# A synthesis of AI literacy competencies aimed at education: An umbrella review and research world café approach.

**Christo Sonnekus** 

Faculty of Behavioral, Management and Social Sciences, University of Twente Educational Science and Technology

Supervisor: Prof. dr. Kim Schildkamp

2<sup>nd</sup> Supervisor: Dr. Ilona Friso – van den Bos

## Acknowledgements

I dedicate this thesis to Renard, whose steady support and patience have meant more than I can say. A special mention also goes to my dogs, Oma and Ubbe, who have been constant companions through long writing days and even longer thinking pauses. Furthermore, I would like to thank my supervisors, Kim Schildkamp and Ilona Friso-van den Bos, for their guidance, encouragement, and valuable feedback. I also extend my appreciation to the members of the Npuls research group—your insights and discussions have been an important part of this journey. Thank you for sharing your knowledge with me.

#### Abstract

Artificial intelligence (AI) will play a significant role in the future of education, which will require users to be AI literate. At present, there are a variety of AI literacy frameworks available to educators and students, but no clear consensus on the competencies needed to be considered AI literate. This study aimed to identify AI literacy competencies by synthesising findings from international literature and insights from Dutch stakeholders. An umbrella review was conducted to extract AI literacy competencies deemed important for educators and students by extracting information from the 15 included articles. Findings were complimented with practitioner and student insights collected during two research world cafés. The study identified knowledge (e.g., limitations of AI), attitude (e.g., confidence), skill (e.g., system thinking), and ethics (e.g., bias) as core competencies which are supported by a subset that can be added to customise and adjust the learning to the context or learning environment. The findings contribute to the development of more comprehensive and context-driven AI literacy frameworks for education.

Keywords: Artificial intelligence, AI literacy, AI literacy competencies, AI literacy framework

Table of content
Introduction
Theoretical Framework7
The Evolution of Education in the Age of Al7
AI Literacy Explored8
The Role of Education in AI Literacy9
Al Literacy Frameworks and Their Competencies10
The Current Study
Method
Phase One: Umbrella Literature Review:12
Data Collection13
Data Selection
Data Extraction
Phase 2: Research World Café:16
Purpose16
Procedure16
Participants17
Data Extraction
Results
Phase 1: Literature Synthesis19
Overview of Studies
Conceptualizing AI literacy 19   Table 1 Definitions and terms used in the selected articles 20
Al Literacy Competencies21
Knowledge21
Attitude
Skill
Ethics23
Educator vs. Student 24   Figure 2 Education levels and their AI literacy competencies clustered according to the four core competencies 25   Figure 3 Proposed AI literacy competencies to be included in an AI literacy framework 27
Phase 2: Research World Café29
Al Literacy Defined
Al Literacy Competencies Identified
Students

Educators vs. Students	. 32
New Competencies Identified	. 33
Discussion	34
AI Literacy Competencies	. 34
Scientific and Practical Relevance	. 36
Limitations and Future Research	. 37
Conclusion	38
References	40
Appendix A	48
Appendix B	51
Appendix C	52
Appendix D	54
Appendix E	57
Appendix F	58
Appendix G	70
Appendix H	73

#### Introduction

Artificial intelligence (AI) is transforming many aspects of our world, including education. As AI becomes more prevalent, developing "AI literacy" becomes more important (Almatrafi et al., 2024), a term Ng et al. (2024) suggests should be part of the 21<sup>st</sup> century digital literacy skills. Due to the rapid development of AI, it has become a cornerstone of contemporary learning which has evolved into a crucial skill that is just as important as reading and writing (Walter, 2024). It is predicted that in the next 10-years AI will gradually become a prominent fixture in classrooms. It is crucial to expand AI learning beyond higher education and professional training (Chiu et al., 2024) as understanding the science behind AI, its potential and limits, and the impact it will have on society is important as students prepare for future careers (Eguchi et al., 2021). In this AI era, users of all ages will become collaborators and producers of AI (Schüller, 2022).

This unavoidable change compels educators to embrace the change and prepare not only themselves, but also their students. As such, education will play a vital role in society's ability to adapt and succeed in a modern world where it is important for humans to compliment technological advancements as opposed to competing with it (Shelton, 2024). By addressing challenges such as AI literacy, it will be possible to provide educators and students with the necessary skills and behaviours to use AI effectively and responsibly (Lee et al., 2024), ultimately bridging the AI knowledge and skill gap. Due to the rapid evolution of AI, AI literacy will become more and more important. Those with limited understanding of AI technology and the competencies needed to use it, will ultimately lead to misuse, misconceptions (Heyder & Posegga, 2021), or an inability to participate in a technological society.

At its core, AI literacy refers to the ability to understand and interact effectively with AI from both a technical know-how, and ethical perspective (Walter, 2024). As such, many organizations stress the necessity for increased AI literacy among educators and students by formulating AI literacy frameworks to aid the learning process. One such organization is the United Nations Educational, Scientific and Cultural Organization (UNESCO) (AI4edu, 2024). By using a framework, educators have the necessary guidance and structure to incorporate AI into their lesson plans (Young, 2008). Empowering educators to create training programs and assessment tools that are impactful and effective (Almatrafi et al., 2024). However, no standardised AI literacy framework is available (Olari & Romeike, 2021; Schüller, 2022) and educators have a wide selection of frameworks to choose from. Each focussing on a different combination of competencies which might lead to confusion. Synthesising reviews offers a comprehensive understanding of the core competencies required to effectively use AI in an educational setting by consolidating fragmented findings found across different studies. By incorporating Dutch insights, an exploratory comparison can be made with the competencies identified in the literature to provide the Dutch education sector with a clear indication of which competencies to focus on as they prepare their students and educators for a technological future.

The goal of this study is to identify AI literacy competencies that should be included in an AI literacy framework for the Dutch education sector.

#### **Theoretical Framework**

#### The Evolution of Education in the Age of AI

The Organisation for Economic Cooperation and Development (OECD) (2019) defines AI as "a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments" (para.5). Using AI in education is not a new concept. In fact, it has been around since 1991 when educators started using tutoring systems that automatically adapted to a students' learning needs (Pantelimon et al., 2021). Since then, education has evolved and transformed from a "push" system that delivers knowledge to a "pull" system that is technology-enabled where students actively seek information (Fisher, 2024). By utilizing AI in the classroom, educators can offer personalised education tailored to the needs of the student. Increasing student motivation and allows educators to better understand the teaching process. Enabling educators to be more effective as they have access to data about student performance, progress, abilities, and learning strategies (Rouhiainen, 2019).

By incorporating AI into education, there is an opportunity to make education more inclusive, accessible, and offer quality education to students around the world (Harry & Sayudin, 2023). Currently, educators and students can use AI in a variety of ways. Some educators use it for automated grading, administrative tasks, and feedback (University of Iowa, 2024) while others use it for personal development and reflective feedback (Harmer, 2024). Some educators also engage with AI as a collaborator, complimenting

their emotional intelligence with the analytical skills of AI. Enabling educators to offer personalised education while AI analyses student performance and tracks their progress (Haoyang & Towne, 2025). In certain cases, educators are beginning to integrate AI tools in their classrooms to, for example, generate instructional content, or to create assessments – prompting the need for increased AI literacy skills such as prompt engineering and responsible use.

Students can use AI as a personal tutor to understand complex topics, use it to summarise articles or, use AI tools to recommend or fix programming code. Furthermore, students may use AI tools to help structure assignments (Wun & En, 2025). In some cases, students use Microsoft Copilot to rephrase difficult or confusing text into more understandable language. Some elementary school children use "Reading Coach" to practice reading and speaking at home, while others use AI to better understand math problems (Ray, 2024). Currently, there is a variety of tools and programs available to students to suit their specific learning needs. It is important that educators and students use these resources effectively and responsibly. To achieve that, they will require AI literacy.

## AI Literacy Explored

Al literacy refers to the competency to use Al at home, work, and at school. Utilising it for critical evaluation and collaboration while applying it to real-life situations (Kong et al., 2024). Traditionally, literacy was seen as a persons' ability to read and write (Ng et al., 2021b). However, in this new era of intelligence, a combination of literacies are needed to participate in society, of which Al literacy has become important (Ng et al., 2021a). The term Al literacy, introduced by Kandlhofer et al. (2016), framed it as essential knowledge of Al concepts and techniques. The author continued that Al literacy will emerge as an important 21st century skill and stressed the need for users to have basic knowledge of Al-driven technologies. Al literacy education has become important for users of all ages and is no longer a skill limited to computer scientists. In some cases, students are required to not only use Al technologies, but also use it, for example, when problemsolving (Ng, Su, et al., 2024). In addition, the job landscape is evolving and influenced by Al which will require employees to demonstrate a decent understanding of Al (Zootzky & Pfeiffer, 2024). On the other hand, Al developments require educators to be active participants in the processes that conceptualises and leads to Al tools aimed at students.

Professional educator programs help educators understand the ethics of AI and how to use it effectively in their classrooms (Du et al., 2024). This requires educators to foster a critical co-discovery mindset that focusses on AI literacy, equipping educators with critical skills needed to incorporate AI in their classrooms (Dilek et al., 2025).

It is therefore important to prepare educators and students by providing them with AI knowledge and skill to prepare them for future employment (Ng, Su, et al., 2024). This can be achieved by equipping students with AI literacy so they are able to demonstrate their ability to use AI properly and responsibly (Yetisensoy & Rapoport, 2023). Npuls (2025), a Dutch collaborative program for vocational, university of applied sciences, and research universities defines AI literacy as: "the knowledge, skill, and attitude needed to engage effectively and critically with AI systems in various contexts" (para. 5)

#### The Role of Education in AI Literacy

Teaching students how to use AI effectively, but more importantly, how to use it judiciously will play an important role going forward. This also applies to educators and educational institutions as technology and educators will need to work together, operating as partners. This will require training and support to ensure that educators are knowledgeable and comfortable using AI (Haoyang & Towne, 2025). Students and educators alike will need to be able to distinguish between what is real and what is not (Ng et al., 2021b) in a pursuit to create responsible consumers of AI (Lee et al., 2021). In some cases, countries have started this process by introducing AI concepts at all levels of education. Examples of such schemes include the "AI for the future" program in Hong Kong, China, and the DAILy Curriculum introduced in the United States of America, both focusing on teaching secondary school children AI skills (Ng et al., 2022). Using AI in class does however present the educational environment with challenges and opportunities.

Challenges of using AI in an educational setting include overreliance on AI, and the ethical concerns of using it in an educational environment. If students rely on AI to solve problems, it could hinder their ability to use critical thinking. Policy and legislation is in a constant state of development, resulting in instances where students and educators will be able to use AI in ways that is not considered ethical (for example bias, plagiarism, copyright infringement) (British Council, 2025). Additionally, educators and students have varying levels of AI knowledge and how to leverage and implement the available tools (Zhou et al., 2024). Fear and hesitation surrounding AI is another significant barrier

(Gonzales, 2024). On the other hand, AI offers several advantages for education. In the right environment, AI can boost higher order skills, streamline research capabilities, and restructure and enhance the learning process (Zhou et al., 2024). An example includes the facilitation of personalised learning.

As AI becomes part of everyday life, education will play a vital role in preparing users at different stages of their learning. The goal is to prepare future professionals to use and harness the power of AI as they tackle global challenges. This require appropriate skills, knowledge, and the right mindset (Kong et al., 2024). This can be achieved in many ways, but by utilizing a framework to achieve learning goals will offer the necessary scaffolding needed to assist students in their pursuit to construct meaningful knowledge systems (Yale Poorvu Center for Teaching and Learning, n.d). An AI literacy framework would therefore be a suitable tool as a starting point to increasing AI literacy among students and educators.

#### **AI Literacy Frameworks and Their Competencies**

One of the reasons to use a framework is to help educators translate learning goals and integrate them into classroom activities (Mazohl, 2018). These frameworks outline the skills and behaviours needed to effectively use AI, and how to evaluate AI generated content (Olari & Romeike, 2021). By using a framework, educators have the structure and guidance needed to support their students in their pursuit to understanding complex topics such as AI (Young, 2008). In an educational setting, a carefully designed framework can serve as the cornerstone for building everything else, and is customised to fit an institution's vision, values, curriculum, and the needs of the students (Shala, 2018).

Currently, many variations of AI literacy frameworks are available, laying the foundation on which AI literacy can be built (Faruqe et al., 2022), but no standardised AI literacy framework is available (Olari & Romeike, 2021; Schüller, 2022). Some of these include for example the ED-AI Lit (Allen & Kendeou, 2023), the four A's AI literacy framework (Druga et al., 2021), AI literacy – a framework to understand, evaluate and use emerging technology (Lee et al., 2024), and the AI literacy framework for higher education (Pretorius & Cahusac de Caux, 2024). Organisations such as UNESCO have contributed by designing AI competency frameworks for both students and educators.

These AI literacy frameworks feature similar competencies, but do not match completely. The ED-AI Lit framework for example focusses on six competencies that

include "knowledge" (understanding how AI works), "evaluation" (critically evaluate AI), "collaboration" (communicate and collaborate with AI), "contextualization" (using AI as a tool in real-world settings), "autonomy" (self-governance in choices and actions) and "ethics" (addressing moral issues surrounding AI) (Allen & Kendeou, 2023). The framework proposed by Lee et al. (2024) focusses on three competencies and proposed "understand" (acquire basic knowledge), "evaluate" (consider the cost/benefit of AI), and use (interact and problem-solve with AI). UNESCO (2024a) suggests focussing on the competencies human-centred mindset, ethics of AI, AI application and techniques, and Al system design when educating students. For educators, UNESCO (2024b) suggests focussing on human-centred mindset, ethics of AI, AI application and techniques, AI system design, AI pedagogy, and AI for personal development. These diverse competencies could lead to confusion as educators and students are unsure which competencies are required to use AI effectively and responsibly. In addition, some AI literacy frameworks are not evidence-based or assessed with validated measures that align with research and behavioural competencies. These AI literacy frameworks are valuable, but do not reach their full potential due to the lack of rigor (Faruqe et al., 2022). A standardised, evidence-based AI literacy framework would be able to offer educators and students more clarity.

#### The Current Study

Al literacy is a topic that is currently in the spotlight, receiving a significant amount of attention. A comprehensive synthesis of the findings will contribute to current knowledge by revealing definitively which AI literacy competencies are required by educators and students alike. Furthermore, there has been very little research on AI literacy from a Dutch education perspective. According to Generation AI (2025), a Dutch project aiming to anticipate the influence of the European strategy for AI, and the implementation of AI into primary and secondary education, there is not much research on this topic in the Netherlands. To address this gap, this study aims to identify AI literacy competencies by means of an umbrella review and explore how these identified competencies align with the Dutch educational perspective. By doing so, a set of competencies will immerge, revealing which competencies are required by educators and students to effectively use AI. Furthermore, this study will synthesise and consolidate the results, highlighting overlaps and context-specific competencies. This study will

contribute to the development of an AI literacy framework from a Dutch educational context. Either in the form of two separate AI literacy frameworks for educators and students, or as a single AI literacy framework that is applicable to both groups.

