & Brummelen, Wan et al., 2020)

- **few** approaches to identifying students` (mis)**conceptions**
  (e.g. Bewersdorff et al., 2023, Mühling & Große-Bölting, 2023)

=>
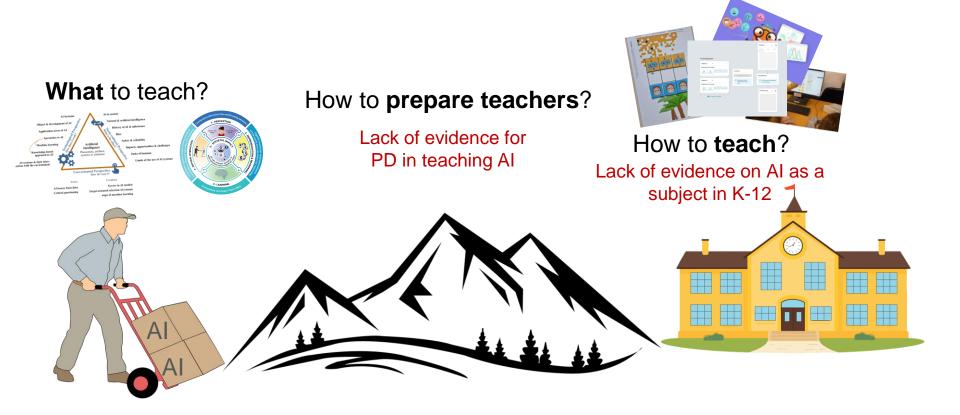
Lack of **systematic research** on teaching and learning processes in K-12 AI education
(Rizvi et al., 2023; Grover, 2024)

What to teach?

How to **prepare teachers**?

Lack of evidence for PD in teaching AI

How to **teach**?

Lack of evidence on AI as a subject in K-12

What to teach? - Bavaria

CS in high schools in **Bavaria**

- **compulsory** subject for about **20 years**
- **different** types of school and **pathways**

AI in the Bavarian CS **curriculum**

- from **24/25**: **new compulsory CS** lessons in **year 11**
- **AI** is **part** of the **new curriculum** in year 11

What to teach? - Bavaria

12-16 lessons

Students…

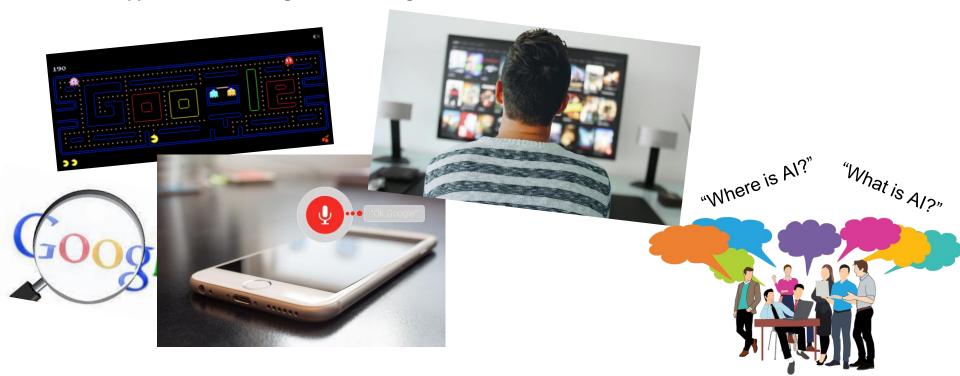- discuss **approaches to defining** the term **artificial intelligence** (AI), describe various **basic ideas of AI methods** (including machine learning) and the areas in which they can be applied.

- explain the **functionality** of a **selected machine learning algorithm** (k-nearest neighbours or decision tree learning) in general and for concrete examples.

- analyse **the influence of training data and parameters on** the reliability of the **results of a machine learning algorithm**, using an appropriate tool.

- explain how an **artificial neuron** (perceptron) works and describe **the basic structure** of a **neural network**.

- **implement**/**simulate** a single **artificial neuron**.

- comment on selected current applications of artificial intelligence and **assess the opportunities and risks** for **individuals** and **society**.

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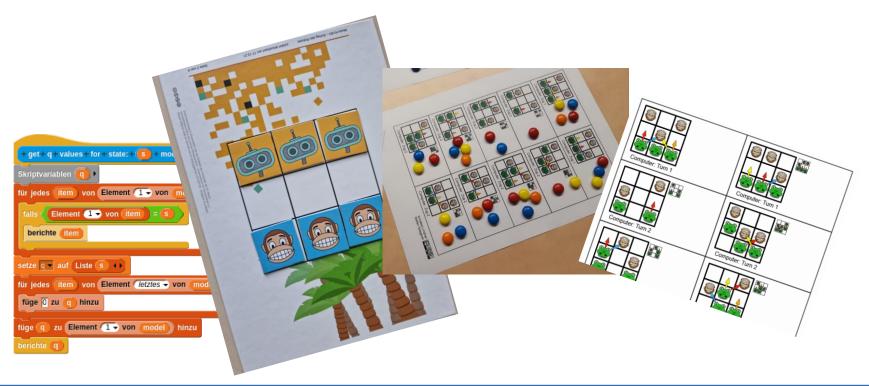
discuss approaches to **defining artificial intelligence**

"Where is AI?"

