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Artificial Intelligence in K-12 Education: eliciting and reflecting on Swedish teachers' understanding of AI and its implications for teaching & learning

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Abstract
Uncovering patterns and trends in vast, ever-increasing quantities of data has been enabled by different machine learning methods and techniques used in Artificial Intelligence (AI) systems. Permeating many aspects of our lives and influencing our choices, development in this field continues to advance and increasingly impacts us as individuals and our society. The risks and unintended effects such as bias from input data or algorithm design have recently stirred discourse about how to inform and teach AI in K-12 education. As AI is a new topic not only for pupils in K-12 but also for teachers, new skill sets are required that enable critical engagement with AI. AI literacy is trying to close the gap between research and practical knowledge transfer of AI-related skills. Teachers' AI-related technological, pedagogical and content knowledge (TPACK) are important factors for AI literacy. However, as teachers' perspectives, beliefs and views impact both the interpretation and operationalisation of curriculum. this study explores teachers' and teacher educators' understanding and preconceptions of AI to inform teacher education and professional development. To gain a comprehensive understanding of teachers' conceptualisations regarding AI an anonymous questionnaire together with focus group discussions were employed. The qualitative content analysis underpinned by the theoretical framework Intelligent TPACK reveals that teachers' AI-related content knowledge is generally gained through incidental learning and often results in pre- and misconceptions of AI. Our analysis also revealed several potential challenges for teachers in achieving core constructs of Intelligent TPACK, examples of such challenges are vague and unclear guidelines in both policy and curriculum, a lack of understanding of AI and its limitations, as well as emotional responses related to participants' preconceptions. These insights are important to consider in designing teacher education and professional development related to AI literacy.

The data that support the findings of this study are available on request from the corresponding author J.V. the data are not publicly available due to them containing information that could compromise research participant privacy/consent.

Extended author information available on the last page of the article

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1 1. Introduction

The increasingly ubiquitous presence of AI in our lives has recently drawn attention to its various potential impacts and consequences (Long & Magerko, 2020; Zhou et al., 2020; Eguchi et al., 2021). The consequences are often ethically related to, for example, the risk of discrimination due to biased or unrepresentative datasets that are used to train Machine Learning (ML) models or algorithmic bias (Arrieta et al., 2020; Mansoury et al., 2020; Mehrabi et al., 2021). Privacy issues are also abundant in the complex realm of data ownership and data aggregation (Kearns & Roth, 2020). Given the mechanisms behind data-driven practices such as data collection and analysis are often hidden from users and the methods for analysis are often very difficult to explain (Arrieta et al., 2020), users are often unaware of the possible impact these practices have on their lives, their agency, and their choices (Pangrazio & Selwyn, 2021). As citizens, these issues affect the way we view the world, they have the power to alter our everyday choices and shape our path in life (Mansoury et al., 2020). Nevertheless, AI and its subfields such as ML, Natural Language Processing (NLP) and Neural Networks (NN) techniques are rapidly evolving and progressing. Its enormous potential for society is already contributing to many positive outcomes such as more accurate and expeditious diagnosis in medicine, energy-saving systems and automation of tedious and time-consuming tasks providing better consistency and performance than manual approaches (Kearns & Roth, 2019). However, associated risks as well as the need for skill sets required to participate in the development and shaping of AI have stirred discourse about integrating AI competencies into K-12 curricula (Touretzky et al., 2019; Pangrazio and Selwyn, 2021; Lindner & Berges, 2020 & Hintz et al., 2018). The presence of data-driven practices in society and not least in education has altered the requirements for awareness and understanding of said practices to harness its potential, and critically engage with and evaluate AI. This "new normality" requires teachers to be able to teach about different aspects of AI related to different subject topics as well as different age groups.

Frameworks and guidelines to inform and inspire the integration of AI-related skills deemed necessary for citizens to participate in an increasingly data-driven society have been introduced by for example UNESCO (Unesco, 2022), the EU in the form of the recently updated Digcomp framework 2.2 (Vuorikari et al., 2022) and the five big ideas of AI to foster AI literacy by *AI4K12* (Touretzky et al., 2019) in the US. These AI-related skills are often referred to as AI literacy. Literacy has always had a strong connection with education as it enables equal opportunities for participation in society (Nichols, 2007; Yi, 2021). Providing AI literacy as part of the K-12 curriculum empowers individuals from diverse backgrounds and interests to engage with and shape the future of AI-driven human–machine interactions (Touretzky et al., 2019; Pangratzio & Selwyn, 2019). To elucidate some of the issues and challenges mentioned above we have conducted a study with Swedish teacher educators