This research aims to answer the following research questions:

**RQ 1:** Which competencies should be included in an AI literacy framework for Dutch students and educators?

**RQ 1a:** Which competencies do Dutch stakeholders view as essential to Al literacy?

#### Method

This study is part of a larger research project conducted by Npuls – a Dutch collaborative program for vocational, university of applied sciences, and research universities that, for example, focusses on developing standards, digital proficiency, and digital learning resources. The aim of the study conducted by Npuls is to develop an AI literacy framework for Dutch higher education, and to develop interventions for students and educators to develop themselves in a data and AI driven world. The Npuls study takes a broad look at AI literacy by investigating reviews from the education sector and other sectors such as healthcare. This study exclusively included reviews related to the education sector.

The method section will follow a qualitative approach that is divided into two phases. Phase one consists of an umbrella literature review to answer RQ1 while phase two includes a research world café to answer RQ1a. An umbrella review was chosen for this study as it provides an overview assessment of existing information on AI literacy as the literature search revealed that multiple reviews were available on the topic of AI literacy. Synthesising the information would provide an overview of current knowledge. A research world café was chosen as it allows for group discussion and collaborative knowledge creation with the aim of recording a Dutch perspective on AI literacy and the competencies that required to be considered AI literate.

## Phase One: Umbrella Literature Review:

The review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) statement approach (Page et al., 2021) (see Figure 1) and includes four stages: data collection, data selection, data extraction, and data synthesis.

#### Data Collection

As part of the larger Npuls study, a literature search was conducted in November 2024 by searching for relevant literature in four databases: Web of Science (n = 551), ERIC (n = 35), Scopus (n = 1852), and PsychInfo (n = 51). These databases were selected as they regularly feature articles related to education. To perform the umbrella literature review, it was important to determine what the scope would be, and which keywords should be included in the search strategy. To assist in this process, a scoping search was performed to identify possible keywords related to artificial intelligence, literacy, and reviews. In addition to the scoping search, a thesaurus was checked to identify synonyms, an information specialist was consulted, and expert opinions were collected. A search was conducted using a search strategy (see appendix A) which produced 2308 search results. The search strategy included terms related to artificial intelligence, skills and competencies, and types of reviews.

#### Data Selection

Data selection included a series of steps. In step one, the results from all database searches were combined into one file and duplicates were removed (n = 43). It was decided to remove all conference proceedings (n = 151) as only peer-reviewed journal articles were included, and finally all results without an abstract (n = 16) were removed as abstracts were evaluated for suitability in the next step. A total of 1792 abstracts remained for further review as part of the Npuls study.

In step two, abstracts were reviewed with the help of the inclusion criteria. This study adhered to six strict inclusion criteria while the Npuls study only adhered to the first five criteria. Studies that did not meet the criteria, were not included. The inclusion criteria included: (1) the full text should be available in Dutch or English; (2) the article should be a review, and the method should be explained in the method section; (3) the article should at the very least explain AI literacy or related concepts (competencies, skills, attitudes, knowledge, ability, or expertise); (4) the purpose of the article should be to review AI literacy or related concepts or include results that lead to AI literacy indicators (AI literacy or related concepts should be mentioned in the research question, or it should be a goal); (5) the literature should be published between 2016 and 2025 as the term AI literacy was introduced in 2016 (Ng et al., 2022); (6) the article should be aimed at education levels (only relevant to this study).

In step three, the research team reviewed abstracts with the use of ASReview, an open-source machine learning platform that facilitates the systematic screening and labelling of large textual datasets. In the first phase, the SAFE procedure was used which consists of four elements that include screening a random set for training, applying active learning, use a different model to find more matches, and finally evaluation of the quality (Boetje & van de Schoot, 2024). A subset of 18 abstracts (1% of 1792) were labelled manually by members of the Npuls research team in two teams of three to train the machine learning model. In the second phase, the Naïve Bayes classifier was used to predict relevant abstracts. The Npuls research team independently labelled abstracts as either relevant or irrelevant. By training the model with relevant and irrelevant abstracts, abstracts presumed to be relevant were constantly moved to the top. Reviewing stopped when 50 consecutive abstracts were deemed not relevant to this study. Initially, 412 abstracts were screened of which 100 were included for full paper review. To ensure that relevant articles were not mistakenly added to the final set due to the first phase, the Sentence BERT with Fully connected neural network was added as machine learning model in ASReview (Boetje & van de Schoot, 2024). A further 60 abstracts were reviewed of which one extra abstract was deemed relevant. In total, 472 abstracts were reviewed of which 101 articles moved to the next step that was full text screening.

In step four, the full texts were screened by members of the Npuls research team with the help of Covidence systematic review management software. Each article was reviewed by two members of the team. In cases where the reviewers did not agree, the article was discussed by the Npuls research team and a final decision was made. After reviewing the full texts, 40 articles remained.

In step five, the quality of the remaining 40 articles were checked by using the Joanna Briggs Institute's (JBI) critical appraisal tool for systematic reviews (Aromataris et al., 2015). Only the first nine criteria on the checklist were used as the last two were not relevant to this review. The criteria used in this study can be found in appendix B. Articles were evaluated by two independent reviewers. Their notes were compared, and disagreements were solved by discussing the article with the research group which led to a final decision on the rating. Articles that scored a minimum of six out of nine ( > 70%) were considered high quality, while articles that scored a minimum of five out of nine (between 50% and 70%) were considered as having medium quality. In both cases,

articles were included in the final set. Articles that scored less than five out of nine ( < 50%) were considered lower quality and were not included in the final set. These threshold scores were based on articles published by Glasgow et al. (2020) and Kundu et al.(2024). After performing the quality check, a total of 31 articles remained of which 15 (see appendix C) were analysed and included in this review.

## Figure 1





#### **Data Extraction**

A codebook was constructed to guide the systematic extraction of relevant information from the selected articles (see appendix D).

A data extraction form was created in Covidence to extract relevant information from the included articles. Data extraction occurred twice for each article, performed by two independent members of the research team. Data extraction forms were compared and discussed by the research group. The extraction form included items such as the definition of AI used, the target group, the education level, and the AI literacy competencies discussed. The complete data extraction form can be found in appendix E. Data extracted was recorded in Excel. By utilizing a thematic analysis, AI literacy competencies were identified and categorised. The first step was to code the group competencies into preliminary groups based on the terminology and descriptions used by the authors. For this step, an inductive approach was used. By using this approach, categories emerged from the dataset as opposed to being pre-imposed. Once the dataset was coded, recurring concepts were identified and thematically clustered into broader, more abstract categories to reflect the main competency domains. In the next step, an iterative categorisation of the competencies was used to refine and merge overlapping concepts and competencies. By using these steps, a more coherent synthesis of competencies was possible.

## Phase 2: Research World Café:

#### Purpose

A "world café" is an exploitative data collection method that is utilized within qualitative research. Experts are brought together in a workshop setting, rotating between multiple discussion tables, each dedicated to a specific aspect of the overall topic. A "world café" stimulates knowledge sharing and collaborative dialogue (Schiele et al., 2022). This method was used to explore and add to the findings of the umbrella review with the purpose of developing a context specific framework that is useful in practice.

## Procedure

For this phase, data was collected at two research world café session organized by the Npuls research team. At both sessions, AI literacy and AI literacy competencies were explored for both students and educators. Participants received an introductory presentation explaining the purpose of the café and what topics would be covered. All participants were asked to sign an informed consent form, and they were informed that audio will be recorded at each of the discussion tables.

Participants were requested to visit each of the three discussion tables for a period of 30, 25, and 15 minutes to discuss a topic related to AI literacy. Each table was provided with a blank poster and pens, allowing groups to record their findings on the same page. A moderator was either present or appointed by the group, at each discussion table to help guide the discussion.

Once a participant joined a discussion table, they were asked to write down their initial thoughts on the AI literacy topic discussed at that table, without conversing with the other participants. With the help of the table moderator, the topic was discussed within the group and participants could share their initial notes. During the student café, moderators were self-appointed students while the moderators at the educator café were members of the Npuls research team and the lecturer of the course. The group, in collaboration with the moderator, took notes and structured discussion points according to themes such as competencies for students and educators.

Once time ran out, participants were requested to visit one of the other discussion tables where the process was repeated with a new AI literacy related topic. Once participants joined a table, they were asked to reflect on the notes made by the previous group, marking comments they agreed with or deemed important. This was done by adding a sticker (during the student café) or a star (during the educator café) next to the statement to show importance.

Topics covered at each of the discussion tables relevant to this study were:

Table 1: What is AI literacy?

Table 2: What constitutes AI literacy for students and teachers (i.e. indicators)?

Table 3: What is the university doing to stimulate AI literacy in teachers and students? (Only applicable to the educator café).

Artifacts and documents produced during the world café were recorded and documented for analysis. These included participant-created posters and recordings made at each discussion table. The recordings were transcribed for analysis.

#### **Participants**

Sixteen MSc Educational Science students and 22 educators/policy advisors/support staff/education designers from a Dutch university participated in the

world café sessions in 2025. Students took part in the café as part of an official MSc Educational Science, course where attendance was mandatory (participation in the café was voluntary), while university staff were invited to voluntarily join a café organised on campus. University staff were invited via email and placeholders in their digital calendar. To stimulate attendance from university staff, some program directors were approached with additional information to stimulate their team to join the café. Participants in the research world cafés had varying roles, but ultimately only represented a small percentage of staff and students from one Dutch university.

#### **Data Extraction**

An inductive strategy was followed to extract relevant data collected during both research world cafés. A series of steps were followed to prepare artefacts for data extraction. In step one, the audio recordings were transcribed with the help of Otter.AI, an AI tool that transcribes audio to text. In step two, the transcriptions were uploaded to Atlas.ti, an online tool used for the analysis and coding of qualitative data. An analysis was conducted to identify commonalities and patterns, highlighting and extracting AI literacy competencies mentioned at each of the discussion tables. A codebook ( appendix F) was created to consolidate details and to create a clear summary of the AI literacy competencies identified. Examples of codes identified include knowledge, bias, ethics, and skill. As some of the AI literacy competencies discussed during the research world café were written down on post its as opposed to discussing them explicitly, the posters generated during the sessions were also consulted to extract further AI literacy competencies to complete the codebook.

Data was analysed and coded independently. While no inter-coder reliability check was conducted, steps were undertaken to ensure methodological rigor. This was done by means of a transparent coding process with clear documentation of the coding process. In addition, cross-referencing between the recordings and posters was used to enhance the credibility of the results. Although an additional coder would have been desirable, there is a risk that reliability is simply based on "interpretative convergence", as suggested in a paper by O'Connor and Joffe (2020). There is no guarantee that coders reach consensus on codes without being influenced by other coders, ultimately influencing transparency.

A synthesis of AI literacy competencies for education.

#### Results

#### Phase 1: Literature Synthesis

In phase one, RQ1 is addressed by performing an umbrella review to identify AI literacy competencies.

## **Overview of Studies**

A total of 15 articles were examined for this umbrella review which included 53% systematic reviews (n = 8), 33% scoping reviews (n = 5), 7% integrative literature reviews (n = 1), and 7% critical reviews (n = 1) (appendix C). Articles covered in this review focussed on higher education (n = 1), teacher education (n = 1), high school education (n=1), primary school education (n = 1), K-16 education (n = 1) a movement in the United States of America that aims to align K-12 and higher education systems to improve career readiness (Kearney et al., 2024), K-12 education (n = 7), early childhood education (n = 1), and higher and adult education (n = 1). 10 of the selected articles utilized selection and reporting guidelines set out by PRISMA (Page et al., 2021). Articles included in this review were published between 2021 and 2024.

#### **Conceptualizing AI literacy**

All selected articles (n=15) referred to the term "Al literacy" when referring to the action of learning/developing Al knowledge or skill. In addition to Al literacy, four articles included other terms such as Al education (Liu & Zhong, 2024; Sperling et al., 2024), Al thinking (Sperling et al., 2024), Al readiness (Sperling et al., 2024), Al knowledge (Yue et al., 2022), and Al teaching and learning (Ng et al., 2022) to compliment the term "Al literacy". In 12 of the 15 selected articles Al literacy was defined. The most common definitions used in the text were definitions by Ng et al (2021b), Long and Magerko (Long & Magerko, 2020b), or a combination of both. In three articles another definition was used (Casal-Otero et al., 2023; Liu & Zhong, 2024; Yim & Su, 2024). Long and Magerko (Long & Magerko, 2020b) define Al literacy as "a set of competencies that enables individuals to critically evaluate Al technologies; communicate and collaborate effectively with Al; and use Al as a tool online, at home, and in the workplace (defining Al literacy section, para 2). Ng et al (2021a) define Al as a combination of knowing, understanding, and evaluating Al, and the consideration of ethical issues. An overview of the selected articles, the definition, and terms used in the text is available in table 1.

A synthesis of AI literacy competencies for education.

Та	bl	e	1

Definitions and terms used in the selected articles

Article	Definition source	Al literacy term	Additional terms
(Yim & Heung, 2024)	/	Alliteracy	
(Ng et al., 2022)	(Long & Magerko, 2020a,	Alliteracy	AI teaching and learning
	2020b; Ng et al., 2021a)		
(Lee & Kwon, 2024)	/	Alliteracy	
(Liu & Zhong, 2024)	(Liu & Zhong, 2024)	Al literacy	Al education
(Wolters et al., 2024)	(Long & Magerko, 2020b)	Alliteracy	
(Casal-Otero et al., 2023)	(Long & Magerko, 2020a;	Alliteracy	
	Miao et al., 2021)		
(Yim & Su, 2024)	(Miao et al., 2021;	Alliteracy	
	Vuorikari, 2022; Wang &		
	Cheng, 2021)		
(Su, Ng, et al., 2023)	(Long & Magerko, 2020a,	Alliteracy	
	2020b; Ng et al., 2021a)		
(Laupichler et al., 2022)	(Long & Magerko, 2020a;	Alliteracy	
	Ng et al., 2021a)		
(Bosarge, 2024)	/	Alliteracy	
(Sperling et al., 2024)	(Long & Magerko, 2020a)	Al literacy	Al readiness, Al
			education, Al thinking
(Yue et al., 2022)	(Long & Magerko, 2020a)	Al literacy	
(Brandão et al., 2024)	(Long & Magerko, 2020a;	Al literacy	
	Ng et al., 2021a)		
(Su, Guo, et al., 2023)	(Long & Magerko, 2020a;	Al literacy	
	Ng et al., 2021a)		
(Cheung et al., 2024)	(Ng et al., 2021a)	Alliteracy	

*Note.* This table provides an overview of the AI literacy definitions used in the selected articles. It shows which sources were used to construct these definitions. Additionally, it shows the terms used to describe the action of learning/developing AI knowledge or skill.