"What is AI?"
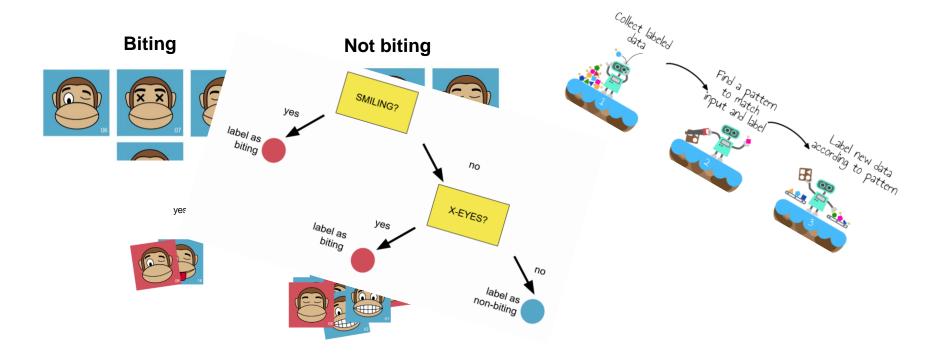
basic ideas of AI methods (including machine learning vs. knowledge-based approaches)

functionality of a **selected machine learning algorithm** (k-nearest neighbours or decision tree learning)

What to teach? - Bavaria
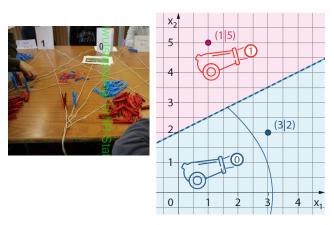
influence of training **data** and **parameters** on the **results** of a machine learning algorithm

What to teach? - Bavaria
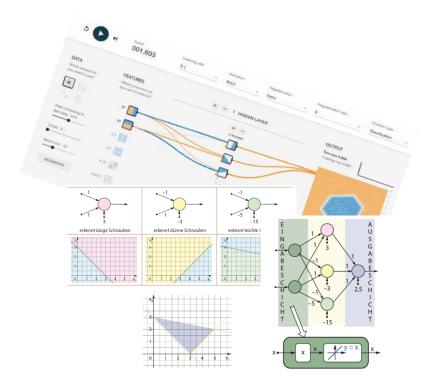
artificial neuron (perceptron) and **basic structure** of a **neural network**

$$\Delta w_{ij} = \alpha \cdot (t_j - o_j) \cdot x_i$$

What to teach? - Bavaria

assess the **opportunities and risks** for **individuals** and **society**
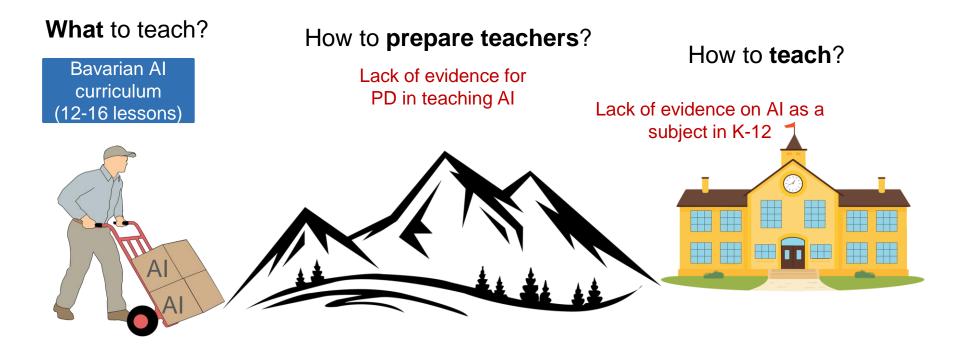
Often done throughout the sequence

Bringing learning about AI into CS lessons

What to teach?

Bavarian AI curriculum
(12-16 lessons)

How to **prepare teachers**?

Lack of evidence for
PD in teaching AI

How to **teach**?

Lack of evidence on AI as a
subject in K-12
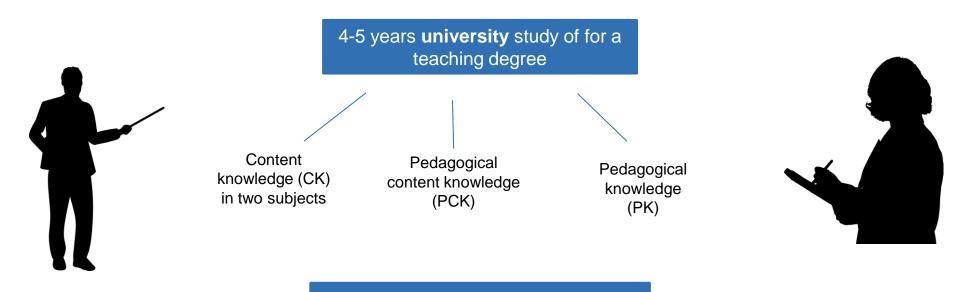
How to prepare teachers? – Conditions

Teacher education in Germany

4-5 years **university** study of for a teaching degree

Content knowledge (CK) in two subjects

Pedagogical content knowledge (PCK)

Pedagogical knowledge (PK)

2 years preparatory service in **school**

How to prepare teachers? – Challenges

- **300-500** CS in-service **teachers**

- **Heterogeneous** backgrounds
  - 50% regular teacher education
  - 50% qualified through extensive two-year PD