and in-service teachers. The emphasis on adequate digital competence and the impact of digitalization on individuals and society has been strengthened in a new national K-12 curriculum, valid from 2022 (Skolverket, 2022). However, to achieve the goals of the curriculum teachers are required to keep updated and acquire suitable skills and knowledge to be able to engage pupils in this teaching. At present AI literacy is not a defined component of adequate digital competence in the curriculum, however, the description of the concept implies competencies including a) an understanding of how digitalisation impacts society and the individual, b) an understanding and use of digital media, c) an ability to critically and responsibly relate to digital technology and d) an ability to actualise these ideas using digital technologies. Recent research indicates that Swedish teachers are still grappling with the integration of programming into their teaching. Programming was introduced in the Swedish curriculum in 2017 and teachers are still coming to terms with understanding the concepts and practice of programming thus lacking the knowledge to achieve technological pedagogical content knowledge in this context (Vinnervik, 2021). One challenge in operationalising adequate digital competence has been identified as the vague and unclear curriculum and policy text leaving teachers with little guidance (Vinnervik, 2021). Several studies have also concluded that the current digital literacy approach is insufficient to address AI-related issues (Pangrazio & Selwyn, 2021; Polak et al., 2022) partly because it often places the onus of the user to adapt their behaviour towards normative safe practices rather than to encourage a more critical approach towards data-driven practices (Pangrazio & Selwyn, 2021). Changes in the curriculum require in-service teachers and teacher educators to update their content and pedagogic knowledge. This in turn assumes that these new competencies are reflected in both teacher education and professional development. Lindner and Berges (2020) point out that the topic of AI is new to both students and teachers. They identified teachers' preconceptions to inform teacher professional development for computer science teachers. Our study similarly examines teacher and teacher educators' preconceptions of AI and further, using Intelligent-Technological Pedagogical and Content Knowledge (TPACK) (Celik, 2023) as a theoretical framework for data analysis, we discuss challenges and opportunities for teachers achieving AI-related TPACK.

1.1 Aim and research question

This paper contributes to an understanding of teacher and teacher educators' AI perceptions, knowledge, and imaginaries to inform the design of suitable teacher education and professional development (Polak et al., 2022). As most previous studies on AI literacy focus on what content is relevant for teaching and learning AI literacy this study also considers teachers' perspectives as these are important for interpreting and operationalising policy and curriculum (Chiu & Chai, 2020). Previous research has also stressed the importance of teachers' content understanding and pre-concepts for several reasons a) it influences their learning, b) it identifies their preconceptions that they potentially pass on through their teaching, c) it influences their ability to elaborate on existing teaching material and interact

with students at their knowledge content level (Lindner & Berges, 2020) and, d) affects their ability to be able to distinguish between accurate conceptions and misconceptions within their curriculum (Antonenko & Abramowitz, 2022). Due to the novelty of the research field of AI literacy and its connection with teacher professional development, the literature that exists on the topic is very sparse. Data gathered from questionnaires and focus groups were analysed with the Intelligent-TPACK framework and results reveal many challenges and opportunities for gaining Intelligent TPACK. These are important to consider as they reveal prerequisites for teachers to engage in AI literacy. As such, this study aims to answer the following Research Questions (RQ):

1. *How do teachers and teacher educators conceptualize AI in terms of awareness, content knowledge, and emotional responses?*
2. *How can these reveal challenges and opportunities for teachers and teacher educators to gain AI-related Technological, Pedagogical and Content Knowledge?*

The remainder of the paper is organized as follows; section two gives an overview of related research to position our work. Sections three and four present the methodological approach and describe the study and tools used for data collection and analysis. Sections five and six present the analysis and discuss the results. The paper ends with a discussion of core ideas related to AI literacy in K-12 education and presents some possible lines for future research.

2 2. Related research

2.1 AI skills, literacy, competence or education?—concept, definition and research history

Literacy extends the ability to read and write and although there is debate over the definition of the concept and what skills are required to be literate it is seen as empowering for societal engagement (Yi, 2021). Education has long been the vehicle for equal opportunities and social participation (Kagitcibasi et al., 2005) and as such literacy has a central role in education. As society changes so do the prerequisite skills for engaging in it, thus literacy is a concept that has branched out to reflect these prerequisite skills. AI literacy is a response to the requirement to understand AI to make informed and independent decisions in data-driven societies (Yi, 2021). However, the issue of agency (considered here to be the ability to exert free will) in the data-intense world has been questioned by Pangrazio and Sefton-Green (2021) as practices such as predictive analysis, targeted advertising, fake news and other methods of manipulating individuals are threatening human agency. They stress the importance of complementing the normative practices that are often taught today and which often focus on how individuals need to adapt to engage in society on the new terms whilst ignoring the aspect of

individuals' ability to engage with and be part of shaping the digital which can further contribute to exacerbating imbalanced power relationships between stakeholders in data-driven practices.

Publications on AI literacy have increased dramatically over the last four years. Inspecting trends in the research field of AI in education (AIEd) reveals that it has evolved from a technology focussed research area to include ethics, social effects, computational thinking, and AI literacy (Mohammed et al., forthcoming). Although AI literacy concerning K-12 education is often referred to, what competencies related to AI need to be taught and how to teach them are still open to interpretation (Olari & Romeike, 2021; Polak et al., 2022). Several reviews have tried to identify such competencies and skills have reviewed existing literature to define researchers' definition of AI literacy. They suggest four aspects that are important for achieving or fostering AI literacy: *Knowing and understanding AI*, *Applying AI, Evaluating and creating AI and AI ethics*. Long and Magerko (2020) identified five of the most important themes to be included in AI education: *What is AI?, What can AI do?, How does AI work? How should AI be used?, and How do people perceive AI?*. And Touretzky et al., (2019) identify five big ideas of AI: *Computers perceive the world through sensors, Agents maintain models/representations of the world and use them for reasoning, Computers can learn from data, Intelligent agents require many kinds of knowledge to interact naturally with humans and AI can impact society in both positive and negative ways*.