#### **AI Literacy Competencies**

The AI literacy competencies identified in this review include knowledge (n = 15), attitude (n = 12), skill (n = 12), ethics (n = 10), data literacy (n = 1), basic understanding of AI (n = 10), bias (n = 2), computational thinking (n = 5), design, development, and evaluation (n = 1), systems thinking (n = 1), collaboration (n = 3), critical thinking and problem-solving (n = 3), soft skills (n = 1), creative thinking (n = 1), limitations (n = 2), programming code (n = 2), interdisciplinary and transdisciplinary content knowledge (n = 1), AI techniques and concepts (n = 1), motivation to learn about AI (n = 4), positive attitude (n = 2), confidence (n = 2), AI readiness (n = 2), trust (n = 1), societal impacts (n = 10) and coding, robotics, and hardware (n = 1). Appendix G provides an overview of the competencies with a definition while appendix H provides an overview of the competencies identified in each of the articles.

Most of the education levels, including teacher education, stressed the importance of knowledge, attitude, basics and foundations of AI (related to knowledge), skill, and ethics as important competencies to be considered AI literate.

Considering the frequency these competencies were identified; one might consider these the core competencies of AI literacy. Furthermore, one could argue that the remaining competencies identified are related to one another, based on the competency one gains or develops, and could be clustered together. As the core competencies were most prominent, it was logical to use those four competencies to help group the remaining competencies. Competencies were grouped according to thematic and functional relevance. By grouping the competencies, a coherent structure is created that highlights the interconnectedness between the identified competencies. In addition, when defining AI literacy in the future, one could argue the importance of referring. to the competencies knowledge, attitude, skill, and ethics

#### Knowledge

The articles included in this review make the following arguments for knowledge as an important AI literacy competency. Yim and Heung (2024) proposes the importance of *interdisciplinary and transdisciplinary content knowledge*. Referring to the integration of methods and concepts from a mix of disciplines, boosting a users' knowledge of AI applications. *Basic and foundational AI knowledge*, for example, what machine learning is and how it works, and deep learning principles, are discussed as an important aspect of AI literacy by Yim and Heung (2024), Ng et al. (2022), Lee and Kwon (2024), Liu and Zhong (2024), Wolters et al. (2024), Yim and Su. (2024), Su et al. (2023), Laupichler et al. (2022), Sperling et al. (2024), Brandão et al. (2024), and Su et al. (2023). Wolters et al.(2024) and Sperling et al. (2024) stresses the importance of understanding the *limitations of AI* to boost knowledge, which can include the inability to recognize the limitations of machine learning, for example. Casal-Otero et al. (2023) and Yim and Su (2024) emphasises the importance of equipping students with the knowledge to recognise AI artifacts by fostering an understanding *AI techniques and concepts* through discussion, simulations, or experiments. This approach helps students comprehend AI algorithms, machine learning, and the identification of AI patterns. Lee and Kwon. (2024) and Sperling et al. (2024) discusses the importance of teaching *programming code*, such as Python. Yim & Heung (2024) identified *data literacy* as an important competency of AI literacy which refers to the knowledge and understanding of how computers learn from data.

## Attitude

The included review highlights the following arguments for attitude as an important AI literacy competency. Yim and Su. (2024), Ng et al. (2022), Lee and Kwon (2024), Wolters et al. (2024) suggests that successful AI teaching is dependent on *motivation to learn about AI*. Lee and Kwon (2024) proposes the importance of engaging students in creative work with the use of AI tools to foster a *positive attitude* towards AI. The authors continue by underlining competition and collaboration as an effective tool to engage students in AI activities to influence their attitude towards AI. Wolters et al. (2024) proposes using a persons' *attitude* and understanding of AI as motivation to enhance AI literacy. Casal-Otero et al. (2023) and Sperling et al. (2024) suggests that an educators' *attitude* towards AI has a significant impact and influence on their ability to use AI in their classroom. Bosarge et al. (2024) and Yim and Su (2024) stress the importance of *confidence* when using AI, creating a positive experience. Lauplicher et al. (2022) and Sperling et al. (2024) highlights the importance of *AI readiness*, referring to an user's perceived preparedness to use AI in their work and personal life, as an important motivator.

## Skill

Articles included in this review proposed the following indicators for skill as an important competency for AI literacy. Su et al. (2023)Yim and Hueng (2024), Liu and Zhong

(2024) Yim and Su (2024) and Lee and Kwon (2024) highlight computational thinking using computer science principles to formulate and solve problems – as a foundational skill for developing problem-solving abilities, logical reasoning, and ultimately, AI literacy. Yim and Hueng (2024) emphasises the role of creative thinking in designing engaging and effective AI literacy learning experiences. By using ones creativity in combination with technology could lead to innovation and increased AI literacy. Yim and Hueng (2024), Casal-Otero et al. (2023) and Lee and Kwon (2024) discuss the importance skill of critical thinking and problem-solving to explore real-world issues regarding AI. Ng et al. (2022) and Sperling et al. (2024) highlights collaboration with AI and/or peers as an important skill for students by engaging them in AI projects. Yim and Su (2024) refer to the acquisition of soft-skills such as feedback and communication as an important skill students learn when they engage in human-computer collaboration. By engaging with AI, students learn how to better collaborate with peers or how to provide feedback on AI generated artifacts. Bosarge et al. (2024) emphasises coding, and robotics and hardware integration as important skills that will assist in the development of technical and problem-solving skills, by teaching students how to code in Python, for example. Using the code to facilitate hands-on learning to program robots as part of the learning. Wolters et al. (2024) discussed the skill of design, develop, and evaluate with AI, referring to the ability to look at a problem from various angles, testing and fixing problems as you learn. Liu and Zhong (2024) suggest system thinking is an important AI competency as it requires students to actively use various elements that include system function and structure aesthetics, and how they interact.

## Ethics

The included articles in this review discussed the following aspects of ethics with regards to AI literacy. Yim & Hueng (2024), Lee & Kwon (2024), Casal-Otero et al (2023), Yim and Su (2024), Lauplicher et al. (2022), Bosarge et al. (2024), Yue et al. (2022), Brandão et al. (2024), Cheung et al. (2024) and Su et al. (2023) discusses *ethics* as an important competency for AI, referring to the ethical and societal issues students and educators will face while using AI. By focussing on ethics, students and educators will have the opportunity to explore the possible impact of AI on their daily lives. Lauplicher et al. (2022) and Yim and Su (2024) discuss the importance of understanding *bias* as an ethical consideration of AI, referring to possible algorithmic biases that exclude groups of

people for example, or the creation of discriminatory content based on available data. Finally, Brandão et al.(2024) proposes *trust* as an important competency for educators, referring to the fact that educators have to trust that AI can be a possible force in their classrooms.

One could argue that ethics is part of knowledge, attitude, or skill. Formulating it as a separate entity is however important. It is not guaranteed that a person with vast AI knowledge and skill will use it ethical. As Wiese et al. (2025) argues, teaching AI ethics is complex. It requires critical thinking and an understanding of the sociotechnical consequences of technology while much is still unknown about AI ethics. Putting it in its own category to stress its importance is therefore critical.

#### Educator vs. Student

Figure 2 provides an overview of each education level, and the competencies identified in those studies. Furthermore, it illustrates in which of the four core competency cluster each competency is grouped. The review included two articles that focussed specifically on teacher education (Brandão et al., 2024; Sperling et al., 2024), while the remaining 13 articles focused on a series of education levels aimed at students, or students and educators.

It is notable that knowledge, attitude, skill, and ethics were most prevalent in most of the education levels and teacher education reviews, aptly referred to as the core competencies. In addition, it is important to mention that this study includes a high representation of K-12 education (n = 7), which provides a relatively clear indication of the competencies important for K-12 AI literacy.

The review revealed an overlap between the AI literacy competencies deemed important for students and educators which is demonstrated in figure 3. Competencies related to educators are coded blue, while competencies for students are coded green. In cases where competencies were regarded relevant for both students and educators, the competency was coded blue/green.

## Figure 2

Education levels and their AI literacy competencies clustered according to the four core competencies



This visual representation of the identified competencies revealed that seven competencies were unique to a specific group. This does not mean that these competencies are not important to other groups, but in this review, they were not found in all the included articles. These included:

- 1. Trust (teacher education) trusting what was produced by Al.
- 2. System thinking (K-12) how different parts of a system works together.
- 3. Soft skills (K-12) personal attributes that enables interaction.
- Coding, robotics, and hardware (High school) understanding code and hardware.
- Design, develop, and evaluate (High school) creation, evaluation and evaluation of what was created.
- Creative thinking (Primary school) looking at problems from a fresh perspective.
- 7. Data literacy (Primary school) exploring and interacting with data.

Based on these results, one could argue that there are not many differences in the competencies required by students and educators, but that the specific context influences what should be learned. To engage high school students, for example, the level of difficulty will need to be adjusted to ensure engagement.

## Figure 3

Proposed AI literacy competencies to be included in an AI literacy framework.





*Note.* Competencies identified for students are colour coded green, while those identified for educators are coded blue. Competencies relevant to both students and educators are coded green/blue. Competencies with an asterisk were only identified during the research world cafés

#### Phase 2: Research World Café

The aim of the research world café was answer RQ1a and to get a Dutch perspective on AI literacy by performing an exploratory comparison. Matching the results found in the umbrella review with those found during the research world cafés and possibly highlighting competencies not discussed in the literature. The cafés were conducted at a Dutch university, ultimately revealing AI literacy competencies from a higher education perspective. The recordings and posters from the research world café sessions were coded and organised according to themes. The codebook is available in appendix G.

#### **AI Literacy Defined**

During the café organized for educators/policy makers/support staff, 22 participants were asked to define AI literacy. The following answers were recorded during the discussion. Some participants stressed the importance of knowing why you need AI literacy, defining the scope and context before working on a definition for AI literacy. Participants started by defining AI literacy as the ability to understanding what AI is, and what it is not. Another aspect discussed by participants was that AI literacy was an awareness of the ethical implications, risks, and limitations of AI. The ability to formulate prompts was another aspect mentioned. Furthermore, participants defined AI literacy as having a set of AI knowledge and skill to effectively use AI tools and programs. Knowledge and skill were also identified in the review phase of this research. Attitude and ethics were not explicitly mentioned during the café.

#### Al Literacy Competencies Identified

An inductive analysis was utilised to identify patterns and similarities discussed during both the student and educator cafés. Results from both cafés were analysed and combined to consolidate the data collected into one coherent overview. It is noteworthy that the competencies identified during the research world cafés either deal with knowledge, attitude, skill, or ethics – once again stressing the importance of these four competencies. As with the umbrella review, competencies could be arranged according to these four core competencies. Table 2 provides an overview of the competencies identified during the research world cafés.

## Table 2

Educators	Students			
Knowledge				
Basic AI knowledge *	Basic AI knowledge			
Limitations of Al	Limitations of Al			
Attitude				
	Self-efficacy			
Skill				
	Creating, evaluating, and			
Co-create *	analysing			
	Collaboration			
	Critical thinking			
	Al recognition *			
	Prompt engineering *			
Ethics				
Bias	Bias			
Ethics *	Ethics *			
	Trust			

Competencies identified during both research world cafés

*Note*. Items with an asterisk represent the items participants considered most important.

## Students

The importance of basic AI knowledge was discussed by participants, referencing the importance of "knowing what AI is, and what it is not". Suggesting a need for a foundational understanding of AI concepts such as being able to recognise when AI was used. Furthermore, it was established that it was important to understand the limitations of AI. Participants discussed the significance of being aware of the capabilities and constraints of AI and being able to leverage AI in an effective manner within the boundaries with one participant noting "...and then they have to all know the capabilities and limitations of AI in order to use it...".

Self-efficacy, the belief in one's own ability, was discussed as an important attitude to have when using AI. Participants discussed the importance of knowing your own abilities and how to improve or utilise AI effectively, with one participant highlighting "self-assessment" as an important element of self-efficacy,

Creating, evaluating, and analysing was mentioned as an important skill to have with participants discussing the value of being able to create with AI, the ability to evaluate your work and improve on it, and finally, analysing the outcomes of what was produced to determine success. One participant referred to this skill as a "higher level" skill that requires self-reflection and being able to determine which information is useful to make adjustments that improves your work. Participants continued by referencing the importance of collaboration when utilising AI. This collaboration could be between humans, or humans and AI. One participant suggested using AI as a collaborator to discuss ideas to create more clarity or to develop an idea further. In addition to collaboration, it was suggested that critical thinking was an important skill when working with AI. Students should be able to question, evaluate, and reflect on AI generated content. This could include critically reflecting on the algorithmic decisions or reflecting on the sources used by the AI. One participant argued the importance of critical thinking by arguing that "...So then critically evaluate what comes out of it, no matter how you use it, even if you're just using it for the most basic things...", while another participant added "...critically assess the output, tools, methods, risks...". Recognising AI is another skill students discussed that refers to the ability to identify when AI technology is used. This is a fundamental skill of AI literacy as students can only critically evaluate AI if they are aware that they are either interacting with it, or viewing Al generated content. Participants highlighted this skill bY discussing the importance of identifying, for example, AI generated pictures and to acknowledge that they have been modified with AI. Finally, prompt engineering was identified as an important AI literacy skill, referring to the ability to effectively interact with AI systems such as natural language models like ChatGPT. The discussion alluded to the importance of being able to craft an appropriate prompt to get the most relevant answers from AI. The ability to engineer the most effective prompt is not only a technical skill, but in some regards also a strategic communications skill.

The ethics of AI is an AI literacy competency that refers to the ability to identify and reflect on the moral and societal impact of AI. A topic that was highlighted multiple times during the café and was believed to be an integral part of AI literacy. When considering the ethics of AI, participants discussed topics such as bias and trust. Bias referring to situations where AI produces inaccurate or unfair results because the data it was trained on was flawed. An example of this could be that an AI system favours male students, putting female students at a disadvantage. With regards to trust, it refers to one's ability to evaluate the reliability of what was generated by AI to make an informed decision. A participant used the AI tool, Grammarly, as an example. Explaining that in some cases the

tool will correct grammar but completely change the structure and meaning of the sentence. They continued by explaining that students need to be critical, and judge generated content to determine whether it is meaningful and correct.

#### Teachers

As was the case for students, basic AI knowledge was highlighted as an important AI literacy competency for teachers by the participants of the research world café. Participants discussed that it was important to not only what AI is, but also how to use it properly. Knowing which tools are available and how to leverage them for a specific goal. In addition to basic AI knowledge, participants highlighted the importance of understanding the limitations of AI. Participants discussed the importance of understanding the pros and cons of AI as more and more teachers use AI in their classrooms.

