

INTRODUCING AI EDUCATION ACROSS SUBJECTS IN PRE-SERVICE TEACHER EDUCATION: INSIGHTS FROM A QUALITATIVE STUDY AND COURSE IMPLEMENTATION

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Abstract. Artificial intelligence (AI) is rapidly transforming how we live, work, and learn. Enabling individuals to participate confidently and responsibly in this digitally evolving society requires a foundational understanding of AI and its role in education, particularly for pre-service teachers preparing to meet the demands of their future professional roles in schools. To examine pre-service teachers' initial conceptions and expectations regarding the relevance and integration of AI in education, we conducted semi-structured interviews with participants from non-computer science backgrounds (N = 11). Based on these insights, we developed and implemented an elective module attended by 39 pre-service teachers from various subject areas and school types. The course was designed to foster AI education by addressing participants' prior conceptions and by providing accessible AI literacy across subject areas, regardless of disciplinary background. This paper presents key findings from the interview study, outlines the course's conceptual foundations and objectives, and reflects on its implications for future developments in teacher education. Building on these results, this exploratory qualitative study highlights best practices and offers recommendations to advance AI education in both national and international contexts.

Keywords: artificial intelligence, teacher education, computer science education.

1. Introduction

In the computer science (CS) education community, there is consensus that the ability to understand, evaluate, and shape the impacts of current technological developments on one's own life and on society has become an essential 21st-century skill for contemporary and educated citizens (K-12 Computer Science Framework Steering Committee, 2016). With the rapid growth of artificial intelligence (AI) as one of the fastest-growing fields in CS (Russell & Norvig, 2021), the justification for teaching AI to learners appears firmly established, as its ongoing development is likely to become one of the most powerful and transformative technological forces shaping our lives, work, and education (Grover, 2024). Consequently, AI education should be integrated not only into school CS curricula but also into teacher education programs, where *all* pre-service teachers, regardless of their teaching subjects, are confronted with the implications of AI. The recent integration of AI-related topics into the curricula of several German federal states demonstrates that the subject is assuming an increasingly prominent role in CS education (Vo & Pancratz, 2023). In addition, the public and professional discourse surrounding the use of AI applications in classrooms, particularly GenAI tools such as ChatGPT and the societal questions they raise, highlights the relevance of the topic across all school subjects and confronts both pre-service CS teachers and those from non-CS backgrounds with the need to engage with this complex and rapidly evolving field in educational contexts.

A central responsibility of university-based teacher education, particularly during its initial phase, is to address such developments and to integrate them meaningfully into the body of professional knowledge required for teaching and learning (Borowski et al., 2010). Shulman

(1986) identifies seven domains of teacher knowledge, among which content knowledge, pedagogical content knowledge, and pedagogical knowledge are regarded as particularly relevant for classroom practice and have therefore been widely discussed in research on teacher professionalism (Borowski et al., 2010). Lindner (2021) similarly examines teachers' professional knowledge related to AI and proposes initial AI-specific competencies within the domains of content knowledge and pedagogical content knowledge.

In response to this growing need, and in line with the consensus within the German CS education community that *all pre-service teachers* should be familiar with foundational elements of CS education, including key aspects of AI (Gesellschaft für Informatik e.V., 2023), we designed and implemented a university-based course for pre-service teachers from non-CS backgrounds. To inform the design of such courses, it is crucial to first examine their pre-conceptions of AI and their expectations regarding its role in teacher education. Building on these considerations, this paper examines the following research questions (RQs):

- RQ1: What pre-conceptions do pre-service teachers from non-computer science backgrounds hold about artificial intelligence?
- RQ2: What views do these pre-service teachers express regarding the integration of artificial intelligence into university-based teacher education?
- RQ3: How can insights into AI literacy competencies and pre-service teachers' pre-conceptions inform the design of a university-based course on artificial intelligence in teacher education?

Based on the qualitative findings related to RQ1 and RQ2, this paper presents key insights and outlines a course model designed to embed AI education within teacher education for all pre-service teachers (RQ3). It discusses the conceptual foundations, emerging challenges, and pedagogical implications and concludes with recommendations to inform both national and international approaches to integrating AI into teacher education.

2. Theoretical Background

2.1. Teacher Education in Germany

Teacher education in Germany is typically structured into three consecutive phases: the initial training phase at university (1st phase), the practical teacher training in schools (2nd phase), and the in-service training and continuing education for experienced teachers (3rd phase). In the context of this study, we refer to *pre-service teachers in the 1st phase*, who are enrolled in teacher education programs at higher education institutions (universities). In the federal state of Lower Saxony, where our university is located, as in most other German states, all candidates, regardless of school type or teaching subjects, are required to study (at least) two subjects (for example: CS and Physics) over a period of five years as part of a structured "Master of Education" program. Only upon successful completion of this 1st phase are they eligible to enter the 2nd phase, an 18-month preparatory service ("Vorbereitungsdienst") in schools, which includes practical teaching under supervision and leads to the final teaching qualification (Cortina & Thames, 2013).

2.2. AI Literacy in Computer Science Education Research

In recent years, several frameworks have been developed within CS education research to conceptualize core competencies associated with AI literacy. These models offer structured perspectives on what learners should know, understand, and be able to do when engaging with AI education. As such, they not only support a deeper understanding of the field but also provide orientation for the design of educational interventions in teacher education, which becomes particularly relevant in Section 0 and when addressing RQ3.

As Long and Magerko (2020) define it, AI literacy comprises "a set of competencies that enable individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (Long & Magerko, 2020, p. 2). Drawing on an

extensive scoping review, they organize 17 competencies around five central questions: *What is AI? What can AI do? How does AI work? How should AI be used? And how do people perceive AI?*

Whereas Long and Magerko (2020) propose a framework of AI literacy based on an exploratory review of interdisciplinary literature (scoping review) comprising 17 competencies, Ng et al. (2021) conducted a structured literature review to examine how AI literacy is defined and implemented in educational contexts. Based on an analysis of thirty peer-reviewed studies, they describe AI literacy as a set of foundational competencies that enable individuals to understand, engage with, and critically reflect on AI in both everyday and professional settings. Their review identifies four key components of AI literacy: *knowing and understanding AI, using and applying AI, evaluating and creating AI, and addressing ethical issues* (Ng et al., 2021). Each of these components represents a distinct yet interconnected area of competence.

2.3. Educational Reconstruction for (Computer Science) Education

Individuals form their own conceptions of specific phenomena or situations long before they encounter scientifically accepted concepts through formal instruction (Duit, 1996). These conceptions are also referred to as *pre-instructional conceptions*: “students and adults construct an intuitive understanding of the world based on their everyday experience” (Vosniadou & Brewer, 1992, p. 536). In educational research, such conceptions are examined and documented, as they are considered “points of departure” (Duit, 2007, p. 6) within the constructivist view of learning. They provide valuable guidance for lesson planning and for shaping learning processes, thereby supporting the development of targeted scientific concepts (Duit, 2007; Diethelm et al., 2012). The *Model of Educational Reconstruction*, rooted in constructivist epistemology, places particular emphasis on learners’ prior knowledge (Duit, 2007). This emphasis is reflected in the integration of students’ perspectives, which contributes to clarifying and analyzing subject matter. Additionally, the model plays a central role in the design and evaluation of learning environments (Duit, 2007). Diethelm et al. (2012) further develop the model by incorporating elements specifically relevant to CS education.

Although the Model of Educational Reconstruction was originally developed within the context of school-based science education (Duit, 2007), its core principles can be meaningfully transferred to teacher education. Pre-service teachers also enter their studies with prior experiences and intuitive assumptions that influence how they understand and engage with complex topics (Vosniadou & Brewer, 1992). As described by Lortie (1975) through the concept of the “apprenticeship of observation” (Hargreaves, 2010, p. 146), many of these assumptions originate from prolonged exposure to classroom practices during their own schooling. These tacit conceptions, often referred to as “lay theories” (Holt-Reynolds, 1992, p. 326), shape how future teachers construct their professional identities and respond to educational challenges.