Several skills are required to be able to engage in AI literacy such as digital and data literacy (Long & Magerko, 2020). Most previous studies concentrated on the content knowledge and methods of how to transmit this to pupils. Chiu and Chai (2020) argue that this approach neglects teachers' perspectives which is important to consider since their beliefs and views contribute to the interpretation of the curriculum and successful and sustainable curriculum development (Chiu & Chai, 2020). Our study connects with these ideas by mapping preconceptions and their implications for realizing teaching according to the policy documentation and curriculum. This is important since teacher education needs to consider these as new knowledge is often built upon existing knowledge (Lindner & Berges, 2020).

2.2 Relevance of teachers' content knowledge and preconceptions in education related to AI

Mapping teachers' content knowledge and attitudes is important to foster their concepts and understanding of AI (Lindner & Berges, 2020). The authors conclude that although teachers have many preconceptions of AI these do not necessarily include the technical aspects of AI (Lindner & Berges, 2020). Moreover, the technical aspects of AI are usually shallow which creates a barrier to adopting existing frameworks such as Digcomp 2.2 and AI4K12 (Lindner & Berges, 2020). Antonenko and Abramowitz (2022) stress the importance of mapping K-12 teachers existing knowledge, conceptions and misconceptions so that these can be considered "*in the design of the curricula that introduce K-12 students to AI and ML*" (Antonenko & Abramowitz, 2022, p.2). Since AI and ML are new

concepts to teachers as well as to students it is equally important to consider these when designing teacher education and Teacher Professional Development (TPD). Recent studies indicate that teachers often transfer their misconceptions to their students (Antonenko & Abramowitz, 2022). Content knowledge and understanding are important factors in the ability to elaborate on existing teaching material and interact with students at their content level (Lindner & Berges, 2020). Teachers also require an understanding of how to apply their learned knowledge by *"making a connection between teaching content and real life"* (Polak et al., 2020, p.2).

Acquiring knowledge from non-experts through for example media and news through what is often referred to as incidental knowledge leads to misconceptions about AI (Antonenko & Abramowitz, 20,222; Lindner & Berges, 2020). These misconceptions can be reinforced by repeatedly using the same sources of media (Antonenko & Abramowitz, 2022) which, considering the widespread use of predictive models serving up appropriate and personalized information, is further strengthened.

TPACK is a well-established framework for eliciting teachers' Technological, Pedagogical and Content Knowledge and how different interactions between these constructs contribute to teachers' ability to incorporate technology effectively in their teaching (Koehler et al., 2013). The instrument for data collection using TPACK however has been challenged due to teachers' self-assessment of technology that is often unspecified (Seufert et al., 2021). Due to the broad and varied conceptualisations of AI, it is difficult to pinpoint concrete questions that can capture teachers' understanding and categorize the data gathered, since the concepts proposed by the framework might not cover their knowledge. Thus eliciting teachers' Intelligent-TPACK in a focus group setting allowed us to gain further insight into teachers' Intelligent-TPACK related to their specific conceptualisations and preconceptions. We elaborate on our methods in the following section.

3 Methodological approach

3.1 Study context: Digital Competence in the Swedish teacher education system

Providing digital competence in Swedish K-12 education is an assignment all teachers at all levels and subject matters in K-12 education are responsible for. It is the responsibility of teachers to acquire the necessary skills and knowledge to teach according to the national policy documentation. The most recent update of the national curriculum emphasizes the role of digitalisation and its impact on individuals and society. Although the curriculum is vague in specifying what aspects should be addressed, the impact that AI and data-driven practices have on individuals and society makes it a relevant topic for inclusion in K-12 teaching. AI literacy can be associated with two main parts in teacher education, firstly via the core education subjects through the democratic assignment (Örtegren, 2022) and secondly through the four aspects of adequate digital competence that recently has been emphasized in the curriculum, the syllabus, and the subject plan. These four

aspects in the policy documents include the abilities to "*understand how digitalisation impacts society, to use and understand digital tools and media, to have a critical and responsible approach and to be able to solve problems and turn ideas into actions''* (Skolverket, 2022). Teacher education on all levels is responsible for providing teacher students with the relevant competence to teach and communicate these aspects of digital competence in general and related to their specific subject matters. The school has a mission to enable pupils to navigate and act in a complex information-rich reality with increased digitalisation and transformation (translated from (Statens Skolverk, Utbildningsdepartementet, 2017)).

Although the four aspects contributing to adequate digital competence imply AI-related knowledge, recent research indicates major challenges in operationalising this policy in classrooms. One such challenge stems from the discrepancy between policy and curriculum changes versus that of teacher education and teacher professional development (Vinnervik, 2021). Another challenge is the delay in operationalizing policy and curriculum changes which can be exemplified by the fact that Swedish teachers are still coming to terms with how to integrate programming into their teaching (Vinnervik, 2021), which was introduced to the curriculum in 2017.