An important skill identified during the café was co-creation, referring to the ability to use AI as a collaborator to produce content and solutions. With effective collaboration between teachers and AI, teachers have the skill and ability to use AI as an extension of their creativity and teaching to enhance the learning experience.

Finally, the ability to understand ethics and biases were discussed as important AI literacy competencies. Participants noted that it was important for educators to understand and be aware of the inherent biases embedded in AI. Furthermore, the participants argued that AI ethics was an important competency to have and that educators should be aware of the societal ethics of using AI.

#### **Educators vs. Students**

In both groups, there is overlap in the competencies identified. Based on the results, students would be required to adopt more competencies than educators. The competencies are however related to one another. An example of this includes the student competency creating, evaluating, and analysing and the educator competency "co-creator". In both instances, educators and students are required to work together with AI to produce and evaluate AI generated content.

A topic of discussion during the research world cafés was the context in which AI is used and learned. Keeping this in mind, an example could include the competency "basic AI knowledge". Basic AI knowledge was identified as an important competency for both students and educators, but the level and depth of knowledge needed will be different for both groups. Educators for example, would receive more in-depth training so they not only know how AI works, but also have enough knowledge to teach students about AI and how to use it effectively.

## **New Competencies Identified**

In addition to the AI literacy competencies identified during the umbrella review, an additional five were discussed and captured during the research world cafés. These new competencies include:

- 1. Co-create (educator competency) creating and collaborating with AI.
- 2. Self-efficacy (student competency) belief in one's own abilities.
- Creating, evaluating, and analysing (student competency) the ability to create with AI, adjusting, and critically evaluating the output.
- 4. Prompt engineering (student competency) crafting effective prompts that deliver the appropriate and desired results.
- 5. Al recognition (student competency) the ability to identify when Al was used.

The new competencies identified during the research world cafés were added to figure 3 to create a comprehensive overview of the competencies identified in both phases of data collection. Competencies unique to the research world cafés can be identified by an asterisk.

#### Review versus research world café

A series of AI literacy competencies were identified in both phases of this study with many overlapping competencies that include basic AI knowledge, limitations of AI, collaboration, critical thinking, bias, creating, evaluating, and analysing (like design, develop, and evaluate), and AI ethics. The review phase did however identify some competencies that were not discussed during the research world cafés. Some of these include computational thinking, system thinking and data literacy. A full overview can be found in Figure 3.

#### Discussion

The purpose of this study was to identify AI literacy competencies that could be included in an AI literacy framework for the Dutch education sector by means of an umbrella review and a research world café approach. Knowledge, attitude, skill, and ethics were found to be the most important competencies educators and students should learn in their pursuit to become more AI literate.

While identifying competencies was the goal of this study, it became clear that using a single term and defining AI literacy important. It became clear that several definitions and terms for AI literacy was being used. The definitions by Long and Magerko (2020a) and Ng et al. (2021a) were most frequently used in articles included in the review. These authors use complex language to define AI literacy and as a result, these definitions might not be suitable for all age groups. Using a standardised AI literacy definition could contribute to more consistency and prevent misunderstandings. A well-crafted definition is one that is easy to understand and does not need additional explanation. Examples of such definitions includes the definitions by Npuls (Npuls, 2025) or IBM (Gomstyn & Jonker, 2025).

As no standardised definition is currently available, it is important to use a definition that makes most sense for the target audience. If you are teaching university students about AI, a definition with more complex language could be appropriate while another definition might be more appropriate for primary school students.

#### AI Literacy Competencies

Knowledge, attitude, skill, and ethics were labelled in this study as core competencies. These results have a degree of overlap with the OECD developed AI literacy framework which outlines the knowledge, attitude, and skill students require to be considered AI literate. Furthermore, the OECD framework aims to enrich learning environments with a variety of subjects such as the ethical and societal impact of AI (OECD Education and Skills Today, 2025). The UNESCO AI literacy framework developed for teachers, focusses on mindset, ethics, AI foundations and applications (skills and knowledge), AI pedagogy, and AI professional development (UNESCO, 2024c). Again, a degree of overlap is present with the educator AI competencies identified in this study.

While the OECD and UNESCO frameworks include knowledge, attitude, skill and ethics as important AI literacy competencies - the present study proposes an additional

layer by including a subset of competencies. The four core competencies are complimented by these AI competencies identified in both phases of data collection. The Centre for Innovation, Design, and Digital Learning (CIDDL) suggests teaching AI literacy according to grade levels. The author continues by stating that a lot of focus is on machine learning for example, but that the topic might not be appropriate at all age levels (Seung, 2023). This suggests that a level of customisation and personalisation is needed when selecting AI literacy competencies for a specific group.

Two articles included for review focussed specifically on educators. Although a small number of AI literacy competencies were identified in these articles and during the research world café, it does not mean that educators need to acquire less competencies. A study conducted by Li et al. (2025) found that currently both students and educators have varying levels of AI literacy which made teaching and learning about AI more challenging. The authors continue by suggesting that more training and support is needed for both groups. Future research could focus specifically on educators to help identify more relevant competencies for this group.

#### Competency mix

Becoming AI literate means acquiring appropriate AI competencies at a suitable intellectual level. This might require a level of customisation. The idea of customising AI learning is supported by Chee et al. (2024) who agrees that the AI literacy competencies taught should be tailored to match the learning level. The four core competencies can be used as a starting point, and by adding competencies from the subset, the learning can be tailored. This interchangeability of the competencies allows for a learning environment that is more engaging.

The concept of customising is applicable to both students and educators. Based on the situation, both groups will have varying levels of AI literacy. Tenberga and Daniela (2024) found that educators with limited computer experience might require additional competencies such as data literacy or critical evaluation. The foundational AI skills and knowledge they require will look different from an educators who is familiar with AI. Similarly, students with less access to computers will likely need to learn more AI competencies as a result of their limited digital skills. According to the Good Things Foundation (2024), a digital inclusion charity, it is important to introduce AI slowly to new users as it could become overwhelming. By leveraging the interchangeability of the AI competencies, educators will be able to customise what is learned. Adjusting the competencies and content being learned to match the student's learning level.

## Scientific and Practical Relevance

Scientifically, this study contributes to the body of research on AI literacy by identifying AI competencies required to be considered AI literate. This study included a research world café methodology with a small Dutch population from one university. By conducting these cafés, exploratory insight was gathered into the Dutch perspective on AI literacy competencies. While the population was small, the results provide a valuable starting point for identifying AI competencies that are relevant in the Dutch context. The interactive nature of the world research cafés allowed for rich conversations that helped identify overarching themes and AI competencies deemed important for students and educators. However, to strengthen the applicability of the findings, a larger and more diverse population would have to be included in future research. This would allow for a more robust understanding of AI literacy competencies in the Dutch context. A qualitative study conducted by Mertala and Fagerlund (2024) in Finland was conducted with a small populations to identify AI misconceptions. Although the results could not be generalised, the findings were based on rich information collected during the data collection phase. The authors argue that the results could lay the foundation for future large-scale studies. Both studies demonstrates that smaller populations can yield valuable, context-specific insights. Studies like these offer a foundational understanding of a topic. The results from the research world café therefore serves as a springboard for future research on the topic.

A key contribution from this study lies in the distinction between core competencies and the subset competencies. While the core competencies offer a foundational structure, the subset competencies enable personalisation and customisation. By utilising this layered structure allows stakeholders to tailor AI literacy to a specific group. For example, both primary school students and higher education students might engage with the same core competencies, but the depth and complexity of the subset competencies will be different. Primary school students will engineer more basic prompts, while higher education students will produce more complex and precise prompts to generate the content they need. An AI literacy framework developed at Stanford University supports this customised concept. Their framework identified core competencies and divided what should be learned into three groups – novice,

36
intermediate, and advanced. A novice would learn the basics of prompting, while the intermediate level focusses on complex prompting (Stanford University, n.d.). This highlights the need for comprehensive and adaptable AI literacy frameworks. Ensuring relevance across diverse educational contexts.

The findings of this study have several practical implications. First, the AI competencies identified can inform the development and improvement of AI literacy curricula across different educational levels. By incorporating the competencies could aid curriculum designers to create more structured and coherent learning pathways. These pathways can be tailored to different age groups, ensuring that AI literacy is not only learned at the correct time, but that it is effectively embedded into existing subjects. In an AI literacy framework for policymakers proposed by Annapureddy et al. (2025), the authors found that embedding AI competencies into educational programs and curriculums could lead to more responsible and informed AI users and creators. By incorporating the competencies identified in this study, curriculum designers might have additional tools to improve AI education in the Netherlands.

Second, the results provide a foundation that policymakers can use to standardise AI literacy guidelines in the Netherlands. Currently, the Dutch government has already taken the first steps in a pursuit to standardise AI in the Netherlands. The government is actively promoting AI literacy among the workforce in an attempt (Digital Government, 2025). By incorporating the AI competencies identified in this study, it could be possible to standardise the skills and knowledge required to be considered AI literate.

Finally, by clarifying what students and educators need to know about AI, could contribute to a broader societal shift. The results could contribute to how AI is taught, understood, and ultimately how it is used daily. This is a notion supported by the OECD who agrees that teaching AI competencies are important in a world that is becoming increasingly digital (OECD Education and Skills Today, 2025). AI is changing how we participate in the world, and it is vital that students and educators know how to navigate this change effectively.

#### **Limitations and Future Research**

This review was limited to studies available via the ERIC, Web of Science, Scopus, and PsychInfo databases published between 2016 and 2024. By excluding other databases and by searching within a specific timeframe, other relevant articles could have been excluded from this review. Additionally, the included studies defined AI literacy in different ways which might have influenced how AI literacy competencies were identified and categorised. Future research could expand the search by searching other databases and timeframes for relevant articles. It is also recommended to use a standardised definition of AI literacy to ensure consistency and accuracy when identifying articles. Articles possibly excluded from this study can potentially highlight other competencies important to AI literacy.

The research world café provided valuable qualitative insight into the competencies Dutch educators/administrators and students valued most, but the results are limited to two small respondent groups from one Dutch university. These two groups provide an initial exploratory view on AI literacy in the Dutch context, but the results cannot be regarded as the national view as the population was too small and diverse. A diverse group can add richness to the collected information but influences the depth of the discussion. Future research could expand on the research world café idea and include multiple groups of respondents across multiple universities. A larger population would provide a clearer idea of the AI literacy competencies deemed important by Dutch educators/administrators and students. By doing so, one might be able to validate the results found in the umbrella review. It is also recommended to cluster similar respondents together to ensure that the collected information is not only rich but represents that specific group of people. For example, a research world café can be organised for only policy advisors. By grouping similar respondents together, one would be able to get a clearer idea of what AI literacy means to that specific group. It could very well be that curriculum designers and policymakers consider different AI competencies important.

ASReview was used to screen articles. While the active learning algorithm helps to streamline the reviewing process, there is a risk that relevant articles were excluded if the algorithm did not recognise it as relevant. To minimise this in future research, it is suggested to manually screen a small selection of the articles to ensure that relevant articles are not excluded.

#### Conclusion

This review set out to identify AI literacy competencies for the Dutch education sector for both students and educators based on existing literature and qualitative

38

insights collected at research world cafés. Both phases identified a variety of relevant competencies, but knowledge, attitude, skill, and ethics were the most common competencies identified. It became clear that these competencies could be regarded as the core competencies, providing the foundation to which other related competencies could be clustered to. Furthermore, the results show that a diverse set of competencies are required to be considered AI literate, and that the competencies required at different educational levels were similar. This also applied to educators where the identified competencies were in many respects like those identified for students. It was revealed that the context in which AI literacy was to be learned would determine the mix of competencies and students required a mix of competencies that are based on technical and content knowledge, while keeping the importance of ethics in mind.

#### References

- Al4edu. (2024). UNESCO's Al competency frameworks: Equipping educators and students for the age of Al. Al4edu. <u>https://ai4edu.eu/2024/11/12/unescos-ai-</u> competency-frameworks-equipping-educators-and-students-for-the-age-of-ai/
- Alagar, R. (2025). *The foundation of Artificial Intelligence*. Skillfloor. <u>https://skillfloor.com/blog/the-foundation-of-artificial-intelligence</u>
- Allen, L. K., & Kendeou, P. (2023). ED-AI Lit: An Interdisciplinary Framework for AI Literacy in Education. *Policy Insights from the Behavioral and Brain Sciences*, *11*(1), 3-10. <u>https://doi.org/10.1177/23727322231220339</u>
- Almatrafi, O., Johri, A., & Lee, H. (2024). A systematic review of AI literacy conceptualization, constructs, and implementation and assessment efforts (2019–2023). *Computers and Education Open*, 6, 100173. https://doi.org/10.1016/j.caeo.2024.100173
- Annapureddy, R., Fornaroli, A., & Gatica-Perez, D. (2025). Generative Al Literacy: Twelve Defining Competencies. *Digital Government: Research and Practice*, 6(1), 1-21. <u>https://doi.org/10.1145/3685680</u>
- Aromataris, E., Fernandez, R., Godfrey, C. M., Holly, C., Khalil, H., & Tungpunkom, P. (2015). Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. *Int J Evid Based Healthc*, *13*(3), 132-140. <u>https://doi.org/10.1097/XEB.0000000000055</u>
- Boetje, J., & van de Schoot, R. (2024). The SAFE procedure: a practical stopping heuristic for active learning-based screening in systematic reviews and meta-analyses. *Systematic Reviews*, *13*(1), 81. <u>https://doi.org/10.1186/s13643-024-02502-7</u>
- \*Bosarge, E. (2024, June 2024). Cultivating tomorrow's innovators: Navigating the landscape of high school AI literacy. ASEE Annual Conference & Exposition, Portland, Oregon.
- Brandão, A., Pedro, L., & Zagalo, N. (2024). Teacher professional development for a future with generative artificial intelligence – an integrative literature review. *Digital Education Review*(45), 151-157. <u>https://doi.org/10.1344/der.2024.45.151-157</u>
- British Council. (2025). AI in education: how to navigate the opportunities and challenges. <u>https://internationalschools.britishcouncil.org/blog/ai-in-education-how-to-navigate-the-opportunities-and-challenges</u>
- Cambridge Dictionary. (2025a). *Bias*. Cambridge Dictionary. https://dictionary.cambridge.org/dictionary/english/bias
- Cambridge Dictionary. (2025b). *Collaboration*. Cambridge dictionary. https://dictionary.cambridge.org/dictionary/english/collaboration
- Cambridge Dictionary. (2025c). Soft skills. Cambridge Dictionary. https://dictionary.cambridge.org/dictionary/english/soft-skills
- Carter, A. G., Creedy, D. K., & Sidebotham, M. (2016). Efficacy of teaching methods used to develop critical thinking in nursing and midwifery undergraduate students: A systematic review of the literature. *Nurse education today*, *40*, 209-218. <u>https://doi.org/https://doi.org/10.1016/j.nedt.2016.03.010</u>
- \*Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: a systematic literature review. *International Journal of STEM Education*, 10(1), 29. <u>https://doi.org/10.1186/s40594-023-00418-7</u>

- Chee, H., Ahn, S., & Lee, J. (2024). A Competency Framework for Al Literacy: Variations by Different Learner Groups and an Implied Learning Pathway. *British Journal of Educational Technology*. <u>https://doi.org/10.1111/bjet.13556</u>
- \*Cheung, K. K. C., Long, Y., Liu, Q., & Chan, H.-Y. (2024). Unpacking Epistemic Insights of Artificial Intelligence (AI) in Science Education: A Systematic Review. *Science & Education*, 1-31. <u>https://doi.org/10.1007/s11191-024-00511-5</u>
- Chiu, T. K. F., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. *Computers and Education Open*, 6, 100171. https://doi.org/https://doi.org/10.1016/j.caeo.2024.100171
- Collings Dictionary. (2025). *Limitation*. Collins Dictionary. https://www.collinsdictionary.com/dictionary/english/limitation
- Davies, L., & Uhles, K. (2022). Understanding systems thinking concepts and workplace applications. University of Phoenix. <u>https://www.phoenix.edu/blog/what-is-</u> systems-

thinking.html#:~:text=A%20systems%20thinker%20is%20someone,formula%20 or%20a%20linear%20approach.