- **Little** prior **experience**
  - AI was neither part of CS teacher education
  - nor a topic in the classroom

just over **a year** until teaching

limited personnel **resources**

Derive learning objectives based on various frameworks and the Bavarian curriculum.
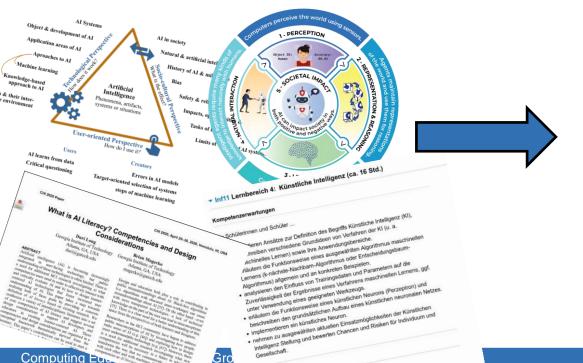
Table 2: Groups of the learning objectives derived for the PD

Definition and historical context of AI, strong vs. weak AI

AI problems, technologies and systems

Different approaches of AI

Concrete methods of machine learning

Influence of training data and hyperparameters on the reliability of the results of selected machine learning algorithms

Opportunities and risks for individuals and society

How to prepare teachers? – Brewing the PD

design principles

working with classroom-ready materials

self-directed and active learning

collaboration between the participants

interchanging between input, experimentation, and reflective components

learning objectives

need for scalability

teachers with great heterogeneity

challenges & conditions

limited personnel resources

teachers with little prior experience

AI PD

How to prepare teachers? – Brewing the PD

design principles

- self-directed and active learning
- collaboration between the participants
- working with classroom-ready materials
- interchanging between input, experimentation, and reflective components

Blended learning

"Pedagogical double-decker"

Advance organizer

Moodle course

challenges & conditions

- teachers with great heterogeneity
- need for scalability
- teachers with little prior experience
- limited personnel resources

How to prepare teachers? – Structure & Content

Cohorts of ~30 teachers

Attendance day 1 **Introduction** 3h	**MOOC** (Massive Open Online Course) „Exploring the world of AI" Approx. 10h (in 3-6 weeks)	Attendance day 2 **Workshops** 6h

=> Since 01/2023 over 300 teachers have completed the PD!

How to prepare teachers? – Structure & Content

- Getting to know each other
- Playful beginning and advance organizer
- Appetite for more

How to prepare teachers? – Structure & Content

MOOC (Massive Open Online Course)
„Exploring the world of AI"
Approx. 10h (in 3-6 weeks)
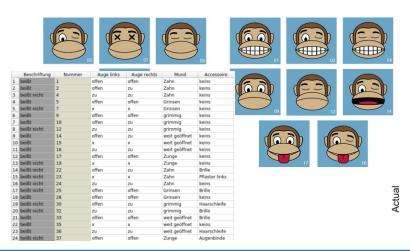
- Advanced content knowledge

- Practical implementation in the classroom

- Flexible Structure
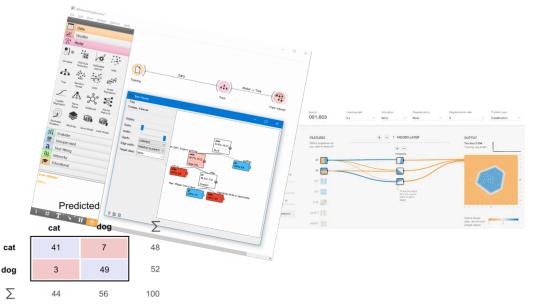
Attendance day 2

Workshops
6h

Predicted

	cat	dog	Σ
cat	41	7	48
dog	3	49	52
Σ	44	56	100
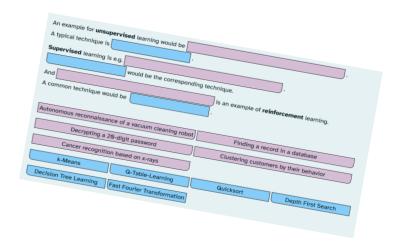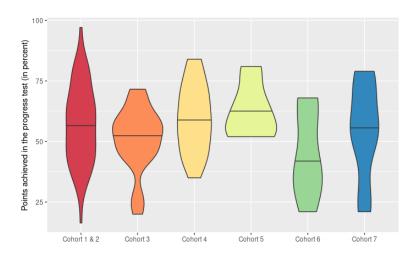
- progress **test** (pre- and post)

- **15** closed-response **questions** covering most of the learning objectives

- no feedback on individual answers, just the **overall result**
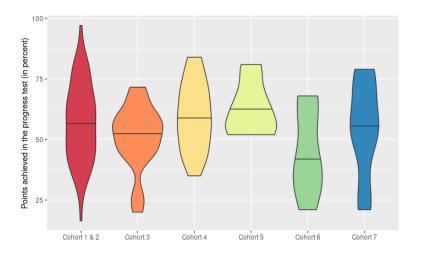
How to prepare teachers? – Short-term Evaluation (CK)

Pre for cohorts 1 and 2 (n=63), 3 (n=25), 4 (n=29), 5 (n=10), 6 (n=8), and 7 (n=9) for teachers that took part in the progress test
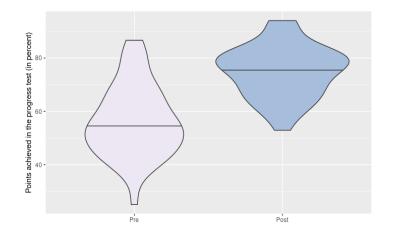
- expected heterogeneity

- cohort 1 & 2 surprised us with their prior knowledge
  => "early adopters"

Pre for cohorts 1 and 2 (n=63), 3 (n=25), 4 (n=29), 5 (n=10), 6 (n=8), and 7 (n=9) for teachers that took part in the progress test

Pre-post comparison of cohorts 1 to 6, where matching was possible (n=42)

"I think I'm very well prepared now in terms of the curriculum […]."