3.2 Respondents and study setting

This study target K-12 in-service teachers and teacher educators in all grade levels in Swedish elementary education. The university contact network with K-12 schools was used to reach respondents shortly after the summer of 2022, 18 teachers and teacher educators responded to the online questionnaire and 19 teachers and teacher educators participated in three focus-group sessions. The respondents of the questionnaire and the focus groups may overlap since the questionnaire was collected anonymously.

3.3 Questionnaire details

A questionnaire was used to gather details on demographics including professional experience related to teaching (3 items), the conceptualisation of AI, content knowledge including where the respondents have acquired the knowledge and their familiarity and imaginaries of AI in the future (9 items). We draw on the work by Lindner and Berges (2020) who use an online questionnaire for understanding teacher preconceptions on AI to inform computer science teacher professional development. As their study aimed to determine teachers' subjective explanatory models about AI, these questions help answer our research questions. The questionnaire can be found in Appendix A. Open-ended questions allow respondents to be spontaneous in their responses as well as avoid the potential bias of predefined options, however, there is an increased risk of missing data and ambiguous responses using questionnaires (Reja et al., 2003).

3.3.1 Data and Analysis from Questionnaires

The data sets arising from the questionnaires were analyzed using qualitative content analysis following the procedural steps of Mayring (2004). A deductive approach based on the themes of the questions was followed by a more inductive approach to allow for the extraction of emerging or additional themes within each response (Gläser-Zikuda et al., 2020). This method was chosen partly to compare results with previous studies in the sense of triangulation and to enable checks for reliability. The method has been evaluated with empirical educational research in mind as well as deemed suitable for stakeholder involvement in group interviews such as focus groups (Gläser-Zikuda et al., 2020). The analysis of data gathered by the questionnaires revealed many aspects of TPACK which is a contributing reason for basing the analysis of the focus groups on the Intelligent-TPACK framework (Celik, 2023) specifically validated for AI in education.

3.4 Focus groups

To gain a deeper understanding of teachers and teacher educators' conceptualisations of AI three focus groups were conducted. The focus group discussions were based on the questionnaire whilst allowing spontaneous discussions to take place to reveal the interests of the participants. Focus group discussions allow participants to query each other and explain themselves to others (Morgan, 1996). Specifically, the discussions regarding the general knowledge and understanding derived based on the questionnaire were extended to include respondents' thoughts and feelings associated with teaching (and using) AI in their profession.

3.4.1 Data Analysis from the focus groups

Transcription and translation of the data from audio recordings were conducted by one of the authors, and two authors then thoroughly familiarised themselves with the content. As the analysis from the questionnaire often revealed themes responding to constructs in the theoretical framework TPACK, we used an extended version of this framework adapted for integrating AI in education called Intelligent TPACK (Celik, 2023) to sharpen our analysis and lean on the solid verification and testing of this method. Teachers' Intelligent TPACK is important for teaching AI literacy and as such reveals challenges teachers face in realising AI literacy teaching. The traditional TPACK framework includes the constructs of Technological Knowledge, Pedagogical Knowledge and Content Knowledge and describes how these constructs relate to and interact with each other to result in effective teaching (Koehler et al., 2013). Increasing integration of AI in education has resulted in adapted and extended versions of the original TPACK framework such as the Intelligent-TPACK framework (Celik, 2023) introducing the construct of ethics as one of its components. Celik (2023) developed and verified the validity of this framework in their recent study (Celik, 2023) which provided us with the opportunity to draw on the

established relationships between the constructs in this expanded framework. With this theoretical framework in place for the qualitative content analysis we initially followed the concept-driven approach where we drew on the categories of the Intelligent TPACK. To avoid limiting our findings to this framework we then allowed a data-driven approach to expand this framework with further categories where necessary. This method allowed a structured way to analyse the data underpinned by a well-established framework to help answer RQ2 and also to gain more in-depth answers to RQ1(Flick, 2014).

4 Results

4.1 Results from the Questionnaire

4.1.1 Demographic data

In total 18 respondents returned complete questionnaires whereof 10 were teachers and six were teacher educators whilst two respondents shared their time between teaching and educational technology. Most teachers work towards grades 4—9 except for two teachers working with grades 0—3 and one in upper secondary school. Eight of the respondents were between 40—49 years old, five were between 50—59, three were above 60 and two were between 30—39.