- Davis, T. (2025). *Positive Attitude: Definition, Examples, & Strategies*. Berkeley Well-Being Institute. Retrieved 12 April from <u>https://www.berkeleywellbeing.com/develop-positive-attitude.html</u>
- Digital Government. (2025). *Government Expands Position on Use of Generative AI*. Digital Government. <u>https://www.nldigitalgovernment.nl/news/government-expands-position-on-use-of-generative-ai/</u>
- Dilek, M., Baran, E., & Aleman, E. (2025). Al Literacy in Teacher Education: Empowering Educators Through Critical Co-Discovery. *Journal of Teacher Education*. https://doi.org/10.1177/00224871251325083
- Druga, S., Yip, J., Preston, M., & Dillon, D. (2021). The 4As: Ask, adapt, author, analyze-AI literacy framework for families. *The MIT Press eBooks* 193-232. https://doi.org/https://doi.org/10.1162/ba67f642.646d0673
- Du, H., Sun, Y., Jiang, H., Islam, A. Y. M. A., & Gu, X. (2024). Exploring the effects of Al literacy in teacher learning: an empirical study. *Humanities and Social Sciences Communications*, *11*(1), 559. <u>https://doi.org/10.1057/s41599-024-03101-6</u>
- Eguchi, A., Okada, H., & Muto, Y. (2021). Contextualizing AI Education for K-12 Students to Enhance Their Learning of AI Literacy Through Culturally Responsive Approaches. *KI - Künstliche Intelligenz : German Journal of Artificial Intelligence -Organ des Fachbereichs "Künstliche Intelligenz" der Gesellschaft für Informatik* e.V., 35(2), 153-161. <u>https://doi.org/10.1007/s13218-021-00737-3</u>
- Faruqe, F., Watkins, R., & Medsker, L. (2022). Competency Model Approach to Al Literacy: Research-Based Path From Initial Framework to Model [Article]. Advances in Artificial Intelligence And Machine Learning, 02(04), 580-587. https://doi.org/10.54364/aaiml.2022.1140
- Fisher, B. (2024). The evolution of education: from push to pull in an AI-driven world. Tulane University. <u>https://thrilling-single-644.notion.site/The-Evolution-of-Education-From-Push-to-Pull-in-an-AI-Driven-World-12934ce6c96f802bba70da7132b83565</u>

- Generation AI. (2025). *AI and education in the Netherlands; where are we?* Generation AI. Retrieved 22 January from <u>https://generation-ai.eu/nl/ai-and-education-in-the-netherlands-where-are-we%EF%BF%BC/</u>
- Glasgow, M. J., Edlin, R., & Harding, J. E. (2020). Comparison of risk-of-bias assessment approaches for selection of studies reporting prevalence for economic analyses. *BMJ Open*, *10*(9). <u>https://doi.org/10.1136/bmjopen-2020-037324</u>
- Gomstyn, A., & Jonker, A. (2025). *AI literacy: Closing the artificial intelligence skills gap.* IBM. <u>https://www.ibm.com/think/insights/ai-literacy</u>
- Gonzales, S. (2024). *AI literacy and the new Digital Divide A Global Call for Action*. UNESCO. <u>https://www.unesco.org/en/articles/ai-literacy-and-new-digital-divide-global-call-action</u>
- Good Things Foundation. (2024). *Developing AI Literacy With People Who Have Low Or No Digital Skills*. Good Things Foundation. Retrieved 15 May from <u>https://www.goodthingsfoundation.org/policy-and-research/research-and-</u> <u>evidence/research-2024/ai-literacy</u>
- Haoyang, D. L., & Towne, J. (2025). *How AI and human teachers can collaborate to transform education*. World Economic Forum. https://www.weforum.org/stories/2025/01/how-ai-and-human-teachers-can-collaborate-to-transform-education/
- Harmer, C. (2024). Can you use GenAI as a tool for teacher development. Cambridge University. <u>https://www.cambridge.org/elt/blog/2024/10/16/can-you-use-genai-as-a-tool-for-teacher-development/</u>
- Harry, A., & Sayudin, S. (2023). Role of AI in Education. *Interdiciplinary Journal and Hummanity (INJURITY)*, 2(3), 260-268. <u>https://doi.org/10.58631/injurity.v2i3.52</u>
- Haseski, H. I., Ilic, U., & Tugtekin, U. (2018). Defining a New 21st Century Skill-Computational Thinking: Concepts and Trends. *International Education Studies*, *11*(4), 29-42.
- Heyder, T., & Posegga, O. (2021). Extending the foundations of AI literacy. International conference on information systems, Austin.
- Kandlhofer, M., Steinbauer, G., Hirschmugl-Gaisch, S., Huber, P., & Conference, I. F. i. E. (2016). Artificial intelligence and computer science in education: From kindergarten to university. In 2016 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). <u>https://doi.org/10.1109/FIE.2016.7757570</u>
- Kearney, C. A., Fensken, M., & Dupont, R. (2024). The K-16 education movement: common themes across K-12 and higher education systems to inform development and evaluation. *Frontiers in Education*, 9. <u>https://doi.org/10.3389/feduc.2024.1272297</u>
- Kong, S.-C., Korte, S.-M., Burton, S., Keskitalo, P., Turunen, T., Smith, D., Wang, L., Lee, J. C.-K., & Beaton, M. C. (2024). Artificial Intelligence (AI) literacy – an argument for AI literacy in education. *Innovations in Education and Teaching International*, 1-7. <u>https://doi.org/10.1080/14703297.2024.2332744</u>
- Kulik, R. (2025). Social issues. Brittanica. <u>https://www.britannica.com/topic/social-issue</u>
- Kundu, A., Sultana, N., Felsky, D., Moraes, T. J., Selby, P., Chaiton, M., & Alhajj, M. N. (2024). An overview of systematic reviews on predictors of smoking cessation among young people. *Plos one*, 19(3). <u>http://dx.doi.org/10.1371/journal.pone.0299728</u>

- \*Laupichler, M. C., Aster, A., Schirch, J., & Raupach, T. (2022). Artificial intelligence literacy in higher and adult education: A scoping literature review. *Computers and Education: Artificial Intelligence*, 3, 100101. <u>https://doi.org/10.1016/j.caeai.2022.100101</u>
- Lee, I., Ali, S., Zhang, H., DiPaola, D., & Breazeal, C. (2021). *Developing Middle School Students' AI Literacy* Proceedings of the 52nd ACM Technical Symposium on Computer Science Education, Virtual Event, USA. https://doi.org/10.1145/3408877.3432513
- Lee, K.-w., Mills, K., Ruiz, P., Coenraad, M., Fusco, J., Roschelle, J., & Weisgrau, J. (2024, 18 June 2024). *AI literacy: A framework to understand, evaluate, and use emerging technology*. Digital Promise. <u>https://digitalpromise.org/2024/06/18/ai-</u> <u>literacy-a-framework-to-understand-evaluate-and-use-emerging-</u> <u>technology/#:~:text=Innovative%20Learning%20Schools-</u> <u>,AI%20Literacy%3A%20A%20Framework%20to%20Understand,Evaluate%2C%2</u> <u>Oand%20Use%20Emerging%20Technology&text=AI%20literacy%20includes%20</u> <u>the%20knowledge,in%20an%20increasingly%20digital%20world</u>.
- \*Lee, S. J., & Kwon, K. (2024). A systematic review of AI education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes. *Computers and Education: Artificial Intelligence*, 6. <u>https://doi.org/10.1016/j.caeai.2024.100211</u>
- Li, H., Xiao, R., Nieu, H., Tseng, Y.-J., & Liao, G. (2025). "From Unseen Needs to Classroom Solutions": Exploring AI Literacy Challenges & Opportunities with Project-Based Learning Toolkit in K-12 Education. *Proceedings of the AAAI Conference on Artificial Intelligence*, *39*(28), 29145-29152. <u>https://doi.org/10.1609/aaai.v39i28.35187</u>
- \*Liu, X., & Zhong, B. (2024). A systematic review on how educators teach Al in K-12 education. *Educational Research Review*, 45. <u>https://doi.org/10.1016/j.edurev.2024.100642</u>
- Long, D., & Magerko, B. (2020a). What is AI literacy? Competencies and design considerations. Proceedings of the 2020 CHI conference on human factors in computing systems.,
- Long, D., & Magerko, B. (2020b). *What is AI Literacy? Competencies and Design Considerations* Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA. <u>https://doi.org/10.1145/3313831.3376727</u>
- Mazohl, P. (2018). Why do we use frameworks in education? <u>https://www.fade-in.eu/web/it/why-to-use-frameworks-in-education/</u>
- Merriam-Webster Dictionary. (2025a). *Attitude*. Merriam-Webster Dictionary. https://www.merriam-webster.com/dictionary/attitude
- Merriam-Webster Dictionary. (2025b). *Ethic*. Merriam-Webster Dictionary. https://www.merriam-webster.com/dictionary/ethic
- Merriam-Webster Dictionary. (2025c). *Knowledge*. Merriam-Webster Dictionary. <u>https://www.merriam-webster.com/dictionary/knowledge</u>
- Merriam-Webster Dictionary. (2025d). *Skill*. Merriam-Webster Dictionary. https://www.merriam-webster.com/dictionary/skill
- Merriam-Webster Dictionary. (2025e). *Trust*. Merriam-Webster Dictionary. Retrieved 28 March from <u>https://www.merriam-webster.com/dictionary/trust</u>

- Mertala, P., & Fagerlund, J. (2024). Finnish 5th and 6th graders' misconceptions about artificial intelligence. *International Journal of Child-Computer Interaction*, 39, 100630. <u>https://doi.org/https://doi.org/10.1016/j.ijcci.2023.100630</u>
- Miao, F., Holmes, W., Huang, R., Zhang, H., & Unesco. (2021). *AI and education : Guidance for policymakers*. UNESCO Publishing.
- Mohamed, A. M., Shaaban, T. S., Bakry, S. H., Guillén-Gámez, F. D., & Strzelecki, A. (2024). Empowering the Faculty of Education Students: Applying Al's Potential for Motivating and Enhancing Learning. *Innovative Higher Education*. <u>https://doi.org/10.1007/s10755-024-09747-z</u>
- \*Ng, D. T. K., Lee, M., Tan, R. J. Y., Hu, X., Downie, J. S., & Chu, S. K. W. (2022). A review of Al teaching and learning from 2000 to 2020. *Education and Information Technologies*, 28(7), 8445-8501. <u>https://doi.org/10.1007/s10639-022-11491-w</u>
- Ng, D. T. K., Leung, J. K. L., Chu, K. W. S., & Qiao, M. S. (2021a). Al Literacy: Definition, Teaching, Evaluation and Ethical Issues. *Proceedings of the Association for Information Science and Technology*, 58(1), 504-509. <u>https://doi.org/10.1002/pra2.487</u>
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021b). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence*, *2*, 100041. <u>https://doi.org/10.1016/j.caeai.2021.100041</u>
- Ng, D. T. K., Su, J., Leung, J. K. L., & Chu, S. K. W. (2024). Artificial intelligence (AI) literacy education in secondary schools: a review. *Interactive Learning Environments*, *32*(10), 6204-6224. <u>https://doi.org/10.1080/10494820.2023.2255228</u>
- Ng, D. T. K., Wu, W., Leung, J. K. L., Chiu, T. K. F., & Chu, S. K. W. (2024). Design and validation of the AI literacy questionnaire: The affective, behavioural, cognitive and ethical approach. *British Journal of Educational Technology*, 55(3), 1082-1104. <u>https://doi.org/10.1111/bjet.13411</u>
- Npuls. (2025). Definitie van AI-geletterdheid: Vooruitgang in het umbrella review onderzoek. Npuls Communityplatform AI en Data. <u>https://www.scribbr.nl/bronvermelding/generator/mappen/mb6YMe9DJU8ZMwQ</u> gspgBe/lijsten/3UMBmFjMcPA7NPmy3jU1Lr/
- O'Connor, C., & Joffe, H. (2020). Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. *International Journal of Qualitative Methods*, 19. <u>https://doi.org/10.1177/1609406919899220</u>
- OECD. (2019, 11 June 2019). Artificial Intelligence in Society. OECD. https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0449
- OECD Education and Skills Today. (2025). *New AI Literacy Framework to Equip Youth in an Age of AI*. OECD Education and Skills Today. <u>https://oecdedutoday.com/new-ai-literacy-framework-to-equip-youth-in-an-age-of-ai/?utm\_source=chatgpt.com</u>
- Olari, V., & Romeike, R. (2021). Addressing AI and Data Literacy in Teacher Education: A Review of Existing Educational Frameworks The 16th Workshop in Primary and Secondary Computing Education, Virtual Event, Germany. https://dl.acm.org/doi/pdf/10.1145/3481312.3481351?casa\_token=CCKR8XzoW xoAAAAA:P0YYgb5KenbFq90eG1eXY9AEk3YW7v2r08lksTy7VIcoHKSuqvdmXXL8 Hw-S8iMQ9DoDqwADN7\_d
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., & Brennan, S. E. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, 372.