Pre for cohorts 1 and 2 (n=63), 3 (n=25), 4 (n=29), 5 (n=10), 6 (n=8), and 7 (n=9) for teachers that took part in the progress test

Pre-post comparison of cohorts 1 to 6, where matching was possible (n=42)

How to prepare teachers? – Long-term Evaluation

Research Question	From the **teachers' perspective**, **which aspects** of the professional development programme contributed to the **successful implementation** of the new topic in the classroom, and which aspects were perceived as **insufficient** or deficient to support the implementation?

Approach	**Interviews** with teachers • semi-structured • 1-2 years after PD participation

UNDER CONSTRUCTION

Analysis	**qualitative** content analysis (Kuckartz, 2019) • **deductive** start • further **inductive** development

Sample
• 9 CS teachers
• 3 female, 6 male
• 3 – 19 years teaching experience in CS (average 11 years)
• 5 regular teacher education

How to prepare teachers? – Long-term Evaluation

First insights

Overall
- Teachers reported being **very well prepared** for both **CK** and **PCK**.
- They feel taken by the hand.

Beneficial aspects
- Provided **materials**, especially unplugged games
- More materials than necessary allowing teachers to choose

Insufficient aspects
- Support in the **design of learning assessments**
- Present **new content** using **familiar tools** rather than introducing new tools.

How to teach?

What to teach?

Bavarian AI curriculum (12-16 lessons)

How to **prepare teachers**?

AI PD

How to **teach**?

Lack of evidence on AI as a subject in K-12

How to teach? – Research Approach
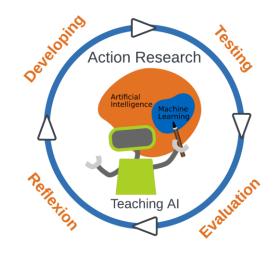
Goal	**Developing** evidence-based **theory about learning** and **teaching processes** that can be implemented directly in practice.

Approach	**Action research** (Eilks & Ralle, 2002) • cyclic • bridging gap between theory and practice • involve practitioners as equals

Developing — Testing — Evaluation — Reflexion

Action Research

Artificial Intelligence
Machine Learning

Teaching AI

Research Questions	1) Which **topic-specific difficulties** can teachers identify among their **students** after they have been taught AI? 2) How do teachers **modify their teaching** in order to **address** these **difficulties**?

How to teach? – Research Approach

RQ 1	Which **topic-specific difficulties** can teachers identify among their **students** after they have been taught AI?

1

14 teachers individually design and teach their lessons in year 11 classes (N=26).

2 Data collection

protocol to reflect on each lesson (9 teachers, 115 protocols)

test for **students** (8 classes, 192 students from 5 teachers)

interviews with teachers (9 teachers)

teaching materials from 4 teachers

3 Data analysis

- following coding-process of **grounded theory** (Strauss & Corbin, 1990)
- using **constant comparison** and memoing
- **triangulation of** different data sources

Sample – teachers

- 9 teachers
- 1 female, 8 male
- 3 – 21 years of teaching experience in CS (average 9 years)
- 6 with regular teacher education
- all passionate and highly motivated

How to teach? – Research Approach
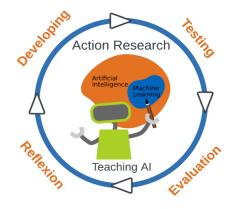
| RQ 2 | How do teachers **modify their teaching** in order to **address** these **difficulties**? |

Collaborative advancement of lessons in a workshop with 6 teachers who participated in the research
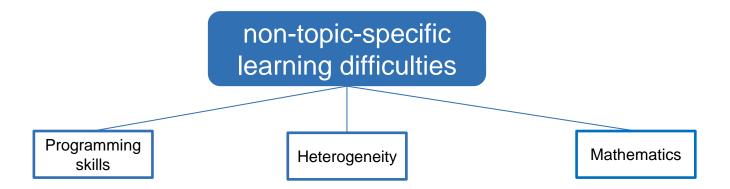
Next week!

| RQ 1 | Which **topic-specific difficulties** can teachers identify among their **students** after they have been taught AI? |

non-topic-specific
learning difficulties

topic-specific
learning difficulties

How to teach? - Results

```
         ┌──────────────────────────┐
         │  non-topic-specific      │
         │  learning difficulties   │
         └──────────────────────────┘
          /            |           \
 ┌──────────────┐ ┌──────────────┐ ┌──────────────┐
 │ Programming  │ │Heterogeneity │ │ Mathematics  │
 │    skills    │ │              │ │              │
 └──────────────┘ └──────────────┘ └──────────────┘
```

topic-specific
learning difficulties

Evaluate tasks for potential use of AI approaches.

Distinction between knowledge-based and data-based approaches.

Validation of AI models and analysis of the influence of data and hyperparameters on the result.

Apply concepts to real-world examples, particularly in the context of reinforcement learning and neural networks.

How to teach? - Results

Finding

Evaluate tasks for potential use of AI approaches.