4.1.2 Framework based on questionnaire data

In the following sections, results are presented based on the theme corresponding to each question. Each theme is presented together with a descriptive text as well as a table containing 1) the main themes corresponding to each question, 2) subthemes based on the prominent themes of each question, 3) representative quote(s) for each subcategory where RX indicates respondent X and 4) whether the majority of responses in this subcategory indicate frequent misunderstandings (MU), technological knowledge (TK) technological content knowledge (TCK) Technological Pedagogical Knowledge (TPK) or Ethical aspects (E) related to AI (Tables 1, 2, 3, 4 and 5). A + next to the construct indicates that there is positive support for the

Table 1 The main category and subcategories with representative quotes are based on respondents' definitions of AI

Main theme	Subthemes	Representative quotes	Constructs
AI concept	Humanlike traits, thinking, conscious, replace humans	**R11:** *"Some "machine" that thinks for itself";* **R18:** *"a consciousness that independently of other (after creation) is able to think"*	**MU**
	Categorise data, learn from experience	**R17:** *"A system that learns from its experiences",* **R2:** *"Trainable software."*	**TK +**

Table 2 The main category, and subcategories with representative quotes are based on respondents' emotions and attitudes associated with AI

Emotions & attitudes	Risks: ethical and legal	**R12:** "*Curiosity and certain **anxiety about how to control it.**",* **R2:** *"Mixed: **trust** if it is well trained and used where it works and for legitimate purposes. However, I **don't trust** that it always will be used where it works and for **legitimate** purposes. One illegitimate purpose would be population **surveillance** in non-democracies."*	**E-/ TK-**
	Opportunities	**R17:** "***Fascination, exciting**, but a bit scary", **R6:** "**Curiosity** but also a bit frightening"*	**E + -**

Table 3 Main category, and subcategories with representative quotes based on respondents' understanding of how ML works

Machine learning	Big data, algorithms and programming	**R3:** *"With the **help of code, computer programs create robots that "learn" to recognise**, perceive situations and carry out tasks, solve problems.",* **R7:** *"**Patterns are discovered** by programmed analysis and a **big amount of data**. The more data analysed the more certainty of the results/analysis."*	**TK +**
	Limitations and complexity	**R6:** *"It's useful for **simple tasks**, like quizzes and pronunciation exercises."*	**TK + MU**

Table 4 Main category, and subcategories with representative quotes based on respondents' everyday use of AI

AI in your life	Specific applications	**R4:** *"Social media that **remembers** and spreads information about me without me knowing"*	**TK + /E-**
	Unspecific	**R5:** *"Perhaps functions in a smartphone?"*	**MU**

Table 5 The main category, and subcategories with representative quotes are based on respondents' imaginaries about AI in the future

AI in the future	Limitations	**R6:** *"I hope never to be subjected to, for instance, AI psychotherapy."*	**E-**
	High expectations for healthcare and education	**R11:** *"It can be of big help for identifying problems for example in **healthcare, education and production** **etc**."*	**E +**
	Ethical aspects	**R9:** *"Probably many applications but one has to make sure that they are **used in the right places**"*	**E**
	Complement human capabilities	**R14:** *"To be an **extra resource**, but also to be able to **draw conclusions from masses of data, where people do not have the ability to do this**.",* **R3:** *"To make many things more efficient and to get **help from AI to discover new things**"*	**E**

construct for example TK + would mean that the data supports teachers gaining TK where as—means that challenges were found for teachers gaining TK.

Knowledge source Out of the 18 respondents, eight acquired their knowledge both incidentally and intentionally. Seven respondents had only incidental sources and three had only intentional ones. The most prominent incidental sources are TV, media, film, online sources and literature. Whereas those who actively acquire knowledge of AI do this through lectures and education. In the following sections, the results from each main theme which corresponds to the questions in the questionnaire are presented.

Conceptualising and defining AI Four respondents provide definitions of AI that indicate some knowledge and understanding of what AI is, however, the relatively short descriptions respondents provide make it difficult to discern how well the concept is understood. An example of such a response is *"[sic] analyse data and then produce some new knowledge, [sic] conclusion and do this better and faster, i.e. it learns."*. Many participants associate AI with machines or robots that can think or are conscious. Although these human-like traits are misconceptions, AI is also referred to as able to learn and make decisions based on data which somewhat explains the basic aspects of ML.

Emotions Emotions of excitement and curiosity are almost always associated with a condition relating to ethical aspects and values such as trust, privacy and control.

Machine learning and neural networks Most respondents indicate some technological knowledge when it comes to ML where they frequently mention the need for large amounts of data for computers to learn. Although there are basic terminology frequently used that indeed are associated with ML these are often mentioned in combination with fundamental misunderstandings of ML. The table represents respondents' thoughts on how ML works and the table for NN is left out due to the lack of respondents who attempted to reply to the question on how they envisage NN.

AI in your life All respondents provided answers about how they use AI in their daily lives. However, six respondents stated that they were unsure. Many refer to their mobile phone without specifying which applications might use AI whilst some respondents indicate a good understanding of existing AI applications such as image processing, SIRI, social media, translation and spelling tools as well as autonomous cars.

AI in the future Respondents were overwhelmingly positive about the possible role of AI in the future. They expressed their expectations for AI to be used as an extra resource in healthcare, education and precision work. Attached to these expectations are often conditions related to ethical issues.

Ethics Mentioned throughout the responses and scattered amongst the different topics are references to ethical and sometimes legal issues. To a certain extent, we

see here a similarity with the emotional responses referred to above. Considering the gaps in knowledge and uncertainty concerning technological developments it is unsurprising that emotional expressions and responses regarding AI in the future converge.

4.2 Results from the focus groups

4.2.1 Demographic data

Three focus groups were conducted, two with teachers and one with teacher educators. Focus group one (FG1) consisted of seven teacher educators all of which had previously worked as teachers in K-12 education, Focus group (FG2) consisted of three teachers teaching the grade band 4—6, and Focus Group 3 (FG3) where nine teachers teaching grade bands 4—6 and 7—9 participated.