- Pantelimon, F.-V., Bologa, R., Toma, A., & Posedaru, B.-S. (2021). The Evolution of Al-Driven Educational Systems during the COVID-19 Pandemic. *Sustainability*, *13*(23), 13501. <u>https://doi.org/10.3390/su132313501</u>
- Pouget, A., Drugowitsch, J., & Kepecs, A. (2016). Confidence and certainty: distinct probabilistic quantities for different goals. *Nature neuroscience*, *19*(3), 366-374. <u>https://doi.org/10.1038/nn.4240</u>
- Pretorius, L., & Cahusac de Caux, B. (2024). The AI literacy framework for higher education: A grounded theory exploration of the foundational, social, conceptual, ethical, and affective domains of AI literacy.
- Ray, S. (2024). Smart ways students are using AI. Microsoft. https://news.microsoft.com/source/features/work-life/smart-ways-studentsare-using-ai/
- Rouhiainen, L. (2019). *How AI and data could personalize higher education*. Harvard Busienss Review. <u>https://hbr.org/2019/10/how-ai-and-data-could-personalize-higher-education</u>
- Schiele, H., Krummaker, S., Hoffmann, P., & Kowalski, R. (2022). The "research world café" as method of scientific enquiry: Combining rigor with relevance and speed. *Journal of business research*, 140, 280-296. <u>https://doi.org/10.1016/j.jbusres.2021.10.075</u>
- Schüller, K. (2022). Data and AI literacy for everyone. *Statistical Journal of the IAOS*, 38(2), 477-490. <u>https://doi.org/10.3233/sji-220941</u>
- Seung, Y. (2023). Teaching AI Literacy in K-12 Education Part Two: Recommendations by Grade Levels. CIDDL. <u>https://ciddl.org/teaching-ai-literacy-in-k-12-education-part-two-recommendations-by-grade-levels/?utm\_source=chatgpt.com</u>
- Shala, C. (2018). *What is an educational framework?* Retrieved 27/09/2024 from https://shala-books.com/education-blog/what-is-an-educational-framework
- Shelton, P. (2024). Redefining Readiness: Higher Education's Role in an AI World How Higher Education Can Bridge the Gap Between Human Talent and Machine Intelligence for the Workforce of Tomorrow University of Maine at Farmington]. https://scholarworks.umf.maine.edu/honors\_theses/21/
- Slot, E. (n.d). *Multi-, inter-, and transdisciplinarity; what is what?* University of Utrecht. Retrieved 12 April from <u>https://www.uu.nl/en/education/educational-</u> <u>development-training/knowledge-dossiers/interdisciplinary-education-and-</u> <u>cel/multi-inter-and-transdisciplinarity-what-is-what</u>
- \*Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. Computers and Education Open, 6. <u>https://doi.org/10.1016/j.caeo.2024.100169</u>
- Stanford University. (n.d.). Understanding AI literacy. Stanford University. <u>https://teachingcommons.stanford.edu/teaching-guides/artificial-intelligence-teaching-guide/understanding-ai-literacy?utm\_source=chatgpt.com</u>
- Stobierski, T. (2021). *Data Literacy: An Introduction for Business*. Harvard Business School Online. <u>https://online.hbs.edu/blog/post/data-literacy</u>
- \*Su, J., Guo, K., Chen, X., & Chu, S. K. W. (2023). Teaching artificial intelligence in K–12 classrooms: a scoping review. *Interactive Learning Environments*, 32(9), 5207-5226. <u>https://doi.org/10.1080/10494820.2023.2212706</u>

- \*Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial Intelligence (AI) Literacy in Early Childhood Education: The Challenges and Opportunities. *Computers and Education: Artificial Intelligence*, *4*. <u>https://doi.org/10.1016/j.caeai.2023.100124</u>
- Tenberga, I., & Daniela, L. (2024). Artificial Intelligence Literacy Competencies for Teachers Through Self-Assessment Tools. *Sustainability*, *16*(23), 10386. <u>https://doi.org/10.3390/su162310386</u>
- Terrell Hanna, K. (2025). *Definition code*. TechTarget. <u>https://www.techtarget.com/whatis/definition/code#:~:text=In%20computer%20</u> <u>programming%2C%20computer%20code,i.e.%2C%20the%20object%20code</u>).
- UNESCO. (2024a). Al competency framework for students. UNESCO. https://doi.org/https://doi.org/10.54675/JKJB9835
- UNESCO. (2024b). AI competency framework for teachers. UNESCO. https://doi.org/https://doi.org/10.54675/ZJTE2084
- UNESCO. (2024c). What you need to know about UNESCO's new AI competency frameworks for students and teachers. UNESCO. https://www.unesco.org/en/articles/what-you-need-know-about-unescos-newai-competency-frameworks-students-and-teachers?utm\_source=chatgpt.com
- University of Iowa. (2024). *The role of AI in modern education*. University of Iowa. https://onlineprograms.education.uiowa.edu/blog/role-of-ai-in-moderneducation#:~:text=Teaching%20AI%20literacy%20is%20crucial,will%20help%20 maintain%20academic%20integrity.
- University of South Carolina. (2024). What Is creative thinking? Definition, examples, and how to showcase it during your job search. University of South Caronlina. https://careers.usc.edu/blog/2024/08/05/what-is-creative-thinking-definitionexamples-and-how-to-showcase-it-during-your-jobsearch/#:~:text=Creative%20thinking%20is%20the%20ability,science%20to%20 technology%20and%20education.
- Upwork. (2024). The top 4 AI techniques to know in 2025. Upwork. <u>https://www.upwork.com/resources/ai-</u> <u>techniques#:~:text=What%20are%20AI%20techniques%3F,identify%20patterns</u> <u>%2C%20and%20offer%20predictions.</u>
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). DigComp 2.2: The digital competence framework for citizens – With new examples of knowledge, skills, and attitudes. J. P. Repository.
- Walter, Y. (2024). Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education*, 21(1), 15. <u>https://doi.org/10.1186/s41239-024-00448-3</u>
- Wang, T., & Cheng, E. C. K. (2021). An investigation of barriers to Hong Kong K-12 schools incorporating Artificial Intelligence in education. *Computers and Education: Artificial Intelligence*, 2, 100031. <u>https://doi.org/10.1016/j.caeai.2021.100031</u>
- Wang, X., Li, L., Tan, S. C., Yang, L., & Lei, J. (2023). Preparing for AI-enhanced education: Conceptualizing and empirically examining teachers' AI readiness. *Computers in Human Behavior*, *14*6, 107798.

https://doi.org/https://doi.org/10.1016/j.chb.2023.107798

- Wiese, L. J., Patil, I., Schiff, D. S., & Magana, A. J. (2025). Al ethics education: A systematic literature review. Computers and Education: Artificial Intelligence, 8, 100405. <u>https://doi.org/https://doi.org/10.1016/j.caeai.2025.100405</u>
- \*Wolters, A., Arz Von Straussenburg, A. F., & Riehle, D. M. (2024). AI Literacy in Adult Education-A Literature Review. Proceedings of the 57th Hawaii International Conference on System Sciences, Hawaii.
- Wun, M., & En, N. (2025). *An insider's guide to how students use GenAl tools*. Times Higher Education. <u>https://www.timeshighereducation.com/campus/insiders-guide-how-students-use-genai-tools</u>
- Yale Poorvu Center for Teaching and Learning. (n.d). *Teaching and Learning Frameworks*. YALE.

https://poorvucenter.yale.edu/BackwardDesign#:~:text=Teaching%20and%20lea rning%20frameworks%20provide,they%20learn%E2%80%9D%20(Ambrose%20e t.

- Yasar, K., & Terrel Hanna, K. (2024). *What is robotics*? TechTarget. Retrieved 28 March from <u>https://www.techtarget.com/whatis/definition/robotics</u>
- Yetisensoy, O., & Rapoport, A. (2023). Artificial intelligence literacy teaching in social studies education. *Journal of Pedagogical Research*, 7(3), 100-110. https://doi.org/https://doi.org/10.33902/JPR.202320866
- \*Yim, I. H. Y., & Su, J. (2024). Artificial intelligence (AI) learning tools in K-12 education: A scoping review. *Journal of Computers in Education*, 1-39. <u>https://doi.org/10.1007/s40692-023-00304-9</u>
- \*Yim, Y., & Heung, I. (2024). A critical review of teaching and learning artificial intelligence (AI) literacy: Developing an intelligence-based AI literacy framework for primary school education. *Computers and Education: Artificial Intelligence*, 7. <u>https://doi.org/10.1016/j.caeai.2024.100319</u>
- Young, S. F. (2008). Theoretical frameworks and models of learning: tools for developing conceptions of teaching and learning. *International Journal for Academic Development*, *13*(1), 41-49. <u>https://doi.org/10.1080/13601440701860243</u>
- \*Yue, M., Jong, M. S.-Y., & Dai, Y. (2022). Pedagogical Design of K-12 Artificial Intelligence Education: A Systematic Review. *Sustainability*, *14*(23), 15620. <u>http://dx.doi.org/10.3390/su142315620</u>

Zhou, X., Schofield, L., Zhang, J., Abuelmaatti, A., & Howell, L. (2024). Building bridges in Al: Enhancing Al literacy for students and staff across disciplines. *PGR Student Partners–Empowering doctoral students through partnership and co-creation in institutional equality, diversity and inclusion change projects, 20, 20-23.* <u>https://www.researchgate.net/profile/Xue-Zhou-</u>

19/publication/384291235\_Building\_bridges\_in\_AI\_Enhancing\_AI\_literacy\_for\_st udents\_and\_staff\_across\_disciplines/links/66f2f434869f1104c6b45c50/Building -bridges-in-AI-Enhancing-AI-literacy-for-students-and-staff-acrossdisciplines.pdf

Zootzky, G., & Pfeiffer, A. (2024). Educational transformation through AI: Preparing for a new era of learning. 18th International Technology, Education and Development Conference, Valencia, Spain.

Note. Articles included in the umbrella review can be identified with an asterisk.

# Appendix A

## Search strings

Database	Search string
Eric	(TI "AI" OR AB "AI" OR SU "AI" OR TI "artificial intelligence" OR AB "artificial intelligence" OR SU "artificial intelligence" OR TI "LLM*" OR AB "LLM*" OR SU "LLM*" OR SU "LLM*" OR TI "Large Language Model*" OR AB "Detection of the tearning" OR AB "LLM*" OR SU "LLM*" OR AB "Large Language Model*" OR TI "chatbot*" OR AB "chatbot*" OR SU "chatbot*" OR TI "machine learning" OR AB "machine learning" OR SU "machine learning" OR TI "GenAI" OR AB "GenAI" OR SU "GenAI" OR TI "GAI" OR AB "GAI" OR SU "GenAI" OR TI "GenAI" OR AB "GenAI" OR SU "GenAI" OR TI "GAI" OR AB "GAI" OR SU "GenAI" OR TI "generative AI" OR AB "GenAI" OR SU "GenAI" OR TI "generative AI" OR AB "GAI" OR SU "generative AI" OR AB "G-AI" OR SU "GenAI" OR AB "neural network*" OR SU "neural network*" OR TI "deep learning" OR AB "deep learning" OR SU "deep learning" OR TI "conversational agent*" OR TI "natural Language Processing" OR AB "Natural Language Processing" OR SU "Natural Language Processing" OR AB "Natural Language Processing" OR SU "Natural Language Processing" OR TI "NLP" OR AB "readiness" OR SU "NADD (TI "literac*" OR AB "literac*" OR SU "literac*" OR TI "competen*" OR AB "readiness" OR SU "readiness" OR SU "neatine of TI "skill" OR AB "skill" OR SU "skill" OR TI "attitude" OR AB "attitude" OR AB "digital competen*" OR TI "digital competen*" OR SU "digital competen*" OR TI "digital competen*" OR TI "digital literac*" OR AB "digital literac*" OR TI "digital knowledge" OR TI "digital knowledge" OR SU "digital literac*" OR AB "digital literac*" OR AB "Attitude" OR AB "Attitude" OR AB "digital attitude" OR SU "digital attitude" OR AB "AB "digital Attitude" OR AB "digital Attitude" OR AB "A adtitierac*" OR SU "AI knowledge" OR TI "digital howledge" OR SU "AI knowledge" OR TI "AI skill" OR AB "AI knowledge" OR SU "AI knowledge" OR TI "AI skill" OR AB "AI skill" OR SU "AI knowledge" OR SU "AI knowledge" OR TI "AI skill" OR AB "AI competen*" OR AB "AI co
	(TI "Critical Review" OR AB "Critical Review" OR SU "Critical Review" OR TI "Literature Review" OR AB "Literature Review" OR SU "Literature Review" OR TI "Mapping Review" OR AB "Mapping Review" OR SU "Mapping Review" OR TI "Systematic Map" OR AB "Systematic Map" OR SU "Systematic Map" OR TI "Meta- Analysis" OR AB "Meta-Analysis" OR SU "Meta-Analysis" OR TI "Mixed studies review" OR AB "Mixed studies review" OR SU "Mixed studies review" OR TI "mixed methods Review" OR AB "mixed methods Review" OR SU "mixed methods Review" OR SU "Qualitative Systematic Review" OR AB "Qualitative Systematic Review" OR SU "Qualitative Systematic Review" OR SU "Qualitative Evidence Synthesis" OR AB "Qualitative Evidence Synthesis" OR SU "Qualitative Evidence Synthesis" OR TI "Rapid Review" OR AB "Rapid Review" OR SU "Scoping Review" OR TI "Scoping Review" OR AB "State-of-the-Art Review" OR SU "State-of-the-Art Review" OR TI "Systematic Review" OR AB "Systematic Review" OR SU "Systematic Review" OR TI "Systematic Search and Review" OR AB "Systematic Search and Review" OR SU "Systematic Search and Review" OR TI "Systematized Review" OR AB "Systematized Review" OR SU "Systematized Review" OR TI "Systematic Review" OR AB "Systematized Review" OR AB "Umbrella Review" OR SU "Umbrella Review") AND YR 2016-2025
Scopus	TITLE-ABS-KEY ( "AI" OR "artificial intelligence" OR "LLM*" OR "Large Language Model*" OR "chatbot*" OR "machine learning" OR "GenAI" OR "GAI" OR "G-AI" OR