For which of the following tasks can AI approaches be used beneficially?

object recognition on images	84%
therapy suggestions for certain diseases	58%
sorting a very large amount of data	89%
product recommendations in online stores	82%
creating deep fakes	73%
speech to text conversion	84%
tracking on the Internet with cookies	51%
positioning with GPS	48%

Possible reasons
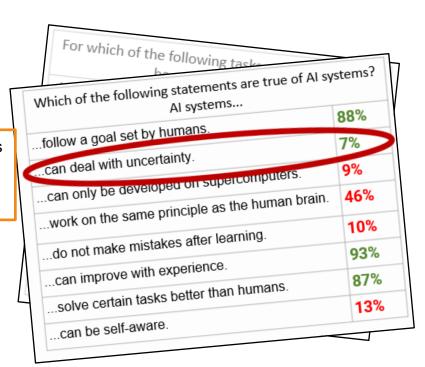
Students are not aware that AI systems have to deal with uncertainty

Finding

Evaluate tasks for potential use of AI approaches.

For which of the following tasks...

Which of the following statements are true of AI systems?
AI systems...

AI systems...	
...follow a goal set by humans.	88%
...can deal with uncertainty.	7%
...can only be developed on supercomputers.	9%
...work on the same principle as the human brain.	46%
...do not make mistakes after learning.	10%
...can improve with experience.	93%
...solve certain tasks better than humans.	87%
...can be self-aware.	13%

Possible reasons

Students are not aware that AI systems have to deal with uncertainty

Students overestimate the capabilities of AI systems.

Learners' perception that AI approaches can only be useful for very complex tasks.

Finding

Evaluate tasks for potential use of AI approaches.

"So they haven't had the less complex ones on their radar. So AI is the ultimate for them, [...] underneath it is somehow quite nice. But somehow it has nothing to do with AI. So that was the feeling. So the boundary to AI started very, very late."
(interview, teacher 9)

How to teach? - Results

Possible reasons

Students are not aware that AI systems have to deal with uncertainty

This is also a difficult task for teachers.

Students overestimate the capabilities of AI systems.

Learners' perception that AI approaches can only be useful for very complex tasks.

Finding

Evaluate tasks for potential use of AI approaches.

"It's even hard for me sometimes."
(interview, teacher 1)

How to teach? - Results

Possible reasons

Students are not aware that AI systems have to deal with uncertainty

This is also a difficult task for teachers.

Students overestimate the capabilities of AI systems.

Learners' perception that AI approaches can only be useful for very complex tasks.

Finding

Evaluate tasks for potential use of AI approaches.

Further Questions and Hypothesis

The lessons lead students to believe that AI can be used everywhere.

Teachers do not go into enough detail about what an AI problem is.

How to teach? - Results

Possible reasons

Students are not aware that AI systems have to deal with uncertainty

This is also a difficult task for teachers.

Students overestimate the capabilities of AI systems.

Learners' perception that AI approaches can only be useful for very complex tasks.

Finding

Evaluate tasks for potential use of AI approaches.

Implications

Teaching of what an AI problem is.

Analyse real systems for the potential of AI approaches and identify underlying AI concepts.

Further Questions and Hypothesis

The lessons lead students to believe that AI can be used everywhere.

Teachers do not go into enough detail about what an AI problem is.

How to teach? - Results

Possible reasons

Implications

Finding

Distinction between knowledge-based and data-based approaches.

Further Questions and Hypothesis

Possible reasons

Perception that a fully trained ML system becomes a knowledge-based system

Language

Decision tree learning does not appear to be "intelligent", but rather rule-based.

Knowledge-based approaches don't fit with students' perceptions of AI.

Finding

Distinction between knowledge-based and data-based approaches.

Implications

Further Questions and Hypothesis

How to teach? - Results

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Implications

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Distinction between knowledge-based and data-based approaches.

Further Questions and Hypothesis

Decision tree learning as example of a data-driven approach, exacerbates this difficulty.