In the context of AI, such pre-existing conceptions are particularly relevant, as even teachers who do not explicitly teach the subject may convey implicit conceptions about AI through their language, instructional choices, and classroom discourse. As Lindner and Berges (2020) point out, there is a concern that insufficiently reflected conceptions from teachers may unintentionally be transmitted to K–12 students. Addressing these conceptions in teacher education is therefore essential to fostering responsible and reflective engagement with AI across all subject areas. This approach aligns with broader calls to include university students’ perspectives in curriculum development, as instructor-centered designs often fail to address learners’ actual needs and experiences (Brooman et al., 2015).

3. Method

The research design focused on two thematic areas within a single semi-structured interview format. The sample consisted of 11 pre-service teachers (6 males, 5 females) enrolled in a teacher education program. Sampling followed the principle of minimum and maximum contrast, aiming to achieve broad variation within the sample: an approximately balanced gender distribution,

representation across a wide range of subjects (excluding CS), and different stages within the teacher education program (early, intermediate, and advanced).

The first thematic area explored the pre-conceptions that pre-service teachers from non-CS backgrounds held regarding AI. The interviews were guided by a set of guiding questions, each supported by *follow-up prompts* (Nitz & Fechner, 2018) intended to elicit reflective responses and to facilitate deeper analysis for addressing RQ1. The guiding questions included:

- How do you understand AI, and what comes to mind when you think of it?
- Where do you encounter AI in everyday life, and how do you recognize it?
- What do you think about AI's role in society today and in the future?

The second thematic area addressed participants' views on the role of AI in university-based teacher education (1st phase, see Section 0) for addressing the second research question (RQ2).

The guiding questions were:

- How do you perceive the relevance of AI within your university-based teacher education?
- Where and in what form do you think AI should be integrated into your teacher education program?

The interviews were audio-recorded and transcribed verbatim. Each interview lasted approximately 20 minutes, providing a manageable duration while yielding valuable data. Data analysis followed the principles of qualitative content analysis as outlined by Mayring (2015) and was conducted using MAXQDA 2024. For this exploratory study, we employed inductive-deductive content analysis (Mayring, 2015), a method that supports the exploratory process by avoiding biases such as building categories solely on theories or existing findings on conceptions of AI. The overall coding procedure implemented suggestions from Campbell et al. (2013): One rater marked sentences, developed, and applied the category systems. Then, a second rater applied the category system to randomly chosen interviews (i.e., for 33% of the data). The results were compared, ambiguities were discussed, and the category systems were refined. After resolving all issues, the entire material was (re)coded.

Based on the identified pre-conceptions (RQ1) and positions (RQ2), we designed a university course that responds to the expressed needs and expectations regarding AI in teacher education. This course was subsequently implemented as a module offered to all pre-service teachers at the University of Hildesheim (RQ3).

4. Results and discussion

4.1. Results

4.1.1. RQ1: Conceptions of Artificial Intelligence among Pre-Service Teachers from Non-Computer Science Backgrounds

The six identified conceptions (C1–C6) are outlined below, each illustrated with statements from pre-service teachers without a CS background (N = 11). These pre-conceptions should not be understood as mutually exclusive categories; rather, they may overlap, and individual pre-service teachers can be associated with multiple conceptions.

Anthropomorphic Thinking (C1). Pre-service teachers from a non-CS background often described AI in ways that suggested human-like qualities, particularly in how it acts, thinks, or responds emotionally. Several participants associated AI with actions typically performed by humans, such as serving food or offering verbal assistance. One participant imagined “systems that could take over ordinary tasks [...] like working in hospitality or doing service jobs” (B4). Smart assistants such as Alexa were frequently mentioned, and their capabilities were described in ways that implied human-like cognitive abilities: “You can ask it something and it responds immediately, almost like it understands everything you say” (B1). Emotional responsiveness was also suggested in a description of “robots that help in elderly care and talk to the person” (B6), indicating a form

of empathetic interaction beyond functional behavior. In other accounts, AI was thought of as “something that could calm you down or encourage you when you feel sad, kind of like a person would” (B8). The idea of AI providing companionship also recurred, for instance in the notion of “[a robot] that keeps company when people are alone at home” (B9). These descriptions reflect a tendency to interpret AI not only as a technical system but also as a quasi-social actor capable of thinking, reacting, and assisting in ways reminiscent of human beings.

Everyday Technology Thinking (C2). Pre-service teachers from a non-CS background often described AI in relation to everyday technologies without clearly distinguishing it from general digital or automated functionality. Smartphones were commonly mentioned, sometimes with direct attribution of AI capabilities. One participant remarked, “my phone can do everything. That would be artificial intelligence to me” (B7). Music recommendation services were also cited, with one participant noting, “Spotify somehow suggests things that match my mood. That’s kind of AI” (B6). Some descriptions were more general or speculative, based on impressions of automation and technical advancement. As one participant put it, “I think it’s somehow in everything that works automatically” (B5). Others expressed comparable views, such as describing “vacuum robots that move on their own and find their way” (B10). These statements reflect a blurred conceptualization of AI as something embedded in familiar technologies that act or react in seemingly intelligent ways, shaped more by habitual usage and surface-level impressions than by a clear technical understanding.

Utility and Assistance Thinking (C3). Pre-service teachers from a non-CS background frequently described AI as a supportive tool for managing everyday tasks. Several participants associated it with devices that simplify routines or increase convenience. One participant referred to smart home systems: “At home, when I say ‘play music,’ and then it plays music, or turns off the lights” (B5). Another noted, “It helps with remembering things, like when I ask it to set an alarm or something like that” (B5). Practical support in educational contexts was also mentioned, as in “You just enter a text, and it translates everything into French” (B2). These statements reflect a utilitarian view of AI as a readily available assistant that offers comfort, automation, and relief in both private and educational environments.

Media-Influenced Thinking (C4). Several pre-service teachers from a non-CS background described their understanding of AI as being shaped by media representations, particularly films and general news coverage. One participant explicitly linked their conception of service robots to fictional portrayals: “What I imagine [...] I know that from movies or in the news” (B7). When reflecting on their own conception, the same participant expressed uncertainty about its accuracy: “I’m not sure if this is really how it works [...] it might just be what I’ve seen in movies” (B7). They also acknowledged the broader influence of external narratives: “I think the media influence all of us in some way” (B3). Another participant mentioned that their first ideas of AI came “from what you see in the news about machines taking jobs” (B11), which underlines how broader societal discourses can feed into individual conceptions. These statements illustrate how media exposure can shape intuitive understandings of AI, often in the absence of technical knowledge and through dramatized or idealized imagery rather than lived experience.

Ethical and Social Conceptions (C5). Pre-service teachers from a non-CS background expressed concerns about the societal implications of AI. A recurring theme was the fear of human labor being replaced. One participant remarked, “If teachers get replaced by artificial intelligences, that would be really disastrous, I think” (B3), highlighting anxieties around job loss and the devaluation of professional roles. Similar concerns were voiced regarding AI taking over tasks such as waitressing or caregiving. While risks were emphasized, potential benefits were also acknowledged. Another participant added, “Machines will probably take away many jobs, and not everyone can just switch to something else” (B8), underlining the conceptions of structural risks for workers. Discomfort with pervasive data collection and the feeling of being constantly monitored

when using digital services was also expressed (B6). These responses reflect emerging ethical reasoning around automation, surveillance, and the human role in a digitized society.

Indication of *Stereotypical Representation Thinking* (C6). Some pre-service teachers from a non-CS background described AI in ways that revealed stereotypical associations with technical expertise and control. It was often framed as something developed by others with advanced knowledge, referred to as “people who build these things” (B7) or “those who program it to do all of that” (B5). Similar notions appeared in the idea that AI belongs to a highly specialized field and is therefore perceived as distant and inaccessible (B11). These statements, voiced by *female* participants, conveyed a sense of distance from the domain of AI development, with developers imagined as external and authoritative figures. While gender was not explicitly addressed, the way AI was conceptualized reflects a broader cultural narrative in which technological expertise is attributed to others rather than to oneself. Such representations may contribute to a diminished sense of belonging and reinforce the conception of AI as a field shaped by others.

4.1.2. RQ2: Views on the Integration of Artificial Intelligence into University-Based Teacher Education

The interview responses concerning *where* and in *what form* AI education should be integrated into university-based teacher education were grouped into four thematic categories (T1–T4). These categories reflect the diverse expectations and suggestions of pre-service teachers from a non-CS background and are presented below. While these individuals may not directly influence curricular content or instructional design, their perspectives nonetheless offer valuable insights into how they perceive the importance of AI education for their *own* professional development and future teaching practice in schools.

Some participants referred to established mandatory interdisciplinary formats in teacher education and expressed interest in incorporating AI into such settings, suggesting that a small number of shared sessions for all pre-service teachers could raise awareness without requiring deep technical expertise (*T1: Cross-Subject Lecture Series*). Others proposed connecting AI education directly to the school subjects they study as part of their teacher education, particularly in courses related to ethics or social studies. The desire to explore the societal dimensions of AI was implied in multiple statements (*T2: Integration into Subject-Specific Courses*). One participant voiced concerns about making AI a compulsory topic, stating, “I would have to drop another course. My schedule is already very full” (B5). This highlights the need for flexible, non-mandatory formats that respect individual study paths, especially since she had deliberately chosen not to study mathematics or CS (*T3: Rejection of Mandatory Inclusion*). The most frequently mentioned and widely supported suggestion was to offer AI education as an elective module that counts toward their credit requirements. Participants regarded this format as a meaningful and manageable way to engage with the topic on a voluntary basis. It was seen as particularly valuable because it allows for individual interest, prevents overload in mandatory curricula, and makes AI education accessible across subject boundaries (*T4: Elective Module Format*).

Across all categories, pre-service teachers emphasized the importance and necessity of acquiring competencies in AI education, stressing that such knowledge should *not* be limited to future CS teachers alone. As one participant put it, “It’s already here, so we should know something about it” (B2), while another noted, “It’s important that we at least get a basic understanding because it’s everywhere now” (B7). These responses highlight a widespread recognition that AI literacy is becoming essential across disciplines and should be included in teacher education for all.

4.1.3. RQ3: Introducing AI Education Across Subjects in Pre-Service Teacher Education

In the federal state of Lower Saxony, where our university is located, all pre-service teachers are required to complete a three-year bachelor’s program followed by a two-year master’s program leading to the Master of Education (see Section 0). Within this framework, the course discussed in this study was implemented as an *elective module* (T4). At the time of its development, alternative formats for integrating AI education into teacher training were not yet feasible, making the elective structure the most appropriate option. Pre-service teachers could

enroll in the course voluntarily and have it count toward the credit requirements of their teacher education program. This elective module extended over three consecutive semesters within the master’s program. Thematic emphasis on AI education, as detailed in Table 1, was placed primarily on the first semester, while the remaining sessions addressed broader topics in CS education and interdisciplinary computing. We titled the course “Computer Science Education for All Pre-Service Teachers” to highlight its accessibility for pre-service teachers from all subject areas and to allow for thematic flexibility. With a comparatively high credit value, the course covered multiple key areas of CS education across semesters, with a particular focus on AI literacy in response to learners’ prior conceptions.

Each thematic unit listed in Table 1 (e.g., “Introduction to AI”) was implemented as a 90-minute session including interactive activities and was supplemented by further reading and open-access materials made available to pre-service teachers for continued exploration.

We worked with 39 pre-service teachers from non-CS backgrounds who selected the course as part of their teacher education program. The selection and development of topics were collaboratively refined within the research group. Discussions within the research group included which AI literacy competencies should be addressed in light of the identified pre-conceptions, to what extent they should be emphasized, and which topics were considered especially relevant. The specific pre-conceptions (C) addressed among pre-service teachers are labeled C1 to C6 (see Section 0.1). AI literacy competencies derived from Long and Magerko (2020) are marked as K1 to K17 for the 17 competencies (K), and key components (KC) from Ng et al. (2021) are marked as KC1 to KC4 (see Section 0) for the four key components of AI.

Table 1. Overview of our approach

Topic	Description	Mapped Conceptions	AI Literacy Dimensions
Introduction to AI: <ul style="list-style-type: none"> ▪ What is intelligence? ▪ What is Artificial Intelligence? ▪ History of AI ▪ Activity: “Find the AI” 	Basic introduction to the concepts of intelligence and artificial intelligence, including a playful activity in which pre-service teachers identify and discuss examples of AI in everyday contexts.	C1, C2	K1-K4 KC 1
Conception research on AI: <ul style="list-style-type: none"> ▪ Discussing existing conceptions of AI among different groups in schools ▪ Discussing: strong AI vs. weak AI ▪ Activity: “Concept Cartoons on AI” 	Analyzing pre-conceptions about AI held by key stakeholder groups (e.g., K-12 students and teachers), using visual prompts (concept cartoons) to stimulate reflection and discussion among pre-service teachers.	C1-C4	K2, K4, K16-K17 KC1, KC4
Introduction to Machine Learning I (ML) (Unplugged Activities) <ul style="list-style-type: none"> ▪ Classical AI (knowledge-based approaches) ▪ Machine Learning: Reinforcement Learning 	Comparison of rule-based symbolic AI systems and reinforcement learning as key paradigms in the development of intelligent systems, using unplugged activities to illustrate core concepts.	C2, C3	K7-K10, K14 KC1-KC3
Introduction to Machine Learning II (Unplugged Activities) <ul style="list-style-type: none"> ▪ Supervised Learning ▪ Unsupervised Learning 	Overview of central types of ML with a focus on the differences between learning from labeled data (supervised learning) and discovering patterns in unlabeled data (unsupervised learning).	C2, C3	K9, K11-K14 KC1-KC3

Exploring and designing large language models (LLMs): <ul style="list-style-type: none"> ▪ Introduction to LLMs ▪ <i>Activity</i>: “SoekiaGPT” 	Practical engagement with large language models (LLMs), in which pre-service teachers explore the functioning of LLMs and collaboratively discover an educational chatbot based on statistical patterns	C2, C3	K8-K10, K12-K13, K17 KC2, KC3
Discussing ethical aspects of AI: <ul style="list-style-type: none"> ▪ <i>Activity</i>: “AI in Society” ▪ Data awareness ▪ AI in education 	Reflection on the societal implications of AI, including questions of fairness, bias, and the role of AI in education. Pre-service teachers are encouraged to critically examine data practices and responsible AI use.	C5, C6	K5-K6, K11, K13, K15-16 KC3-KC4

Description of Table 1. Based on the analysis of naïve pre-conceptions, we mapped the core dimensions of AI literacy to the content of our elective module (see Table 1). To structure this mapping in line with the educational needs and conceptions of learners, we drew on established frameworks in computing education, particularly the *Dagstuhl Triangle* (Brinda & Diethelm, 2017; Michaeli et al., 2022). Widely recognized in (German) computing education, this model provides a didactic structure that interrelates three equally important perspectives:

The technological perspective (1), which focuses on understanding how digital systems function and how their operation is determined by underlying technical principles. This perspective was addressed in our module through a sequence of *unplugged activities* that introduced key AI learning paradigms, including supervised, unsupervised, and reinforcement learning, as well as classical AI approaches. Following Lindner et al. (2019), these hands-on, analog activities offered accessible entry points for pre-service teachers from non-CS backgrounds by illustrating core AI mechanisms without requiring prior technical knowledge and by encouraging reflection on how AI systems work. Building on this foundation, the module then moved to selected *plugged activities* to deepen pre-service teachers’ understanding of AI systems, with a particular focus on large language models (LLMs). This shift was motivated by the growing use of generative AI tools such as ChatGPT or Gemini in educational contexts, thereby increasing the need for pre-service teachers to understand not only how to use these systems but also how they function and how they can be critically evaluated.

The user-oriented perspective (2), which emphasizes the effective and efficient use of digital systems and tools. This perspective was addressed in the module, for instance, through the exploration of LLMs. To support this, we discussed the learning environment “SoekiaGPT” (Hielscher, 2023), a didactic language model developed in Switzerland for school use, which provides a simplified yet conceptually rich illustration of statistical text generation. Engaging with SoekiaGPT enabled pre-service teachers to examine how such LLMs generate responses based on statistical patterns. Guided reflection supported their understanding of how AI systems adapt to user input and the implications this has for transparency, user agency, and data privacy. This engagement aligned with key AI literacy objectives, such as recognizing that AI learns from user data and critically questioning the outcomes and recommendations generated by AI technologies in everyday digital environments (Long & Magerko, 2020; Michaeli et al., 2022).

The socio-cultural perspective (3), which examines interactions with individuals and society. This perspective was addressed through dedicated elements within the course. Within this perspective, our module introduced AI by prompting pre-service teachers to reflect on their own understanding of intelligence and AI and then systematically explored pre-conceptions in educational contexts. As outlined in Section 0 and supported by our empirical study in Section 0, we focused on the conceptions that key target groups, such as students and teachers, hold about AI and the implications they associate with it. Pre-service teachers were encouraged to critically reflect on these conceptions and consider

their relevance for AI education in schools and society. Furthermore, the module encouraged learners to engage with AI not only as a technical subject but also as a sociotechnical system embedded in everyday life, education, and public discourse.

Importantly, these three perspectives from the Dagstuhl Triangle were not treated in isolation. In several sessions, we designed activities to integrate two or more perspectives in order to foster a comprehensive and connected understanding of AI. We argue that only a holistic integration in AI education, covering socio-cultural, technological, and user-oriented perspectives, can address the identified naïve conceptions (C1–C6), as also advocated in the Recommendations for K-12 Computing Education (Michaeli et al., 2022). While we do not claim to offer a fully comprehensive approach to AI education, we designed the course to provide both orientation and practical guidance for developing AI-related learning opportunities for *all pre-service teachers* as part of their professional development in national and international teacher education contexts.

4.2. Limitation and Discussion

The implementation of such an approach, however, is shaped by institutional and structural conditions. The extent to which AI education of this kind can be implemented depends on the specific structure of teacher education programs at individual universities and in different (inter-)national contexts, as well as on the degree to which interdisciplinary integration is institutionally supported and feasible. A proposal for such integration has been developed and implemented at the University of Hildesheim in Germany. Nevertheless, our approach in Table 1 provides entry points that can be adapted to different contexts, for example as a mandatory introductory module in teacher education, as a series of workshops embedded in disciplinary programs, as micro-credentials, or as professional development courses for in-service teachers. In this way, the approach offers opportunities for adaptation across diverse national and institutional settings.

Due to time constraints, we were only able to briefly address the naïve conception C6, which indicates stereotypical representations of AI, during the session on “AI and Society” (see Section 4.1.1). In future iterations of the course, we intend to revisit this topic in greater depth, particularly because women remain significantly underrepresented in CS-related professions in Germany (Bitkom e.V., 2025). International assessments such as the International Computer and Information Literacy Study point to a paradox: although eighth-grade girls often outperform boys in computer- and information-related competencies (Bos et al., 2014), many discontinue traditional CS courses at the upper secondary level (Schubert & Schwill, 2011). This pattern may be linked to the persistent image of the “stereotypical computer scientist” as male, socially isolated, and unattractive, yet highly competent and confident (Cheryan et al., 2013), which aligns with the stereotypical representation thinking (C6) observed in our data. To counter such conceptions and avoid reproducing clichés, we plan to include explicit references to female researchers and entrepreneurs who have made substantial contributions to the development of AI. Incorporating female role models is therefore consistent with existing literature on gender research in CS (Cheryan et al., 2013). Crucially, such role models need not necessarily be internationally renowned, as women from local or personal contexts can also serve as effective role models and are often open to engaging in educational initiatives.

Furthermore, future research should systematically examine the potential influence of disciplinary background (e.g., natural sciences vs. social sciences) on these pre-service teachers’ conceptions of AI from non-CS backgrounds. Such an analysis may reveal subject-specific patterns that can inform more differentiated and targeted instructional designs in AI education.

In addition, the present study should be understood in light of its methodological limitations. The sample size ($N = 11$) and the conceptions identified (C1–C6) remain restricted to German-speaking pre-service teachers. In this sense, the course design presented here represents a first iteration, intended to serve as a foundation for future refinement. Subsequent research with larger and more diverse cohorts, potentially including international comparisons, will be necessary to test the robustness of the

conceptions and to strengthen the transferability of the course design across different cultural and institutional contexts. At the same time, it remains an open question whether the naïve pre-conceptions identified in the interviews (see Section 0) were sustained or transformed (i.e., conceptual change) as a result of the module (see Table 1). Assessing such change was neither the focus of our research questions nor investigated within the scope of this study. Upcoming studies should explore whether and how conceptual change occurred, particularly with regard to persistent beliefs shaped by science fiction or personal experience.

Acknowledging these limitations, we frame our contribution within a design-based research approach, emphasizing the iterative refinement of the course design. While we collected additional data after the module (questionnaire, final interviews), these data were not analyzed within the scope of the present study. The present study therefore provides a foundation for re-designing the course for subsequent cohorts once the final data have been analyzed, for example to examine whether conceptual change can be empirically observed.

5. Conclusions

In order to prepare pre-service teachers adequately for their future professional responsibilities, it is essential that they acquire foundational professional knowledge in AI education. From the perspective of CS education, this enables them to make well-informed and reflective decisions, thereby strengthening their professional agency in the classroom. At the same time, it empowers them to support their future students in developing AI-related competencies and adopting age-appropriate perspectives. This does *not* imply that all pre-service teachers should be trained as CS teachers, *nor* that a full teacher education program in CS can be replaced by the elective course described in this contribution. Rather, the educational goals and project ideas outlined here should be understood as part of broader discussions on teacher education.

Paving the way for future learning, we propose the following seven recommendations, grounded in the insights gained from this contribution, to inform and enrich broader *national* and *international discussions* on the future of teacher education:

(1) All pre-service teachers, regardless of their subject area or intended school type (e.g., primary or secondary education), should acquire foundational AI competencies in order to meet the demands of their future professional roles and to respond effectively to the growing challenges of digital transformation in schools and society.

(2) Our empirical interview study revealed that pre-service teachers without a CS background explicitly expressed a desire for AI-related courses in teacher education that are tailored to their needs rather than designed exclusively for future CS teachers.

(3) AI education should build on pre-service teachers' existing pre-conceptions of AI and use these as points of departure for learning and teaching, since many hold naïve conceptions that might otherwise be implicitly transmitted to K-12 students in their subject areas.

(4) Teacher education courses on AI should address common conceptions held by relevant stakeholder groups (e.g., students and in-service teachers), as these represent key target groups for future AI-related instruction and should be understood and critically reflected upon.

(5) We propose a holistic approach to AI education that draws on the Dagstuhl Triangle and links individual conceptions with technological, user-oriented, and socio-cultural perspectives. Consistent with established AI literacy frameworks, this approach should guide the design of teacher education courses and foster a balanced and reflective engagement with AI.

(6) To enable such preparation, universities and political education institutions should actively embed a mandatory introduction to AI within a broader framework of CS education for all pre-service teachers, as the presence of existing naïve pre-conceptions among this group suggests that such a requirement is a necessary consequence.

Finally, these recommendations also address those responsible for shaping teacher education, including university lecturers and professors, professional development providers, curriculum developers, and policymakers: (7) It is therefore important to examine whether current teacher educators *themselves* are sufficiently prepared to engage meaningfully with AI education. The growing challenges in this field require serious and sustained attention, not only with regard to the structure and content of teacher education programs but also with respect to the professional competencies of those involved. Developing and, where necessary, expanding their own competencies is essential to fulfilling educational responsibilities toward pre-service teachers and to contributing to a future in which AI is not only used but also understood, questioned, and shaped in reflective and responsible ways.

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