	"generative AI" OR "neural network*" OR "deep learning" OR "conversational agent*" OR "Natural Language Processing" OR "NLP" ) AND
	TITLE-ABS-KEY ( "literac*" OR "competen*" OR "readiness" OR "skill" OR "attitude" OR "digital competen*" OR "data literac*" OR "digital literac*" OR "digital knowledge" OR "digital attitude" OR "information literac*" OR "AI literac*" OR "AI knowledge" OR "AI skill" OR "AI competen*" OR "AI abilit*" OR "AI expertise" OR "AI attitude" )
	TITLE-ABS-KEY ( "Critical Review" OR "Literature Review" OR "Mapping Review" OR "Systematic Map" OR "Meta-Analysis" OR "Mixed studies review" OR "mixed methods Review" OR "Qualitative Systematic Review" OR "Qualitative Evidence Synthesis" OR; "Rapid Review" OR "Scoping Review" OR "State-of-the-Art Review" OR "Systematic Review" OR "Systematic Search and Review" OR "Systematized Beview" OR "Umbrella Review" ) AND PUBYEAR > 2016 AND PUBYEAR < 2025
Web of Science	TS=("AI" OR "artificial intelligence" OR "LLM*" OR "Large Language Model*" OR "chatbot*" OR "machine learning" OR "GenAI" OR "GAI" OR "G-AI" OR "generative AI" OR "neural network*" OR "deep learning" OR "conversational agent*" OR "Natural Language Processing" OR "NLP") AND
	TS=("literac*" OR "competen*" OR "readiness" OR "skill" OR "attitude" OR "digital competen*" OR "data literac*" OR "digital literac*" OR "digital knowledge" OR "digital attitude" OR "information literac*" OR "AI literac*" OR "AI knowledge" OR "AI skill" OR "AI competen*" OR "AI abilit*" OR "AI expertise" OR "AI attitude") AND
	TS=("Critical Review" OR "Literature Review" OR "Mapping Review" OR "Systematic Map" OR "Meta-Analysis" OR "Mixed studies review" OR "mixed methods review" OR "Qualitative Systematic Review" OR "Qualitative Evidence Synthesis" OR "Rapid Review" OR "Scoping Review" OR "State-of-the-Art Review" OR "Systematic Review" OR "Systematic Search and Review" OR "Systematized Review" OR "Umbrella Review") AND PY=(2016-2024)
PsycINFO	(TI "AI" OR AB "AI" OR DE "AI" OR TI "artificial intelligence" OR AB "artificial intelligence" OR DE "artificial intelligence" OR TI "LLM*" OR AB "LLM*" OR DE "LLM*" OR TI "Large Language Model*" OR AB "Large Language Model*" OR DE "Large Language Model*" OR TI "chatbot*" OR AB "chatbot*" OR DE "chatbot*" OR TI "machine learning" OR AB "machine learning" OR DE "machine learning" OR TI "GenAI" OR AB "GenAI" OR DE "GenAI" OR TI "GenAI" OR AB "GenAI" OR DE "GenAI" OR TI "GenAI" OR AB "GenAI" OR DE "GenAI" OR TI "generative AI" OR DE "GAI" OR TI "generative AI" OR TI "neural network*" OR AB "neural network*" OR DE "neural network*" OR TI "conversational agent*" OR AB "conversational agent*" OR TI "Natural Language Processing" OR AB "Natural Language Processing" OR AB "NALP" OR DE "NLP")
	<ul> <li>(TI "literac*" OR AB "literac*" OR DE "literac*" OR TI "competen*" OR AB</li> <li>"competen*" OR DE "competen*" OR TI "readiness" OR AB "readiness" OR DE</li> <li>"readiness" OR TI "skill" OR AB "skill" OR DE "skill" OR TI "attitude" OR AB "attitude"</li> <li>OR DE "attitude" OR TI "digital competen*" OR AB "digital competen*" OR DE</li> <li>"digital competen*" OR TI "data literac*" OR AB "data literac*" OR DE "data literac*"</li> <li>OR TI "digital literac*" OR AB "digital literac*" OR DE "digital literac*" OR TI "digital</li> <li>knowledge" OR AB "digital knowledge" OR DE "digital knowledge" OR TI "digital</li> <li>attitude" OR AB "digital attitude" OR DE "digital attitude" OR AB "information literac*" OR DE "literac*" OR AB "AI literac*" OR AB</li> </ul>

(TI "Critical Review" OR AB "Critical Review" OR DE "Critical Review" OR TI "Literature Review" OR AB "Literature Review" OR DE "Literature Review" OR TI "Mapping Review" OR AB "Mapping Review" OR DE "Mapping Review" OR TI "Systematic Map" OR AB "Systematic Map" OR DE "Systematic Map" OR TI "Meta-Analysis" OR AB "Meta-Analysis" OR DE "Meta-Analysis" OR TI "Mixed studies review" OR AB "Mixed studies review" OR DE "Mixed studies review" OR TI "mixed methods Review" OR AB "mixed methods Review" OR DE "mixed methods Review" OR TI "Qualitative Systematic Review" OR AB "Qualitative Systematic Review" OR DE "Qualitative Systematic Review" OR TI "Qualitative Evidence Synthesis" OR AB "Qualitative Evidence Synthesis" OR DE "Qualitative Evidence Synthesis" OR TI "Rapid Review" OR AB "Rapid Review" OR DE "Rapid Review" OR TI "Scoping Review" OR AB "Scoping Review" OR DE "Scoping Review" OR TI "State-of-the-Art Review" OR AB "State-of-the-Art Review" OR DE "State-of-the-Art Review" OR TI "Systematic Review" OR AB "Systematic Review" OR DE "Systematic Review" OR TI "Systematic Search and Review" OR AB "Systematic Search and Review" OR DE "Systematic Search and Review" OR TI "Systematized Review" OR AB "Systematized Review" OR DE "Systematized Review" OR TI "Umbrella Review" OR AB "Umbrella Review" OR DE "Umbrella Review") AND

YR 2016-2025

#### Appendix B

# Joanna Briggs Institute critical appraisal checklist for systematic reviews and research synthesis – included criteria

	Question	Yes	No	Unclear	Not Applicable
1	Is the review question clearly and explicitly stated?				
2	Were the inclusion criteria appropriate for the review question?				
3	Was the search strategy appropriate?				
4	Were the sources and resources used to search for studies adequate?				
5	Were the criteria for appraising studies appropriate?				
6	Was critical appraisal conducted by two or more reviewers independently?				
7	Were there methods to minimize errors in data extraction?				
8	Were the methods used to combine studies appropriate?				
9	Was the likelihood of publication bias assessed?				

# Appendix C

#### Articles included in this review

Nr.	Author(s)	Title	Study Type	Education level	Relevant for
1	(Yim & Heung, 2024)	A critical review of teaching and learning artificial intelligence (AI) literacy: Developing an intelligence- based AI literacy framework for primary school education	Critical review	All education levels*	Educators and students
2	(Ng et al., 2022)	A review of AI teaching and learning from 2000 to 2020	Systematic review	K-16	Educators and students
3	(Lee & Kwon, 2024)	A systematic review of Al education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes	Systematic review	K-12	Educators and students
4	(Liu & Zhong, 2024)	A systematic review on how educators teach AI in K- 12 education	Systematic review	K-12	Students
5	(Wolters et al., 2024)	AI Literacy in Adult Education — A Literature Review	Systematic Review	Higher education	Students
6	(Casal-Otero et al., 2023)	AI literacy in K-12: a systematic literature review	Systematic review	K-12	Educators and students
7	(Yim & Su, 2024)	Artificial intelligence (AI) learning tools in K-12 education: A scoping review	Scoping review	K-12	Educators and students
8	(Su, Ng, et al., 2023)	Artificial intelligence (AI) literacy in early childhood education: The challenges and opportunities	Scoping review	Early childhood	Students

A synthesis of AI literacy competencies for education.

9	(Laupichler et al., 2022)	Artificial intelligence literacy in higher and adult education: A scoping literature review	Scoping review	Higher and adult education	Students
10	(Bosarge, 2024)	Cultivating Tomorrow's Innovators: Navigating the Landscape of High School AI Literacy	Systematic review	High school	Educators and students
11	(Sperling et al., 2024)	In search of artificial intelligence (AI) literacy in teacher education: A scoping review	Scoping review	Teacher education	Educators
12	(Yue et al., 2022)	Pedagogical Design of K-12 Artificial Intelligence Education: A Systematic Review	Systematic review	K-12	Educators and students
13	(Brandão et al., 2024)	Teacher professional development for a future with generative artificial intelligence – an integrative literature review	Integrative literature review	Teacher education	Educators
14	(Su, Guo, et al., 2023)	Teaching artificial intelligence in K–12 classrooms: A scoping review	Scoping review	K-12	Educators and students
15	(Cheung et al., 2024)	Unpacking Epistemic Insights of Artificial Intelligence (AI) in Science Education: A Systematic Review	Systematic review	K-12	Educators and students

*Note.* The article by Yim and Heung is aimed at primary school education, but the competencies reveal in research question three is relevant to all educational levels.

# Appendix D

#### Codebook – Umbrella review

Identifiers	Study ID	Record the study ID
	Reviewer 1	Record the name of the first reviewer
	Reviewer 2	Record the name of the second reviewer
	Title	Record the title of the study
	First Author	Record the name of the first author
	Language	In what language is the review
Conceptual focus	Term AI literacy	Record the term/s used to describe AI literacy in the text
	Definition AI literacy	Record the definition of AI literacy used in the text
Methodology	Type of review	Select the type of review.
		Critical Review. An evaluative summary and analysis of a work, assessing strengths, weaknesses, and contributions to its field while providing balanced critique.
		Mapping Review. Provides a broad overview of research activity within a specific topic, highlighting key areas and gaps without a detailed analysis of individual studies.
		Systematic Map. Categorizes and visualizes existing research evidence to illustrate patterns, gaps, and trends across a field.
		Meta-Analysis. Combines quantitative data from multiple studies to statistically evaluate overall effects or relationships.
		Mixed studies review. Review integrates and analyses both qualitative and quantitative evidence within a single synthesis framework.
		Mixed methods review. Review integrates and analyses both qualitative and quantitative evidence within a single synthesis framework.
		Qualitative Systematic review. Review synthesizes qualitative research to develop a deeper understanding of phenomena or experiences.
		Qualitative Evidence Synthesis. Synthesis aggregates qualitative studies to identify patterns, themes, and insights.
		Rapid Review. Delivers an accelerated synthesis of evidence to inform decision-making within a constrained timeframe
		Scoping Review. Maps the breadth of research on a topic, identifying key concepts, evidence, gaps, and research priorities.

		State-of-the-Art Review. Synthesizes the most current and advanced research in a field,
		emphasizing emerging trends and innovations.
		Systematic Review. Provides a comprehensive and methodical synthesis of all relevant research
		on a topic, adhering to rigorous methodological standards.
		Systematic Search and Review. Combines systematic searching methods within narrative
		synthesis to provide a detailed analysis of the literature.
		Umbrella Review. Synthesizes findings from multiple systematic reviews, providing a high-level
	Target group described	overview of evidence across a broad topic.
	Target group described	Indicate the target group the review focusses on
	larget group classification	Indicate the target group. Leachers, students, or non-education
	Educational level	Select an education level. Primary, secondary, vocational, university of applied sciences or
	Freely size a with the	research university, no education, and other.
	Exclusion criteria	Record the exclusion criteria
	Inclusion criteria	Record the inclusion criteria
	Number of included	Record the number of articles included in the study
	articles	
Findings	Indicator 1: Knowledge	Record the indicator knowledge if mentioned and discuss the components
	Indicator 2: Attitude	Record the indicator attitude if mentioned and discuss the components
	Indicator 3: Skill	Record the indicator skill if mentioned and discuss the components
	Indicator 4:	Record any additional indicators and discuss its components
	Indicator 5:	Record any additional indicators and discuss its components
	Indicator 6:	Record any additional indicators and discuss its components
	Indicator 7:	Record any additional indicators and discuss its components
	Indicator 8:	Record any additional indicators and discuss its components
	Indicator 9:	Record any additional indicators and discuss its components
	Indicator 10:	Record any additional indicators and discuss its components
	Notes on indicators	Record any additional notes on indicators relevant to the study
	Notes on dimensions	Record the dimensions of indicators mentioned. For example, different layers, levels, domains, or interpretations
	Notes on the assessment of AI literacy	Record how AI literacy is assessed in the study. Briefly summarize

Notes on the concerns about Al	Record any AI concerns mentioned in the text. Briefly summarize
Notes on ethics for Al	Record whether ethics is mentioned in the text. Briefly summarize
Notes on professionalisation	Record whether professionalisation is mentioned in the text. Briefly summarize
Notes on the factors that influence AI literacy	Briefly indicate whether predictors of AI literacy is mentioned and how it is approached
Notes on the area of application	Briefly discuss. For example - it requires a different approach when using AI for assessment as opposed to applying it to formative practices
Notes on digital literacy vs Al literacy	Briefly explain if the relationship between AI literacy and digital literacy is explored

## Data extraction form

Item	Description
Study ID	
Title	
Reviewer 1	
Reviewer 2	
Title	
First Author	
Language	
Term AI literacy	
Definition AI literacy	
Type of review	
Target group described	
Target group classification	
Educational level	
Exclusion criteria	
Inclusion criteria	
Number of included articles	
Indicator 1: Knowledge	
Indicator 2: Attitude	
Indicator 3: Skill	
Indicator 4:	
Indicator 5:	
Indicator 6:	
Indicator 7:	
Indicator 8:	
Indicator 9:	
Indicator 10:	
Notes on indicators	
Notes on dimensions	
Notes on the assessment of AI literacy	
Notes on the concerns about AI	
Notes on ethics for Al	
Notes on professionalisation	
Notes on the factors that influence AI literacy	
Notes on the area of application	
Notes on digital literacy vs AI literacy	

# Appendix F

## Codebook – Research world café

Indicator	Subset	Explanation	In-text quote	Student/educator indicator	Source
Knowledge		Theoretical or practical understanding of a subject	"knowing what Al is and what it's not"But if I know there's different types for different purposes, then I already have enough knowledge to deepen my knowledge to use what I need to use for my purpose" "have the knowledge about different kinds of AI, the risks, how it works and how to use it"	Student	Recording
			"The last one was they require teachers who are equipped at it, but then that will come there, so we then go into that in depth"	Educator	Recording
			"understanding what AI is and	Student	Poster
			"being able to use AI effectively" "figuring out how to include AI into the curriculum effectively" "structured curriculum of AI literacy for teachers so that they are knowledgeable	Educator	Poster

		in their classroom and also guide their students" "knowing and understanding Al" "technical knowledge"		
Basic Al knowledge	A basic understanding of Al principals	"Basic layer, what is kind of the foundational knowledge and skills and attitudes, maybe what people need" "yeah, efficiently and effectively, I guess, yeah, first of all, like, basic knowledge about it"	Student	Recording
		"teacher side, missing like how to use. Ai, yeah, so I have one knowing and understanding"	Educator	Recording
		"how to learn it. Use un the classroom to teach. How to use it as a companion and not completely rely on it" "teacher literacy - know about the possibilities. What are we able to do and achieve with Al" "base knowledge on how Al works - tools, what and how to use it"	Educator	Poster

Lifelong learning	The practice of gaining new skills and knowledge on a continuous basis	"the one on keeping up to date is, is the is what I framed as a lifelong learning" "lifelong learning, dynamic learning, keeping	Student	Recording
Limitations	An understanding of the pros and cons of Al	"like how to use it properly and understanding Al limitations and stuff" "also this understanding what Al is and what it does" "and then the they have to all know the capabilities and limitations of Al in order to use it"	Student	Recording
		"like how to use it properly and understanding Al limitations" "understanding the capabilities and limitations of Al tools"	Educator	Recording
		"understanding the capabilities and limitations of Al tools" "understand Al	Student	Poster
		understanding the capabilities and limitations of Al tools "understand Al capabilities" "knowing pros and cons of Al"	Educator	Poster