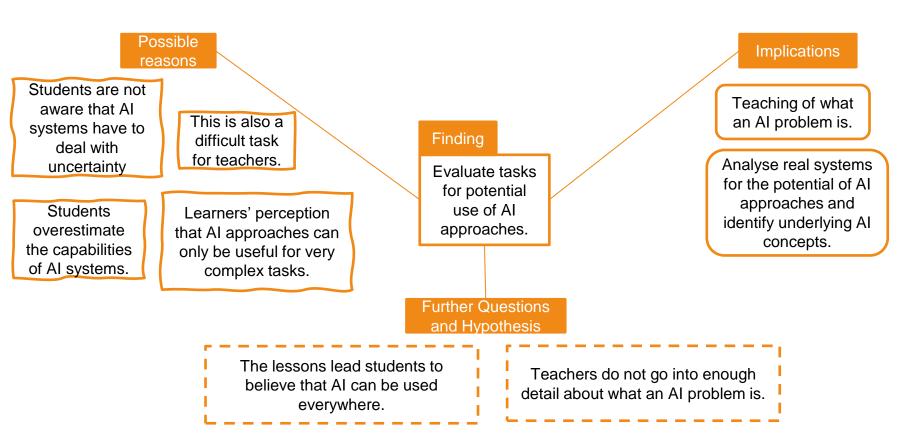Need for conceptual change in relation to knowledge-based systems.
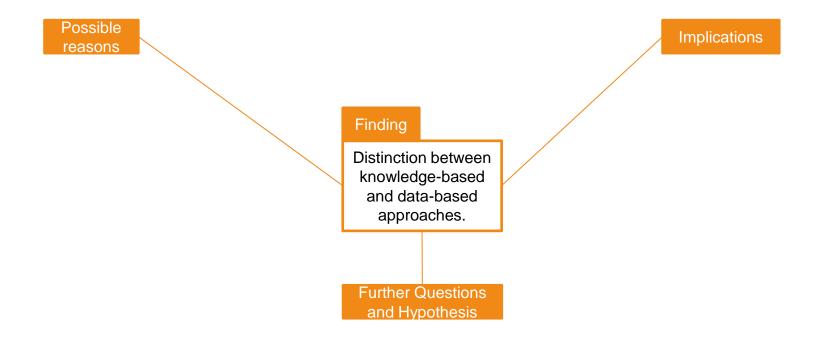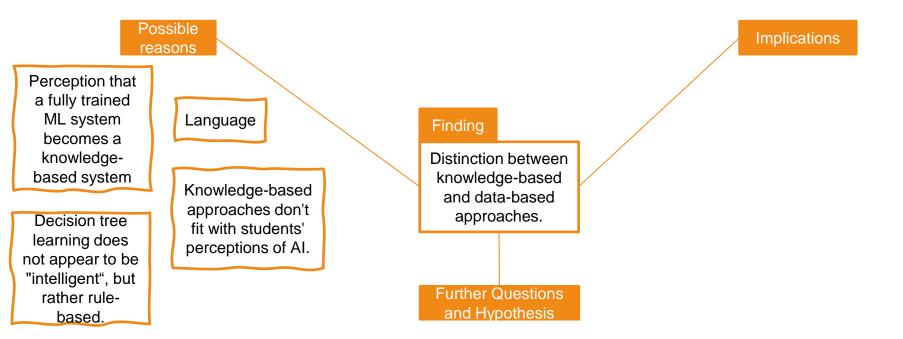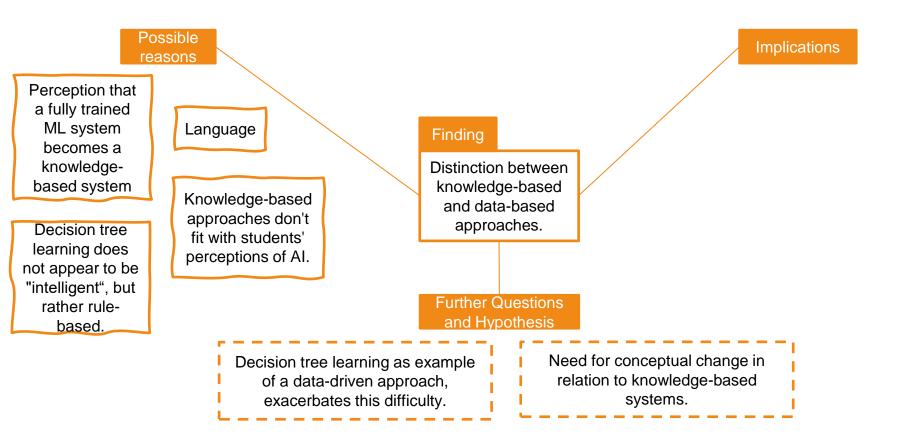
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Finding

Distinction between knowledge-based and data-based approaches.

Implications

When teaching decision trees, emphasise the difference between data-based and knowledge-based trees.

Connect with students' perceptions.

Further Questions and Hypothesis
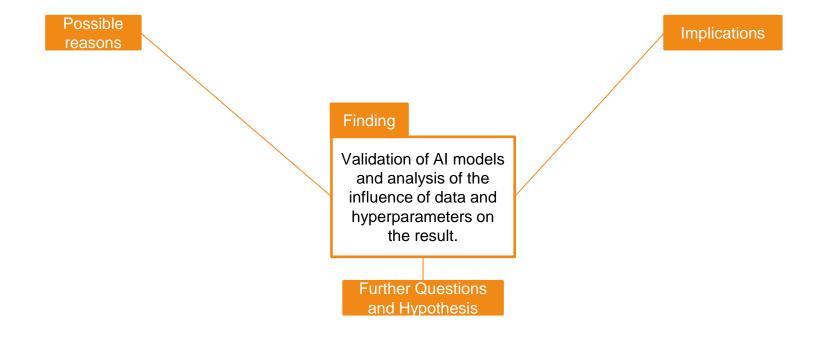
Decision tree learning as example of a data-driven approach, exacerbates this difficulty.

Need for conceptual change in relation to knowledge-based systems.

Possible reasons

Implications

Finding

Validation of AI models and analysis of the influence of data and hyperparameters on the result.

Further Questions and Hypothesis

How to teach? - Results

Possible reasons

Difficulties in applying ML algorithms (e.g. decision tree learning)

Difficulties with concepts such as information gain, hyperparameters, over- and underfitting

"Orange Data Mining" is not an appropriate low floors/heigh ceiling tool

Finding

Validation of AI models and analysis of the influence of data and hyperparameters on the result.

Further Questions and Hypothesis

Implications

How to teach? - Results

Possible reasons

Implications

Finding

Difficulties in applying ML algorithms (e.g. decision tree learning)

"Orange Data Mining" is not an appropriate low floors/heigh ceiling tool

Validation of AI models and analysis of the influence of data and hyperparameters on the result.

Difficulties with concepts such as information gain, hyperparameters, over- and underfitting

Further Questions and Hypothesis

Is there an appropriate low floors/ high ceilings tool?

Teaching doesn`t get to the point where students design meaningful AI systems.