4.2.2 Extended framework based on focus group data

Tables 6 presents an extended framework which is based on the data from the discussions that took place in the focus groups. These discussions reveal both understandings of and misunderstandings related to AI and it also reveals related challenges and opportunities for teachers to enact teaching on AI literacy. The results are also elaborated on in the text after this table.

Technological knowledge Conceptualizations range from sci-fi-related scenarios to machine learning methods used in more specific applications of AI. A recurring pattern is an ability to define AI as related to data, decision making and machine learning for example. However, more in-depth and elaborate discussions often lead to increased uncertainty as to what qualifies as AI. Content knowledge of AI is overall low, this is especially apparent from the focus group discussions where uncertainties related to AI are often revealed only after lengthier discussions. There was an overall tendency to talk about digital competence generically without specifying to what extent this includes AI-related topics.

Technological content knowledge All group discussions highlight the discrepancy between both teachers' and pupils' expected content knowledge related to digital technology and their actual content knowledge. This is apparent for example when one participant says that "*We feel that they (students) have such unlimited access to computers and phones at home and in school, but they [sic] don't know anything about computing.*". Apart from this, pupils' AI literacy is also low and both teachers and teacher educators express several issues and implications for this such as filter bubbles and implications for students' agency as citizens in the democratic society resulting in societal consequences.

Table 6 Depicts the framework from the focus group analysis underpinned by the Intelligent TPACK framework as indicated by the constructs in the fourth column.

Main theme	Subthemes	Representative Quotes	Construct
AI concept	Representative of current AI applications	*"We often think of AI as replacing humans or humanity but in reality, it is AI that replaces more specific and smaller tasks."*	**TK +**
	Representative of AI in sci fi and future	*"sci fi and films. They are often dealing with issues in society that are not real here yet, but maybe they will be in the future"*	
	Uncertainties and misunderstandings	*"I am actually a bit unsure about what AI is. Is it self-taught? Or what can an AI do? I don't feel sure. Is it an AI if it just looks through data and finds the same information?", "What is the difference between an algorithm and an AI? So personalized ads, for example, it is based on previous clicks, this is not an AI?", "it states the document that we are supposed to work with* ***these issues****…"*	**TK-**
AIEd	Human AI collaboration	Regarding ChatGPT: *"…you have to be kind of smart when you are writing to the AI as well."*	**TPK +**
	Lack of Professional Development	*"I agree with participant x that teachers have far too little competence to provide adequate teaching in these issues.", "It is expected of us that we know this, it's not like we have this knowledge from our education. A lot has happened since we were newly graduated teachers.", "It is expected of us that we know this, it's not like we have this knowledge from our education. A lot has happened since we were newly graduated teachers. Like programming and other things where you, on your own initiative, have to find the time to learn these things and feel that you are competent enough, and there are many that feel uncertain…"*	**TPK-**
	Instant feedback and personalised learning	*"…there are applications where you do exercises and then it is adjusted to your level."*	**TPK +**
	AI literacy	*"…these are difficult things to explain. When you explain this you have to do it in an abstract way.", "AI controls more of students' everyday lives than they realize. We, teachers, know too little about this to carry out adequate training. We are also not aware of how little we know.", "There are motives for these like making people buy new things and like you say you get owned. And this in turn has consequences for how you engage in society which is related to democracy. The information that you get is often determined by algorithms and what you might already know and like."*	**TPK**
	Difficulty linking high-level concepts with practice	"*we take examples like how to give instructions like how to make a sandwich for example. And to start with they do not know that they need to be precise and specific so the computer will understand. The computers are dumb, they don't consider things like us", "We teach it [social media and sharing data] and use it but we don't connect it to the democratic assignment."*	**TPK-** **TCK-**

Table 6 (continued)

Main theme	Subthemes	Representative Quotes	Construct
AI in daily life	Understanding through real-life applications	*"…like my diabetes tracker, here I feed it with as much information I can so it can help me to regulate my living better. The more data I give it the better it can help me."*	**TCK +**
	Mismatch between expected knowledge and actual knowledge based on the presence of technology	*"They sit with their phones, but they do not even know how to send an email on the phone. So, we expect that they know certain things and they don't, when we use it in class then we think they know this. So, we don't have a plan on what skills they should have at what stage."*	
AI in future	Teacher role	*"Our role might change, it might improve so it can be better since we can be present as humans and free up the time from the repetitive tasks."*	**TPK**
	AR and VR	*"We can bring the world into the classroom…with biology you can have sensors* etc. *to measure things in your body"*	**TPK**
Ethics	Accountability	*"How can we trust that AI does not take over and make the wrong decisions from a human perspective I also want to say this about worry, that it causes some anxiety in all of us. And you feel, at least I feel that I am not in control."*	**E**

Technological pedagogical knowledge As participants attended in a professional capacity, they mostly related AI in their lives to education. There were hopes and expectations for AI in education and both teachers and teacher educators see the opportunity to monitor student progress, identify students in difficulty and provide suitable help as an important and helpful manner in which to employ AI in education. Teacher educators also saw an opportunity to utilize AI in information dissemination given student data today is plentiful yet stakeholders like parents and students are often unaware of their children's educational progress.

Attitudes and perceptions of AI Emotional responses are related to participants' conceptualizations and understanding of AI and its limitations. Fear and anxiety are often associated with high expectations of what AI is and will be capable of, this is also true for feelings of powerlessness to influence and control the use of and the future of/with AI. Negative feelings are related to a reluctance to use it both in a private capacity and professionally, and this "mindset" which is discussed by participants that technology is bad can be difficult to change.

Ethics The ethical construct added by Celik (2023) provides a space to consider teachers' awareness of ethics in AI. Participants have an overall good understanding of data and algorithms' role in decision-making and how the motives for optimising algorithms are important for agency and the ability to take informed decisions which in turn relates to values of equality, justice, democracy and trust. There is a concern about the extensive use of data-driven practices on for example social media and its influence on behaviour and opinions which can be difficult for teachers to challenge as one individual's filter bubble is perceived as truth. At the same time, participants see many opportunities for using student data to understand student progress and

learning. Although participants seem aware of the ethical implications of AI they are not able to elaborate on the more technical reasons for these.

Challenges in gaining Intelligent-TPACK An additional finding concerns the opinion expressed by both teachers and teacher educators regarding the many challenges they face acquiring AI-related TPACK to teach AI literacy as part of adequate digital competence in the new curriculum. These obstacles are related to vague and unclear definitions in the curriculum, expectations on teachers to know how to interpret the vague policy documentation, difficulty in keeping up to date with unspecified knowledge and skills, lack of time and resources and lack of available TPD. Difficulties in identifying the prerequisite skills required to competently teach AI literacy are also related to the vague definitions in the curriculum.

Participants agreed that current efforts to teach the new curriculum fall under the topic of social science or Swedish and deal with information literacy given these are the only subjects which have any specific guidelines in the curriculum. All teachers expressed issues with being pinpointed as "technology enthusiasts'' or someone that through their own initiative takes part in TPD regarding digital technologies in general. This places an expectation on them to be a resource for knowledge, and while they do want to share their technological pedagogical content knowledge, they often instead end up assisting with more practical technology-related issues related in the classroom. Teacher educators confirmed this stereotype and indicated that school leaders and colleagues are often aware that there are enthusiasts on staff and thus rely on these people to "handle" these aspects of teaching.

5 Discussion

Here we discuss the findings and where appropriate refer to existing research to give credence to or expand our discussions. As participants' conceptualisations, awareness, content knowledge and emotional responses are revealed during the analysis in response to RQ1and the extended Intelligent TPACK frame (RQ2) is presented in the previous sections, the discussion focuses on the implications of these findings related to opportunities and challenges that exist for the teaching profession to effectively incorporate AI technology and AI literacy.

5.1 Relating AI literacy to adequate digital competence in the curriculum

Although all teachers and teacher educators participating in the study overwhelmingly agree with the importance of AI literacy in K-12 education there is little understanding of how it relates to adequate digital competence which is specified in the curriculum. Several potential reasons for this emerged whilst analysing the data from the focus group discussions.

5.1.1 Misconceptions and the missing link

Misconceptions are often related to unrealistic expectations of AI. Participants frequently refer to AI as conscious or thinking machines or robots indicating a general intelligence that is not yet realised. The narrow AI that is currently used mostly through ML is often associated with data and algorithms however this connection remains undefined by most participants. In terms of NNs, only two teacher educators out of all study participants attempted to describe how they envisage these. Since the topics of ML and NNs are technically difficult and considering that the assignment to teach AI literacy (which entails these aspects) is given to all teachers at all levels of K-12 education, teachers and teacher educators have difficulty in identifying what competencies and awareness are important to gain at what stage in education so pupils can build on previous knowledge. This highlights the importance of being able to understand the relationship between preconceptions, essential background content knowledge and specific AI concepts. A good grasp of content knowledge is important for teachers to feel confident about elaborating on "textbook material" and contextualising it in a manner which allows pupils to create their own knowledge. This ability to elaborate and contextualize seems an important aspect to consider when developing TPD and teacher education since students will also bring their own preconceptions and misconceptions which may need to be deconstructed for an efficient learning experience.

The discussions uncovered a lack of understanding of the connection between different skills that are currently included in education such as algorithms, programming and computational thinking skills and how they are related to AI. As indicated in the results section although teachers involve pupils in making algorithms they could not motivate the teaching of algorithms or make the connection between algorithms and AI.

Overestimating the abilities of AI without realising its limitations often results in feelings of fear and anxiety when considering the future of AI. Teachers and teacher educators both refer to two aspects of this that contribute to a lack of engagement. The feeling that AI is bad or evil results in teachers wanting to "hide" this from pupils.. This attitude also hinders teachers from engaging in TPD to gain a realistic perspective on AI which instead risks being reinforced by repeatedly using the same sources of media (Antonenko & Abramowitz, 2022).