Future use	An understanding of the evolution of Al and that the way it is used will constantly adjust and change	"Yeah, so think about it, yeah. In a broader sense the consequences, right? So maybe, how in your future job would you use AI and for what? Which part will you not use AI" "I think it is more like, when does it make sense to to use it and when not"	Student	Recording
Resource utilization	The ability to leverage available resources to advance AI knowledge and skill	"so we have all of that here, and then we have the second thing, which is the resources. This is more broader things like, Are there enough technological tools available so that students can practice AI are there also maybe like networks so that students can reach out to based on their interests. So these are more the resources that are required" "And then we have the second which is resources which are more on the periphery, at a university level or at a course level, that students need to again, like get adapted using those tools"	Student	Recording

		"technological tools in place to practice" "network of experts" "licences and access to software	Student	Poster
		"understanding how AI can create personal learning experiences" "how to generate higher order thinking among students"	Educator	Poster
Skill	The ability to use knowledge effectively to perform a task	"and then I have a second one more about skills so you can actually do it" "Yeah, I think this one is pretty important, right, being able to use it" "and then we had a few dots, and the main points were that the students have to know how to use AL"	Student	Recording
		"Being able to use AI tools and to structure their work" "Being able to use AI to enhance the quality of their work" "use it as an additional tool, rather tha a replacement"	Student	Poster

		"to use it in different ways, not only for like one thing, but like multiple things, to build a whole, the whole class around AI" "They're able to use it themselves, like, correctly, and able to teach" "for teachers how to learn it use in the classroom to teach content generation, objectives, methods, how to use"	Educator	Recording
		"applying AI"	Educator	Poster
Prompt engineering	The ability to formulate GenAl input to generate Al output	"do I want to have prompt engineering? Good prompting skills is what I wrote down. Prompt engineering is inputs" "prompt engineering, yeah, how to give good input"	Student	Recording
		"Promt engineering - How to get what you are looking for" "guidance on how to effectively use Al tools (e.g. what promsts to use, what tools for what outcome)"	Student	Poster

Critical thinking	The ability to critically evaluate genAl input and output.	"So then critically evaluate what comes out of it, no matter how you use it, even if you're just using it for the most basic things" "critically assess the output, tools,	Student	Recording
Al recognition	The ability to recognise wehther the genAl output generated is true or sound	methods, risks" "So basically, everyone that should then, in that sense, for AI, be able to, at least if they use it for whatever purpose, be aware that this is the responsibility that is not necessarily true it comes out of it to have this critical view on it" "recognizing AI, maybe, like, if there was, like, a picture and it's like, AI, but you don't recognize it, can be kind of a risk. I guess"	Student	Recording
		"how to check the authenticity of the sources generated by AI" "understanding that some info can be wrong and affect results" "recognising AI generated pictures for example - fake information"	Student	Poster

	Creating, evaluating, and analyzing	The ability to create, evaluate and analyse genAl input and output	"remember, creating, evaluating, analyzing. Yes, evaluating and analyzing was kind of like the highest level where you should be able to determine what information is useful and how to how to improve"	Student	Recording
Attitude		A way of thinking or feeling towards a specific idea or concept	"and being Al literate is more like a state of mind, I think. And together with attitude, you can act" "But I think besides knowledge skills, you also need attitudes. I think it's so for example, the critical attitude is a very important one, and also the Lifelong Learning kind of attitudes, because this is going so fast, you have to keep on following, otherwise you stay behind. So attitudes, stuff and to reinforce what you just said is we have to change the work processes the way, the way we work"	Student	Recording
			"Students feeling comfortable using AI tools"	Student	Poster

	Self-efficacy	The confidence in ones own ability to successfully use a tool or participate	"so it's about knowing, but also doing and applying, but also the self efficacy, the self assessment that you know what level you are, but that's maybe an important point of attitudes "	Student	Recording
	Reflection	Serious thought or consideration	"students like, how to, you know, they check the authenticity of the sources, or authenticity of the information given by Al" "also reflect on the outcome of your prompt"	Student	Recording
	Collaboration	Working together with others to achieve a common goal or to produce something	"The last piece of paper that we need AI as a collaborator? Yeah, I mean, it's like, it can be like having a colleague that you bounce ideas off"	Student	Recording
Ethics		A persons moral principals that govern one's behaviour or conduct	"be able to use Al responsibility critically analyze Al output" "also consider ethical aspects of using Al and different tasks" "use of Al, and then there were many sub components, like, what are the risks? What are the ethical uses, privacy, environmental and also critical reflection on	Student	Recording

outputs of Al" "I think like understanding how to use it as an addition rather than a replacement"		
"understanding importance of declaring. But it's also important for teachers. So it's not only students"	Educator	Recording
"understanding how, where, and when to use AI in line with ethical requirements" "knowledge of ethics, how much use its too much" "the importance of declaring AI use" "understanding plagiarism"	Student	Poster
"understanding the ethical impact of using Al" "defyining clear Al assessment policies" "understanding Al policies" "responsible and ethical use of Al - when to use it or not - when and why use which Al"	Educator	Poster

	Trust	A firm belief in the truth or reliability of something or someone	"grammar checks, they are also AI based, yeah. So we tend to trust it pretty easily, spelling mistake, spelling correction, yes. And then the grammar, yeah. Grammarly, we tend to trust, but sometimes it does not. Could also change the meaning of the sentence, right? Yeah"	Student	Recording
	Bias	Prejudice towards a group or person that could be considered unfair	"there are certain groups the population, that are not represented in data sets, so which means that there's going to be a lot of bias" "And I think how to prevent AI bias also kind of fits"	Student	Recording
			"teachers, is a bit more divided and but again, we have kind of limitations and biases, which also falls into the site"	Educator	Recording
			"prevent Al bias"	Student	Poster
Definiting of AI		A descripton of a topic with an exact meaning	"knowing what Al is and isn't. Knowing different types of Al - different pusposes. Responsible use of Al - risks, ethical, privacy, critical reflection"	Student and Educator	Poster

" C " C L	'Al literacy is context- dependent" 'there are different evels/layers"		
r t t t t t t t t t t t t t t t t t t t	'first, understanding that AI doesn't know things, and hence its reliability is questionable. And second, being able to formulate good brompts to get relevant results. And third, being mindful of botential privacy risks" "mine is the knowledge and skills to use AI effectively, ethically and responsibly"	Student and Educator	Recording

## Appendix G

# Competencies and their definitions identified in the umbrella review

Competency	Description	Sample text
Knowledge	Knowing something about a fact or condition with familiarity gained through association or experience (Merriam-Webster Dictionary, 2025c).	Al literacy has grown from data, digital, and scientific literacy into a broad field incorporates knowledge, skills, ideas, and attitudes from a variety of disciplines (Yim & Heung, 2024). The Al literacy priority axes identified experiences where the aim was to gain Al knowledge, understand Al mechanisms, use Al tools effectively, and recognize Al artifacts (Casal-Otero et al., 2023).
Attitude	Feeling or emotion towards state or fact (Merriam-Webster Dictionary, 2025a).	Successful teaching relies on more than just tools, but also on effective teaching methods that engage and motivate students to learn about AI. (Ng et al., 2022)
Skill	One's ability to use knowledge effectively to execute a task (Merriam- Webster Dictionary, 2025d)	The results showed that after engaging with AI activities, children displayed increased creative, collaborative, and emotional inquiry (Su, Guo, et al., 2023). When engaging with AI as a problem- solving process, students must be able to evaluate AI algorithms and strategies to develop effective solutions, utilizing their conceptual understanding and skill to solve problems (Lee & Kwon, 2024).
Ethics	Moral values or moral principles. A set of principles a group or individual adheres to (Merriam-Webster Dictionary, 2025b).	A few teaching units focus on societal and ethical implications of AI. Yue et al. The articles reviewed revealed that responsibility and accountability is regarded as important by the authors (Brandão et al., 2024). AI ethics is considered a critical component (Wolters et al., 2024).
Data literacy	The basic ability to read, understand, and utilize data (Stobierski, 2021).	It is vital to understand how computers learn from data is important for AI literacy. For example, machine learning algorithms will make changes to their internal logic based on the data input to improve its reasoning (Yim & Heung, 2024).

Computational thinking	Helps individuals make active and systematic decisions that are ethical and informed while using ICT (Haseski et al., 2018).	Computational thinking helps students understand AI problem-solving processes (Liu & Zhong, 2024).
Design, develop, and evaluation	Design, develop, and evaluate.	A critical area identified was the design, development, and evaluation of AI artifacts such as robots, interactive AI, or software applications (Wolters et al., 2024).
Systems thinking	Ability to look at complex systems and consider the interdependencies and interconnectedness. Able to think holistically rather than linear (Davies & Uhles, 2022).	Students must actively coordinate different elements which include system function, structure aesthetics, and how they interact (Liu & Zhong, 2024).
Trust	Confidence on the ability, character, truth, or strength of something or someone (Merriam-Webster Dictionary, 2025e).	It is important that teachers understand and trust how they can incorporate AI tools into their teaching. It is important to understand how students use AI and how teachers can intervene when mistakes are made which leads to a higher level of AI literacy (Brandão et al., 2024).
Coding, Robotics and hardware integration	Conception, design, manufacturing, and operation of robots with the objective of creating an intelligent machine (Yasar & Terrel Hanna, 2024)	Improved technical and problem-solving skills can be achieved with the use of robotics and AI (Bosarge, 2024).
Limitations	The act or process of controlling or reducing something (Collings Dictionary, 2025).	The ability to comprehend that AI has limitations. It is important to understand the strengths and weaknesses of AI (Wolters et al., 2024).
Programming code	A set of system rules or instructions in a specific programming language (Terrell Hanna, 2025).	A lack of programming skills can be a barrier to AI learning as students need the hands-on experiences that allows them to play with datasets (Lee & Kwon, 2024).
Al techniques and concepts	Algorithms, methods and data sciences approaches to permit computers to process tasks (Upwork, 2024).	There is a need for teachers to be able to leverage AI techniques to ensure academic success of their students (Casal-Otero et al., 2023).
Interdisciplinary and transdisciplinary content knowledge	Interdisciplinary requires individuals to integrate perspective and insights from various perspectives by interacting with others. Transdisciplinary refers to co- creation between academics and societal partners (Slot, n.d).	Interdisciplinary is important as it prevents the exclusion of societal impacts of AI technology while a transdisciplinary approach includes ethical and cognitive engagement with AI (Yim & Heung, 2024).
Basics and foundations of Al	Basic AI concepts and core principles such as basic knowledge of algorithms, models, and natural language processing (Alagar, 2025).	It is very important to teach students basics AI skills and competencies (Bosarge, 2024).

# A synthesis of AI literacy competencies for education.

Bias	Supporting a person or thing in an unfair way based on influences or personal judgement (Cambridge Dictionary, 2025a).	By designing a robot, students were able to get a better grasp on Al biases (Yim & Su, 2024) (Yim & Su, 2024).
Soft skills	The ability to work together and communicate effectively with others (Cambridge Dictionary, 2025c).	Soft skills are developed when students engage and understand AI (Yim & Su, 2024).
Critical thinking and problem-solving	The process of actively analysing, conceptualising, and evaluation of gathered information (Carter et al., 2016).	The ability to use critical thinking and problem-solving skills allows students to explore real-world societal issues and how AI has an effect on the world (Yim & Heung, 2024).
Creative thinking	Looking at problems or tasks from a new/fresh perspective (University of South Carolina, 2024).	Creativity has the potential to enhance Al literacy in informal environments (Yim & Heung, 2024).
Positive attitude	What others observe in you when you interact with the world or others in a positive manner (Davis, 2025).	Intrinsic motivation to learn about AI is enhanced with a positive attitude (Lee & Kwon, 2024).
Al readiness	The level and state of preparedness in terms of ability, cognition, ethical considerations, and vision on AI (Wang et al., 2023).	It has many similarities to AI literacy, but focusses predominantly on skills, attitude, and knowledge needed to effectively use AI applications (Laupichler et al., 2022).
Confidence	The ability to base a decision or description on the probability that information is correct and based evidence (Pouget et al., 2016).	Hands-on projects increases student engagement and leads to more confidence when using AI (Bosarge, 2024).
Motivation to learn about Al	Motivation to learn affects involvement and interaction with an environment (Mohamed et al., 2024).	Utilising AI tools and programs helps to increases a students' motivation to learn about AI (Lee & Kwon, 2024).
Collaboration	The ability for two or more people to work together to achieve a common goal (Cambridge Dictionary, 2025b).	To effectively engage students in AI, one can use collaboration and competition as a tool (Lee & Kwon, 2024).
Societal issues	A behaviour or condition that negatively impacts an individual or community (Kulik, 2025).	A comprehensive interdisciplinary view on the impact of AI is needed to avoid significant societal impact (Yim & Heung, 2024).
## Appendix G

Overview of the competencies identified in each of the articles included in the umbrella review.

							Αι	ithor/s							
	(Yim & Heung, 2024)	(Ng et al., 2023)	(Lee & Kwon, 2024)	(Liu & Zhong, 2024)	(Wolters et al., 2024)	(Casal- Otero et al., 2023)	(Yim & Su, 2024)	(Su et al., 2023b)	(Laupichler et al., 2022)	(Bosarge, 2024)	(Sperling et al., 2024)	(Yue et al., 2022)	(Brandão et al., 2024)	(Su et al., 2024)	(Cheung et al., 2024)
							Educa	tion sector							
	Primary school	K-16	K-12	K-12	Higher education	K-12	K-12	Early childhood	Higher and adult education	High school	Teacher education	K-12	Teacher education	K-12	K-12
							Con	npetency							
Knowledge Attitude	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Skill	Tes	res	res	165	Tes	res	res	N.	res	res	Tes		res	N/	res
Ethics	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	
Bias	Yes		Yes			Yes	Yes		Yes	Yes		Yes	Yes	Yes	Yes
							Yes		Yes						
Trust													Yes		
Computational Thinking System thinking	Yes		Yes	Yes			Yes	Yes							
Soft skills				100			Yes								
Coding, robotics, and hardware integration Design, develop, and evaluate					Yes					Yes					
Collaboration		Yes	Yes								Yes				

## A synthesis of AI literacy competencies for education.

Critical thinking													
and problem-													
solving	Yes		Yes		Yes								
Creative													
thinking	Yes												
Basics and													
foundations of													
Al													
Limitations				Yes					Yes				
Data literacy	Yes			100					100				
Programming													
code			Yes						Yes				
Interdisciplinary													
and													
transdisciplinary													
content													
knowledge													
Al techniques													
and concepts													
					Yes	Yes							
Motivation to													
learn about Al		Yes	Yes	Yes		Yes							
Positive attitude			Vos			Voc		Voc					
Confidence			163			163		163					
Connucliee						Yes		Yes					
Al readiness							Yes		Yes				
Societal issues	Yes		Yes		Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes