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Empowering K-12 Education with AI
Preparing for the Future of Education and Work

Student AI Literacy and Competency

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> Empower your mind with AI literacy and competency; it's the key to unlocking your potential in a digital world. With the right attitude and skills, you won't just adapt to the future—you'll create it!
>
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2.1 INTRODUCTION

It is crucial for young children to possess a strong grasp of AI knowledge and skills as they will be immersed in educational environments, professional settings, and communities that heavily rely on AI technology. Lack of comprehension of this technology leads to diminished levels of health, safety, productivity, and employability (Casal-Otero et al., 2023; Chiu, 2023; Chiu et al., 2024; Knoth et al., 2024). Therefore, it is important for schools and teachers to understand the specific AI knowledge, skills, and attitudes that K-12 students should possess, which is referred to as AI literacy and competency (Chiu et al., 2024; Long & Magerko, 2020). This includes knowing how to use AI tools effectively, recognizing the ethical implications of AI technology, and being able to critically evaluate the information provided by AI technology. Students are not only competent users of AI technology but responsible and knowledgeable citizens in a society where AI plays an increasingly important role. Teachers and researchers increasingly recognize the value of defining AI literacy and competency (Casal-Otero et al., 2023; Long & Magerko, 2020).

AI literacy is closely linked to AI education, which involves teaching AI knowledge and concepts. On the other hand, AI competency is primarily focused on the use of AI in the field of education, specifically using AI as a tool for teaching. AI literacy guides the learning objectives and results of students in AI curricula. It determines the specific AI themes that should be incorporated into K-12 curricula (e.g., Chiu, 2021a; Long & Magerko, 2020; Touretzky et al., 2019, 2023; Williams

et al., 2023; Zhang et al., 2023). Does having a sufficient level of AI literacy prepare individuals enough for the future classroom? Students are experiencing a growing availability of AI-powered educational tools, specifically utilizing AI in the process of learning. This suggests a shift from teaching AI to learning with AI. For instance, students use voice recognition programs to enhance their speaking skills, huge language models to produce review questions, and adaptive learning systems to focus on the areas they need to enhance. The introduction of ChatGPT, a generative artificial intelligence (GenAI), enhances the utilization of AI in the field of education. ChatGPT possesses the capability to produce responses that resemble those of humans and participate in significant discussions, rendering it an essential resource for both teachers and students. The ability to offer tailored comments, respond to inquiries, and even create learning resources enhances the student learning experience and facilitates comprehension of intricate ideas. Integrating AI into learning with ChatGPT introduces novel opportunities for creating interactive and captivating learning environments. The impact of GenAI on student learning is a subject of contention, as discussed by Chiu (2024), Mintz et al. (2023), and Yusuf et al. (2024). For instance, students may get greater comprehension from the feedback provided by ChatGPT, which has a facilitating effect. However, they may also complete assignments without grasping the solutions when utilizing ChatGPT, which has a hindering effect (Rasul et al., 2023). The extent to which students can proficiently utilize AI in their learning directly impacts whether it has a beneficial or detrimental impact. This skill surpasses AI literacy and encompasses what is referred to as AI competency (Chiu et al., 2024; Falloon, 2020; UNESCO, 2024). To reap the advantages of AI, students must possess a solid AI competency; however, the definition of AI competency for K-12 students remains ambiguous (Chiu et al., 2024; UNESCO, 2024).

This chapter provides definitions of AI literacy and competency specifically tailored for K-12 students. The definitions outline the precise content and assessment that should be incorporated into the AI curriculum in a K-12 setting, as well as the essential competencies that students need possess in order to effectively learn AI. We provide a comprehensive framework of AI competency that visually illustrates the terminology, with the goal of facilitating a clear and efficient understanding of our ideas. It is crucial to comprehend the level of a

student's learning in AI. Thus, we are also introducing a dependable and verified scale to assess students' AI learning and their proficiency in utilizing AI for learning purposes.

2.2 STUDIES ON STUDENT AI LITERACY

The term "literacy" was first used by Keefe and Copeland (2011), who defined it as "specific ways of thinking about and performing reading and writing in order to comprehend or express ideas or thoughts in writing within a particular context of use". A few studies defined AI literacy for professionals or students who were not majoring in engineering. For example, Long and Magerko's (2020) definition is "a set of competencies that enables individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool online, at home, and in the workplace". This definition, which comprises five main areas and 17 competencies, is very comprehensive and complicated. The definition suggests that individuals with AI literacy should understand (i) what AI is, (ii) what AI can accomplish, (iii) how AI functions, (iv) how to use AI, and (v) how people perceive AI. Long and Magerko's major research areas are engineering-focused, and they used a review method approach to suggest the definition. The review included most of the articles published in engineering journals before 2020. In other words, the findings were produced from an engineering rather than education perspective, and with higher education rather than school education knowledge. When defining AI literacy, Long and Magerko (2020) did not take K-12 education into consideration. They recognized these limitations and recommended a future review of the definition.