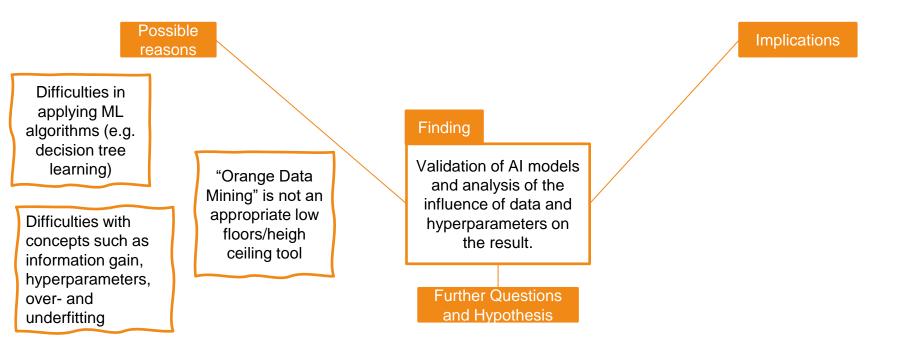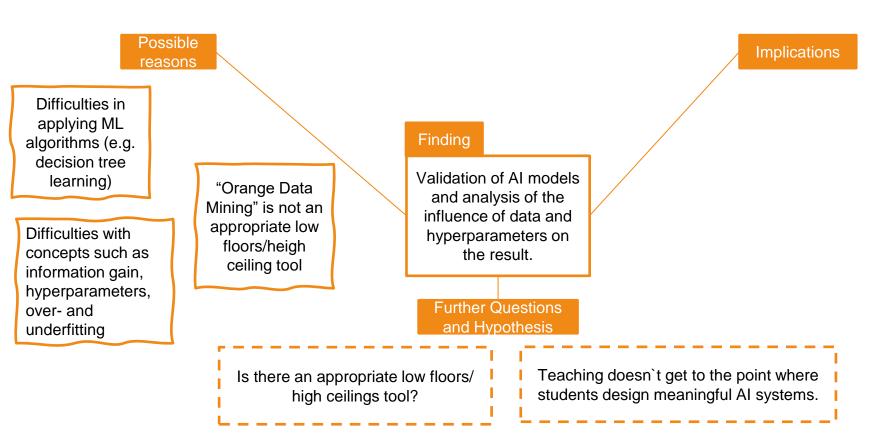# How to teach? - Results

Possible reasons

Difficulties in applying ML algorithms (e.g. decision tree learning)

Difficulties with concepts such as information gain, hyperparameters, over- and underfitting

"Orange Data Mining" is not an appropriate low floors/heigh ceiling tool

Finding

Validation of AI models and analysis of the influence of data and hyperparameters on the result.

Implications

When working with high ceiling tools such as Orange, allow sufficient time and provide special scaffolding.

Use both small "well-prepared" and real data sets.
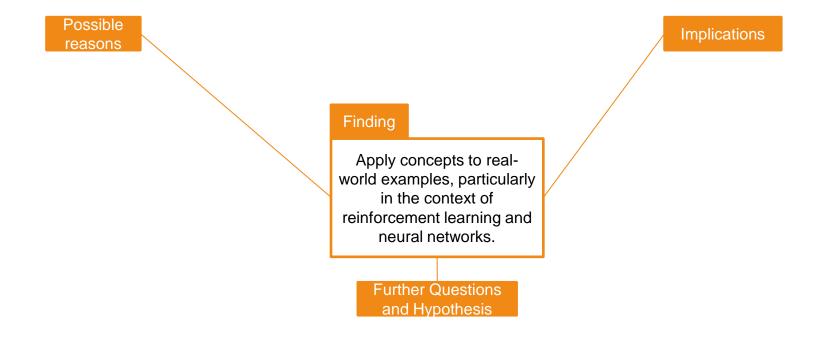
Further Questions and Hypothesis

Is there an appropriate low floors/ high ceilings tool?

Teaching doesn't get to the point where students design meaningful AI systems.

Possible reasons

Implications

Finding

Apply concepts to real-world examples, particularly in the context of reinforcement learning and neural networks.

Further Questions and Hypothesis

How to teach? - Results

Possible reasons

The gap between the pedagogically reduced examples and the reality is too big.

Mathematics

The curriculum does not support the development of a basic understanding of neural networks.

Perceptron with delta learning rule is very complex

Finding

Apply concepts to real-world examples, particularly in the context of reinforcement learning and neural networks.

Further Questions and Hypothesis

Implications
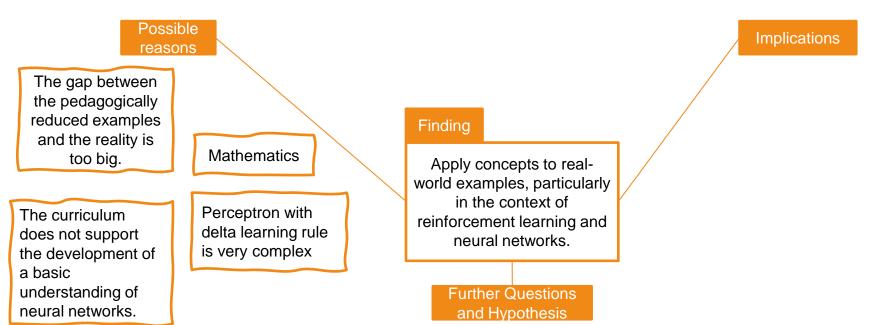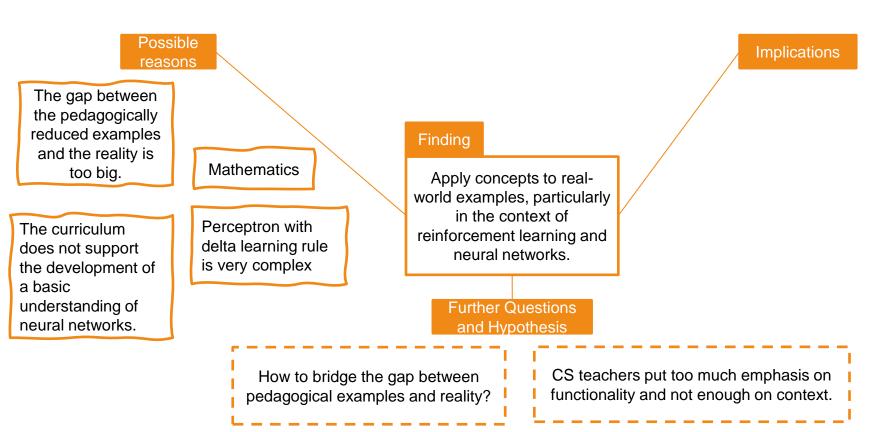
How to teach? - Results

Possible reasons

The gap between the pedagogically reduced examples and the reality is too big.