Participants seem to have a superficial understanding of the risks and implications of using AI, especially concerning social media. Again, however, teachers are unable to provide the link between this understanding and its relationship with ML. For instance, social media recommendations and personalised marketing are discussed in class without explaining how ML and algorithmic optimisation affect user feeds or ad placements.

5.1.2 Agency and its relationship with AI and the democratic assignment

The requirement of education to provide adequate digital competence in line with the democratic assignment is fulfilled partly unbeknownst to teachers, the reason for teaching AI awareness was that it is part of young people's daily lives via social media. It affects pupils and their daily lives. It would be valuable for teachers to

understand how this teaching relates to more technical aspects and enable a deeper understanding of the relationship between ML, algorithmic bias and biased data, for example. Frameworks such as computational thinking could be used to assist teachers since CT frameworks incorporate cognitive, situated and critical framings which allow engagement with, constructing and reflecting on algorithmic artefacts, all of which are relevant for achieving AI literacy (Dohn et al., 2022). As previously mentioned, this is essential not only for future computer scientists but also for a broader engagement in sustainable integration of AI in society considering ethical, legal, and societal aspects (Dohn et al., 2022).

At the end of each focus group, the moderator demonstrated GPT-3 which is available from OpenAI. GPT-3 takes natural language input from users and the natural language processing model constructs a unique reply of specified length and perspective. Teachers and teacher educators commented on several aspects related to this tool. The first and most common category was that of the changing role of the teacher, with this in use it will be next to impossible to assess work done by students outside of class. It will require novel methods r of assessing pupils' learning in the near future. However, one teacher turned the question around relating this to the democratic assignment to ask T1: "*What will this mean for the pupils? What happens to the democratic citizens, what does it mean for a society to deal with them later? If they can not express themselves, what consequences will this have?"* T2: *"Yes for abilities that will be affected, if you want to do something in real life like write a letter to the council you could not just say write a critical text about the dangerous playpark in our village, you need to be able to express and motivate your own feelings on this".*

5.1.3 Does AI literacy concerning adequate digital competence need to be more specifically addressed in the curriculum and policy documentation?

As the concept of AI is broad it might require more specific policies to enable equitable adequate digital competence considering the wide room for interpretation of vague definitions in the curriculum. The difficulty in defining AI combined with its current attention in media and its frequent associations with sci-fi is often associated with ominous scenarios where AI dominates. Such preconceptions are important to understand as they can act as a barrier for teachers to gain AI-related TPACK.

Both teachers and teacher educators express digital competence vaguely and are unable to define this they also express uncertainty about what prerequisite skills are required. What competencies are required, how do they fit into the subject topics, and how to teach these (pedagogic knowledge) are difficult to know.

Teachers often overestimate pupils' knowledge when it comes to digital technologies and computing. Pupils have unlimited access to computers and phones both at home and in school and often teachers expect pupils to have a certain knowledge concerning computing. The debunked myth of the digital native being digitally literate seems to live on in this context.

5.1.4 Reflections about instruments for eliciting participants' understanding of AI

The analysis identified differences in the responses to questionnaires compared to the focus group discussions. It seems that current popular knowledge about AI and its simplistic association with data and decision-making enabled circumscribed and brief responses to the questions posed in the questionnaire. Focus group discussions, however, revealed that the more AI was discussed the more questions and uncertainties regarding AI were raised, such as questions about the difference between algorithms and AI or what AI actually means and what it can and can not do. This could lead to faulty conclusions regarding teachers' content knowledge if using or basing these on surveys where the ability to expand on and probe deeper for more details is impossible.

6 Future research and limitations

Results from this study suggest that teachers' attitudes and perspectives are important factors to consider when eliciting teachers' TPACK. As TPACK can be a useful framework for understanding teachers' ability to effectively integrate technology in their teaching this study suggests two relevant ideas for further research regarding methods for eliciting teachers' TPACK: 1) traditional instruments for eliciting Intelligent TPACK are subject to respondents' conceptualisations and understandings of concepts, in this instance AI which respondents have very varied conceptualisations and understandings of and 2) understanding teachers attitudes, beliefs and preconceptions seem to be important levers for engaging in AI-related TPACK. Therefore we set out to further refine methods for eliciting teachers' TPACK. To this end, we aim to involve teachers and teacher educators in designing methods to use in, for example, focus group discussions and to work towards the design and validation of a formal instrument that considers the current limitations. Given the discrepancy between policy and curriculum content on the one hand and teacher education and professional development on the other there is also a need to design methods for engaging teachers in AI literacy that can be used in teacher education.

Lindner and Berges (2020) found that students' background, knowledge, and attitudes also were important, this result was confirmed in our study and therefore our forthcoming study will investigate students' preconceptions of AI. The sample size for the questionnaire is relatively small and participants were mainly recruited through the university's school contact networks. Given participants worked in the same region, although they state large variations between municipalities, schools and even within schools (concerning teachers' knowledge), this may make our findings difficult to generalise. This limitation is also somewhat addressed by the similarities of the results from Lindner and Berges (2020) in which they received 23 responses from Computer Science teachers in Germany.

Appendix A

Table 7 Lindner and Berges (2020) are used in our online questionnaire

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

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Declarations

Conflict of Interest None.

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