The curriculum does not support the development of a basic understanding of neural networks.

Mathematics

Perceptron with delta learning rule is very complex

Finding

Apply concepts to real-world examples, particularly in the context of reinforcement learning and neural networks.

Implications

Further Questions and Hypothesis

How to bridge the gap between pedagogical examples and reality?

CS teachers put too much emphasis on functionality and not enough on context.

How to teach? - Results

Possible reasons

The gap between the pedagogically reduced examples and the reality is too big.

The curriculum does not support the development of a basic understanding of neural networks.

Mathematics

Perceptron with delta learning rule is very complex

Finding

Apply concepts to real-world examples, particularly in the context of reinforcement learning and neural networks.

Implications

Focus more on how a neural network works than just on its structure.

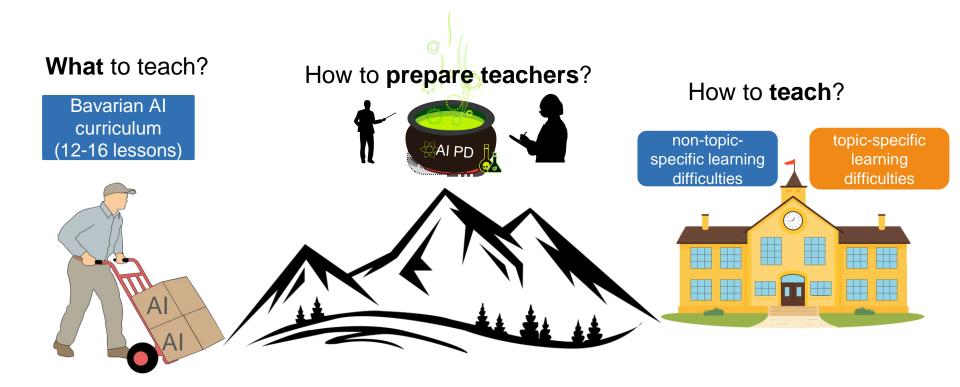Allow sufficient time for neural networks and reinforcement learning.

Always connect to real AI systems.

Further Questions and Hypothesis

How to bridge the gap between pedagogical examples and reality?

CS teachers put too much emphasis on functionality and not enough on context.

How to teach?

What to teach?

Bavarian AI curriculum (12-16 lessons)

How to **prepare teachers**?

AI PD

How to **teach**?

non-topic-specific learning difficulties

topic-specific learning difficulties

AI
AI

Summary

What to teach?

- There are **already curricula** that can be successfully implemented in CS classes to teach about AI.

How to prepare teachers?

- **Effective** and **scalable** PD for new topics is possible by using a **blended learning format** and implementing the principles of effective PD.

- The "**pedagogical double-decker**" approach makes it possible to prepare teachers in CK and PCK.

How to teach?

- Findings on **non-topic specific difficulties** show that teaching about AI needs to **build on previous findings** about teaching and learning CS.

- However, findings on **topic-specific difficulties** confirm that teaching about AI needs to be **investigated separately** and in **depth**.

Artificial Intelligence in Compulsory K-12 Computer Science Classrooms: A Scalable Professional Development Offer for Computer Science Teachers

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ABSTRACT

Given the ever-growing importance of artificial intelligence in our society and daily lives, everyone needs to learn about the core ideas and principles of this technology. While there is still a lack of empirical findings on the teaching and learning about AI in K-12 education, various teaching approaches and materials have been developed in recent years, and the topic is being introduced into K-12 computer science curricula. However, qualifying CS teachers to adequately teach this new field is a significant challenge, as they require extensive content knowledge as well as pedagogical content knowledge. In this paper, we describe the conditions and challenges and the resulting design of a professional development offer to prepare teachers for the introduction of AI into mandatory K-12 CS education in Bavaria (Germany). By designing a scalable PD program in a blended learning format and building on principles such as the "pedagogical double-decker", we successfully addressed challenges such as limited resources, a large number of teachers to be trained, and the significant heterogeneity of teachers' back-

1 INTRODUCTION

Artificial intelligence (AI) has become an integral part of our world, and students are constantly confronted with AI-related phenomena and technology in their daily lives. To educate responsible citizens who can use AI confidently and responsibly, learning about this topic, its core ideas, limits and possibilities as early as in K-12 education is inevitable [35]. Various demands call for just this. At the international level, for example, UNESCO states that AI has fundamentally changed the world and therefore suggests that AI be included in curricula. Based on their analysis of government-endorsed AI syllabi, they point out that resource development and teacher professional development (PD) are essential for implementing AI in curricula [37, 38]. Similarly, on a national level, the German Association for Computer Science calls for integrating AI into CS curricula of all types of schools on a mandatory basis [10].

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