Chan (2023) introduced a fundamental framework for AI literacy, which comprises five key elements: understanding AI concepts, awareness of AI applications, AI affectiveness for human emotions, AI safety and security, and responsible AI usage. This framework, derived from the literature, intends to improve enhance AI proficiency and promotes collective advancement towards a digitized future. It highlights the significance of fundamental AI literacy for the typical individual. Cultivating this suggested AI literacy empowers individuals to make informed choices, engage in conversations regarding the impacts of AI, and understand the ramifications of AI technology for their personal and professional lives. Chan (2023) is a researcher

specializing in higher education, and hence this framework is specifically tailored for the higher education context.

The study of Kong and Zhang (2021) presented a three-dimensional framework for fostering AI literacy, focusing on cognitive, affective, and sociocultural dimensions. The cognitive dimension focuses on teaching basic AI concepts, the affective dimension empowers individuals to adapt to AI's influence, and the sociocultural dimension promotes ethical AI usage. The framework seeks to provide direction for future research on AI literacy initiatives and involve well-informed individuals. It is a versatile framework that is not tailored to any particular group.

Laupichler and colleagues (2022) used a scoping literature review on AI literacy to explore its definition, evolution, and practical applications in higher and adult education. AI literacy is defined as the ability to understand, use, and critically evaluate AI technologies without developing machine learning models. The review discusses various AI literacy programs and their design, objectives, and target demographics, emphasizing the need for adapting educational strategies to cater to diverse learner groups.

Chiu and colleagues (2023) define AI literacy as "an individual's ability to clearly explain how AI technologies work and impact society, as well as to use them in an ethical and responsible manner and to effectively communicate and collaborate with them in any setting". This definition has four components: technology, impact, ethics, and collaboration. Technology concerns AI technical knowledge; impact relates to how AI technologies affect individuals and society; ethics concerns topics related to ethical and moral considerations in the AI era; and collaboration focuses on the knowledge and skills students need to communicate and work with AI in any context. This definition is designed from a teacher's perspective (i.e., a practical view), lacking an engineering perspective.

Markauskaite and colleagues (2022) took a different view from the typical definition of AI literacy. They argued that the phrase "AI literacy" is inappropriate and advocated utilizing the idea of "AI capabilities". They highlighted the importance of cultivating human cognitive capacities, values, and joint knowledge for thriving in an AI-infused world. Their perspective is broad and includes atypical areas such as ecology of technology and humanity. Their research

design was a collaborative discussion among scholars from different backgrounds and aimed to foster a nuanced and inclusive dialogue on AI capabilities.

2.3 FROM STUDENT AI LITERACY TO AI COMPETENCY

We agree with Markauskaite and colleagues (2022) that AI literacy is not enough for our students, and we must go beyond AI literacy to AI competency (UNESCO, 2024).

AI literacy, which pertains to the acquisition of knowledge and skills, may not encompass the complete set of abilities required for students to effectively utilize AI in their studies and professional pursuits, known as AI competency. For example, having expertise in AI technology and application development (AI knowledge) does not automatically result in effective utilization of an AI tool for learning mathematics (learning with AI). Therefore, students should possess AI capabilities that exceed basic AI literacy (i.e., AI competency) (Chiu et al., 2024).

Based on the previously described definitions of AI literacy, students who are AI-literate should possess the ability to ethically utilize, employ, assess, and collaborate with AI technologies to successfully accomplish a task. AI competency encompasses not just the utilization of AI tools and applications, but also the capacity to actively engage in AI-based learning. To encourage the appropriate and healthy use of AI technologies, it is necessary to adopt a comprehensive approach to AI technology. Several research have endeavored to establish a clear definition of students' AI competency.

In the study of Chiu and colleagues (2023), AI competency is defined as

> an individual's confidence and ability to clearly explain how AI technologies work and impact society, as well as to use them in an ethical and responsible manner and to effectively communicate and collaborate with them in any setting. They should have the confidence and ability to self-reflect on their AI understanding in order to continue learning.

This definition encompasses five key areas: technology, impact, ethics, collaboration, and self-reflection. These areas respectively

center around knowledge of AI functioning and data processing, understanding the impact of AI on individuals and societies, awareness of ethical concerns related to AI, the capability to interact with AI, and the mindset of reflecting on one's understanding of AI for ongoing learning. This concept highlights the significance of incorporating the emotional aspect, beliefs, confidence, attitude, and self-reflective thinking.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) drafted an AI competency framework for K-12 students: "the knowledge, skills, and attitudes students should acquire to understand and actively engage with AI in a safe and ethical manner in school and beyond" (UNESCO, 2024). The framework consists of four primary components: a human-centric mindset, the ethics of AI, AI techniques and applications, and AI system design. Each component has three levels: understand, apply, and create. This framework is still under development, and each component needs extensive descriptions.

Overall, most recent research has defined AI literacy and competency for higher education students and the public, with less emphasis on K-12 students (Casal-Otero et al., 2023; Chiu et al., 2024; Long & Magerko, 2020). Their definitions also conflated the concepts of AI literacy and competency (Markauskaite et al., 2022); however, AI literacy and competency are distinct but related. AI competency is rarely explored in the literature, and its definition is still at an early stage of development (UNESCO, 2024).

In this chapter, AI literacy refers to the understanding and knowledge of AI (i.e., AI education). On the other hand, AI competency pertains to the ability to effectively utilize AI in the process of learning (i.e., AI in education). As student AI competency requires engagement with AI (Chiu, 2022), we explicitly include student engagement in the definition and framework.

2.4 STUDENT ENGAGEMENT WITH AI FOR COMPETENCY

Student engagement demonstrates the level of attention, effort, participation, curiosity, enthusiasm, and passion when learning (Reschly & Christenson, 2012). It refers to student involvement in learning and dedication to achieve their learning goals, as well as their perseverance and pleasure with learning (Fredricks et al., 2004). It can

predict how well students would study using AI as a digital tool (Chiu, 2022, 2024). Student engagement is a multidimensional notion that includes behavioral, cognitive, affective, and agentic dimensions (Chiu, 2022; Fredricks et al., 2004).

Behavioral engagement refers to student participation and involvement in learning activities (Fredricks et al., 2004). It reflects how responsible students are for their own learning when using AI as digital tools (Chiu, 2021b, 2024). Cognitive engagement refers to student mental investment in deep strategic learning and self-regulated learning (Fredricks et al., 2004). This reflects how much students learn or want to learn when using AI (Chiu, 2021b, 2024). Affective engagement refers to student affective reactions to their learning, such as joy, sadness, surprise, fear, calmness, and anxiety (Fredricks et al., 2004). This reflects how much students love and are interested in their learning with AI (Chiu, 2021b, 2022, 2024). Agentic engagement refers to proactive efforts to constructively contribute to learning and teaching (Reeve, 2013). This reflects how actively students express what they need to learn to their teachers or peers (Chiu, 2021b, 2024). These four dimensions of student engagement are interrelated, although they are operationalized and understood separately (Christenson et al., 2012; Reeve, 2013; Chiu, 2021b, 2022).

Some dimensions of student engagement are overlooked in existing definitions of AI competency. All the existing definitions often do not explicitly mention behavioral engagement because their primary focus is on the use of AI. It is assumed that students use AI tools in their learning (behavioral engagement). All the definitions link to knowledge and skills (e.g., Long & Magerko, 2020), which implies that cognitive engagement is the most essential component in the definitions. Affective engagement was mentioned in some of the definitions, such as attitude, belief, and confidence (Carolus et al., 2023; Chiu et al., 2024; Knoth et al., 2024). This definition highlights that AI competency not only concerns knowledge and skills but also emotion and affection (Chiu & Sanusi, 2024; Chiu et al., 2024; Knoth et al., 2024). It is necessary to include agentic engagement in defining AI competency and designing its matrix. We believe agentic engagement is one of the key elements in AI competency; we hereby include this in the definition and framework for AI competency.

2.5 OUR AI LITERACY AND COMPETENCY FOR K-12 STUDENTS

The definitions and frameworks of AI literacy and competency for K-12 students must be established to assist students in determining their AI learning goals and assessing their capacity to apply their knowledge and skills, and support teachers in fostering student AI literacy and competency. The frameworks should give precise guidance, with detailed descriptions tailored to the needs of teachers and researchers. Furthermore, the terms AI literacy and AI competency are used interchangeably across the literature (Carolus et al., 2023; Markauskaite et al., 2022; Long & Magerko, 2020; Tenório & Romeike, 2023). It is critical for you to understand the distinction between them.

We engaged in a collaborative process with 50 school teachers, utilizing three Delphi rounds, to establish a clear definition of AI literacy and competency, as well as to propose a framework based on their input. The terminologies and frameworks we employ consider the viewpoints of both practitioners and scholars (Ahmadi et al., 2023; Chiu, 2024; Teixeira et al., 2020). Our all-encompassing strategy for AI literacy and proficiency will be a useful asset for incorporating AI into K-12 education.

2.5.1 Our Definition of K-12 Student AI Literacy

We define K-12 student AI literacy as

> an individual's ability to use, apply, evaluate, and interact with AI technologies in a healthy, ethical, responsible, and productive manner, as well as clearly explain how they work and impact society. The ability is technical and skills-focused and is a combination of both behavioral and cognitive abilities, and affection.

To have strong AI literacy, students must demonstrate proficiency in six areas: fundamental knowledge, perception, representation and reasoning, interaction, ethics, and impact (Chiu, 2021a; Chiu et al., 2022; Touretzky et al., 2019, 2023) (see Table 2.1).

- **Fundamental knowledge:** Students should understand how machines learn from data, including machine learning, deep learning, and neural networks (Chiu, 2021a, 2022; Touretzky et al., 2019, 2023). Humans, or the machine itself, may provide the data.

Table 2.1 Our suggested six areas of AI literacy

Knowledge, skills and ability	Topics
Fundamental knowledge	Machine learning, big data, cloud computing
Perception	Read, write, speak, hear
Representation and reasoning	Create, think, reason
Interaction	Human machines interaction, large language model
Ethics	Human bias, ethical principles
Impact	Future of work, future learning, social good

Deep learning uses neural networks to learn from data. Moreover, students should possess a comprehensive comprehension of the practical uses of AI technologies, including generative AI and artificial general intelligence (AGI). They should also analyze tangible examples of AI technologies being applied in real-world scenarios, such as medical diagnostics, self-driving cars, and personalized recommendations on streaming platforms. Additionally, it is essential to investigate the impact of big data on machine learning and its influence on the accuracy of machine learning models. Furthermore, students should acknowledge that cloud computing is vital for the advancement of AI as it offers the essential infrastructure and resources for training and deploying machine learning models. Cloud computing facilitates the real-time processing and analysis of data, enabling AI applications to make quicker and more knowledgeable decisions.

- **Perception:** This area pertains to the manner in which machines interact with their environment and use received data to make intelligent choices. Data interpretation refers to the act of analyzing information obtained from various input devices, such as cameras and microphones, to gain a comprehensive understanding of the surrounding environment. Students should understand how machines perceive the world through the use of sensors and evaluate the capabilities and limitations of AI applications (Chiu, 2021a, 2022; Touretzky et al., 2019, 2023). Therefore, topics should include how machines see, read, write, hear, and speak. **See:** Students should understand how AI can analyze images and

videos to identify objects by extracting valuable data or features and making informed decisions based on what it sees. This falls into the AI subfield of computer vision. **Read:** Students should learn how AI interprets text by analyzing text data to understand their meaning and context (i.e., natural language processing and natural language understanding). **Write:** Students should recognize that machines generate text based on input data and patterns (i.e., natural language generation). **Hear:** Students should understand that AI interprets and understands spoken language by converting audio signals into digital data that can be processed and analyzed (i.e., speech recognition). **Speak:** Students should recognize that AI analyzes the text and determines the appropriate pronunciation, pitch, and emphasis for human-like speech (i.e., text-to-speech). These topics allow students to learn how machines mirror humans' perceptions of the world.

- **Representation and reasoning:** Students should learn how machines represent, think, reason, and create (Chiu, 2021a, 2022). Representation is a key method of intelligence. Machines create representations using data structures, which then allow reasoning processes to generate new information based on existing knowledge (Touretzky et al., 2019, 2023). The topics covered encompass the mechanisms by which AI technologies create, think, and reason. This area is vast and can be exceedingly challenging. We recommend that students possess a fundamental comprehension of concepts, including the different forms of reasoning, such as rule-based and deductive reasoning.

- **Interaction:** Students need to understand how machines interact and communicate with humans (e.g., large language models and generative AI) (Touretzky et al., 2019, 2023). Machines can recognize facial expressions and emotions in order to communicate with humans using human languages (Chiu, 2021a, 2022). They can use conversation history to understand user culture and background, thereby engaging in more appropriate interactions. This level of sophistication in machine communication allows for more personalized and meaningful interactions between machines and humans. As machines continue to advance in their ability to understand and respond to human emotions, the potential for deeper connections and more effective communication will only increase.

This can lead to enhanced user experiences and greater efficiency in various industries such as customer service and healthcare. Topics include human–machine interaction and large language models.

- **Ethics:** Students should understand that AI can perpetuate or exacerbate current biases and discrimination. Both AI algorithms and humans may develop bias. The ethical principles of AI include transparency, justice, safety, security, and privacy in order to reduce the perpetuation of human biases in a future AI-based society (Chiu, 2021, 2022). These principles guide the development, implementation, and evaluation of AI applications to ensure that they are safe, fair, and equitable for all individuals. For example, transparency refers to how AI applications show how their algorithms make decisions and detect bias; justice concerns if AI applications ensure that they do not discriminate against specific groups; safety measures for AI applications to protect users from harm; security measures how AI applications should protect user data; and privacy prevents users' personal information from being misused or exploited. Overall, these ethical principles are essential in shaping a future AI-based society that upholds values of equality and fairness. Students should use ethical principles to determine if AI technologies are ethical or not. Topics include human bias and ethical principles.

- **Impact:** It is important for students to comprehend the influence of AI technologies on persons and society, encompassing both positive and negative aspects (Holzmeyer, 2021). Technologies revolutionize our environment by altering the manner in which we reside, acquire knowledge, engage in employment, and interact with others. The impact of AI on the future of work encompasses automation, displacement of employment, and the emergence of new chances for skill enhancement. The impact of AI on information flows, communication patterns, and linkages in society include phenomena such as deepfakes, fake news, social interactions, and community dynamics. Hence, it is essential for students to possess the capability to assess AI technologies, comprehend their short-term and long-term consequences, and make informed decisions regarding how to reconcile the positive and negative impacts. Topics include the future of work and future learning.

Overall, our definition outlines the necessary knowledge, skills, and abilities required to cultivate AI literacy among K-12 students. It aids researchers and educators in formulating their studies and instructional materials pertaining to AI in K-12 contexts.

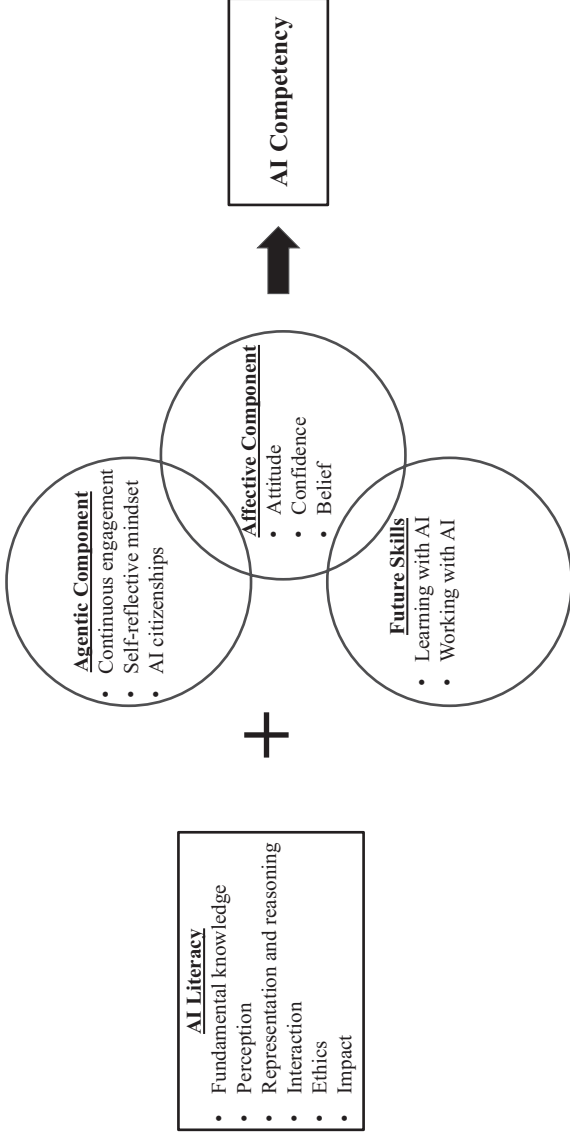### 2.5.2 Our Definition and Framework of Student AI Competency

The scope of AI education in K-12 should be broadened from literacy to competency, as suggested by Chiu and colleagues (2023) and Falloon (2020). AI literacy is an essential aspect of AI competency. The extent to which students actively engage and interact with AI technology indicates the degree to which AI integration is successful. Hence, we establish a clear definition of AI competency for K-12 students by incorporating four aspects of four dimensions of student engagement and future skills to AI literacy.

We define student AI competency for K–12 as

an individual's confidence and ability to use, apply, evaluate, and interact with AI technologies in a healthy, ethical, responsible, and productive manner, as well as clearly explain how they work and impact society (AI literacy). The individual demonstrates a positive attitude, a self-reflective mindset, and strong capacity to learn and work with AI. It is a combination of behavioral, cognitive, and agentic abilities and affection.

Our framework (see Figure 2.1) has four major components.

- **AI literacy** is the core component of the framework, encompassing the essential knowledge, abilities, and skills that students need to effectively utilize AI in their learning. If they lack sufficient AI literacy, students are less inclined to critically assess and appraise AI technologies for personal utilization. This literacy reflects both behavioral and cognitive engagement. In Section 2.5.1, we provide an explanation of its meaning.
- **Affective engagement** pertains to the students' beliefs, attitudes, and confidence when it comes to utilizing and implementing AI. To achieve optimal health, ethical behavior, responsibility, and effective learning, it is essential to include factors beyond cognitive and behavioral aspects. The integration of cognitive and affective

AI Literacy
- Fundamental knowledge
- Perception
- Representation and reasoning
- Interaction
- Ethics
- Impact

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Agentic Component
- Continuous engagement
- Self-reflective mindset
- AI citizenships

Affective Component
- Attitude
- Confidence
- Belief

Future Skills
- Learning with AI
- Working with AI

AI Competency

Figure 2.1 Our AI competency framework for K–12 students

elements is a reliable indicator of self-regulated learning in an AI-driven setting (Georgiadis & Efklides, 2000; Mega et al., 2014; Chiu, 2024). This is supported by the cognitive-emotional-social paradigm for learning in digital contexts (Schneider et al., 2022), which posits that both cognitive and affective aspects play crucial roles in facilitating effective student learning in digital environments. Students with stronger beliefs regarding the utilization of AI in education are more inclined to overcome obstacles. Additionally, students harboring an optimistic attitude towards AI are more prone to perceive AI as beneficial and easy to use. Furthermore, students who possess more confidence are more apt to redirect their attention towards positive aspects.

- **Agentic engagement**, the third component, is connected to student ongoing engagement by staying up to date on the newest AI knowledge. Students should be self-reflective AI citizens (who teach others AI). Agentic students take initiatives that contribute to their learning, teaching, and sharing (Chiu, 2021b, 2022; Reeve, 2013). They would articulate their needs and actions to establish a more supportive and constructive digital learning environment for themselves, such as expressing their preferences and interests and offering assistance (Chiu, 2021b). Students use their agency and initiative to customize and improve the quality of their learning environment (Reeve, 2013). They will take self-directed actions targeted at personal growth and development based on their own goals. They initiate voluntary acts that drive their learning. Moreover, agentic AI students are more effective AI citizens who share their AI knowledge with others and teach others AI, ensuring a healthy, ethically responsible, and productive society. As a result, agentic component is core to AI competency, as AI is an emerging and disruptive technology that has the potential to destroy civilization. We suggest the agentic component should include continuous engagement, a self-reflective mindset, and AI citizenship.

- **Future skills** refers to the capacity to live, learn, and work with AI. More and more AI technologies appear in the classroom and workplace. AI will shape the future of work, with the potential to replace or transform some current professions or occupations on the one hand and create entirely new ones on the other. In other words, future workforces need the skills to work with AI. Moreover,

AI has transformed K-12 education; students will learn with AI (Chiu, 2024; Mintz et al., 2023) and learn AI (Chiu et al., 2022). It is necessary for young students to learn and work with AI (Chiu, 2023; Mintz et al., 2023; Zhang et al., 2023). We suggest future skills include students' ability to learn and work with AI ethically and productively.

Overall, our framework presents a visual representation of the definitions of AI literacy and AI competency, emphasizing their similarities and differences. We also suggest a three-level matrix for the framework and describe criteria for each level (basic, intermediate, advanced) (see Table 2.2). The basic, intermediate, and advanced levels are related to understand, apply/analyze and evaluate/create, respectively, from the orders of thinking in Bloom taxonomy.

2.5.3 Our Three-Level Matrix for the AI Competency Framework

AI literacy

- **AI knowledge and application:** Students must have a solid understanding of both technical and practical AI skills (Chiu et al., 2022). The skills are associated with behavioral and cognitive components. At the basic level, students should be able to understand what AI is, how it collects and analyzes data, and how it interacts with humans. By understanding these fundamental concepts, they can begin to explore the potential AI applications in various industries, such as education, logistics, healthcare, and finance. At the intermediate level, students should be able to select an appropriate AI tool to accomplish a simple task. They should evaluate the performance of the AI tool to see if it is appropriate for the task. At the advanced level, students should be able to create and evaluate their own AI application using user-friendly educational technologies for machine learning, such as Google Teachable Machine. They have the opportunity to gain practical experience in developing machine learning models and understanding their functions. Students can experiment with different parameters and data sets by adopting a hands-on approach to see how they impact their learning models' performance.

Table 2.2 Our three-level matrix for student AI competency in K–12

Components	Basic: Understand	Intermediate: Apply and analyze	Advanced: Evaluate and create
AI literacy			
AI knowledge and application	Understand what AI is and how it collects and processes data	Apply an AI application to complete a task effectively	Evaluate and create an AI application
AI ethics	Understand the key concepts of AI and human bias	Apply the ethical principles to evaluate AI applications	Design and create a set of AI ethical principles
AI impact	Understand the personal and societal impact of AI	Discuss the impact of AI with others	Evaluate the impacts of an AI application
Agentic component			
Continuous engagement	Participate in AI learning activities	Actively seek out AI learning activities	Organize events for AI knowledge sharing
Self-reflective mindset	Understand the latest development of AI	Share the latest development of AI with others	Develop a strong self-reflective mindset towards AI
AI citizenship	Recognize AI is an essential skill for every citizen	Discuss AI with peers, friends, and teachers	Organize events to teach the public AI or discuss AI with the public
Future skills			
Learning with AI	Identify appropriate AI applications for learning	Apply appropriate AI applications to complete a learning task	Regulate their learning with appropriate AI applications (self-regulated learning with AI)
Working with AI	Identify appropriate AI applications for careers	Apply appropriate AI applications to complete their jobs	Evaluate or create AI applications for their careers
Affective component			

There are no suggested levels for attitude, confidence, or belief, because they relate to student feelings.

- **AI ethics:** AI ethics and human bias is one of the key competencies (Long & Magerko, 2020; Touretzky et al., 2019, 2023). All students should understand the ethical concerns raised by AI technologies (basic level). This understanding should include recognizing the potential for bias in AI algorithms and trained data, the implications of AI on privacy and surveillance, and the ethical responsibilities of those developing and using AI applications. Fostering ethical awareness in AI at the basic level will contribute to a more responsible and mindful generation of AI practitioners and users. Moreover, the concepts of ethics are abstract, while ethical principles are more practical. Students should be familiar with AI ethical guidelines published by different organizations, like UNESCO. They should have the ability to use the guidelines to determine how ethical an AI application is (intermediate). Understanding these guidelines will allow them to navigate the complex AI technology ecosystem and make more educated judgments about its use and influence on society. Some students should create a new set of ethical rules for a different context, taking culture and religion into account (advanced). Students can learn how to manage ethical difficulties that arise in various cultural contexts by including varied opinions and values in the conversation. This approach will improve their understanding and prepare them for moral dilemmas in their careers. When it comes to AI ethics, they should be inclusive and culturally aware, ensuring the production and implementation of AI technologies in ways that benefit all parts of society.
- **AI impact:** At the basic level, students should understand how AI impacts our lives and society by giving examples. Understanding these examples can help students understand the significance of AI in their everyday lives and the broader world. At the intermediate level, students should be able to discuss how AI impacts us with others. They can engage in conversations about the impact of AI, such as job displacement, future skills, and academic integrity. At the advanced level, students can determine the potential benefits and risks brought by an AI tool, so they can actively participate in the ongoing conversations around the responsible usage and governance of AI. Overall, our suggested levels are in line with the studies of Long and Magerko (2020), and Touretzky and colleagues (2019, 2023).

- **Continuous engagement:** AI is a broad discipline, and K-12 education cannot cover all of its key knowledge and skills. Students will need to continue to learn more about AI after school. They should engage in AI learning activities outside classrooms (basic level), actively seek out AI learning activities to participate in (intermediate), and plan events to share their AI knowledge (advanced) (Chiu et al., 2024).
- **Self-reflective mindset:** AI is an emerging technology, and its knowledge and skills are evolving. Outdated knowledge may lead to misunderstanding and bias, so students should be aware of how current their AI knowledge is (Chiu & Sanusi, 2024). Therefore, students should understand the latest developments in AI (basic), share the latest developments in AI with others (intermediate), and develop a strong self-reflective mindset towards AI (advanced), which is in line with the study of Chiu and colleagues (2023). Students with strong self-reflective attitudes regularly identify what AI areas they need to improve through self-evaluation and monitoring.
- **AI citizenship:** AI is a disruptive technology, and has an influence on humans across fields, such as entertainment, healthcare, and the environment, as well as across geographical (districts, countries, and regions) and societal (individuals, communities) levels. Everyone should have basic AI literacy, and every citizen should communicate with friends and family to help maintain an ethical and orderly AI society (Lee & Kwon, 2024). Therefore, students should recognize AI is an essential skill for every citizen (basic), discuss AI issues with peers, friends, and teachers (immediate), and organize events to teach or discuss AI issues with the public (advanced). Overall, students should become good AI citizens.

Future skills

- **Learning with AI:** AI tools have been integrated into schools (Chiu, 2023, 2024; Mintz et al., 2023), and self-regulated learning with AI is required in AI-based classrooms (Chiu, 2024; Molenaar, 2022; Xia et al., 2023). Since AI-based learning enables students to get personalized learning, actively seek feedback and recommendations,

and generate multimedia resources, teaching students to self-regulate their learning with AI is crucial for future schools. The capacity to learn with AI not only encourages them to take control of their own learning but also prepares students for the future workforce (Yusuf et al., 2024; Zhang et al., 2023). Nurturing young students to self-regulate their learning with AI will be instrumental in creating a generation of life-long learners. Therefore, students should be able to identify appropriate AI applications for learning (basic), use appropriate AI applications to accomplish a learning activity (intermediate), and regulate their learning with appropriate AI applications (advanced).

- **Working with AI:** Future workforces are required to collaborate with AI (Chiu, 2023; Yusu et al., 2024; Zhang et al., 2023). For example, a member of staff in a restaurant works with a robot to prepare meals, distribute meals to the customers, and clean tables; bus drivers work with AI-driven cars to provide a more accurate and safer ride. Students should have the ability to identify appropriate AI applications for careers (basic), apply appropriate AI applications to complete tasks for a career (intermediate), and develop AI applications for a career (advanced). With the continuous advancement of AI, it is crucial for individuals to acquire the essential abilities to collaborate with these technologies in order to stay competitive in the job market.

Affective component

- **Affective component:** This component includes students' attitude, confidence, or belief, which is related to student feelings (Bong et al., 2012). Therefore, there are no suggested levels for this component.

By incorporating the framework into curriculum design, teachers can help students develop the AI literacy and competency necessary for navigating the increasingly AI-driven classrooms, workplaces, and society. The matrix provides a structured approach for assessing student progress and understanding of AI competency, allowing teachers to tailor instruction to cater to individual differences. Moreover, researchers can use the definition and framework of AI literacy to design and evaluate intervention studies, for example, on how project-based learning affects each sub-component of AI literacy. They can also

use the framework and matrix of AI competency to measure student capacity to use AI to support their learning for correlation studies, for example, to study how student AI competency relates to student engagement and performance. Overall, the matrix can help you create engaging learning activities both inside and outside the classroom to improve student AI competency.

2.6 CONCLUSIONS

This chapter provides a clear definition of AI literacy and competency and presents a framework for incorporating them into K-12 educational settings. The framework suggests that to thrive as a student in the AI era, one must possess behavioral, cognitive, agentic, and affective engagement. These qualities are essential for maintaining good health, ethical behavior, responsibility, and productivity. The framework can be utilized to enhance your students' ability to effectively utilize the advantages of AI in a sustainable manner, both within and outside of the classroom. By engaging with this framework, your students will develop the necessary skills and knowledge to effectively handle the complex ethical challenges and societal impacts that will inevitably emerge as AI becomes increasingly pervasive in our everyday existence. They will acquire enhanced readiness to make constructive contributions to the advancement and execution of AI technologies in the future. Teacher AI competency is closely linked to the growth of student AI literacy and AI competency in K-12 education. Chapter Three focuses on the necessary AI competencies that K-12 teachers require.

Actions you may consider taking

- Establish or revise the learning objectives for your AI curriculum using our definition of AI literacy.
- Make changes to the learning outcomes of your student digital education by using our definitions of AI competency.
- Update your digital education policy using our AI competency framework.
- Create a rubric using the matrix to evaluate students' AI competency.
- Create a self-reported questionnaire for students to reflect on themselves using the matrix.
- Develop your own definitions of AI literacy and competency based on our suggestions.

Questions you may ponder

- How can our framework for student AI competency stay relevant and adapt to the emerging AI technologies?
- How can our definitions and frameworks for AI literacy and competency be extended to higher education?
- How can our definitions and frameworks for AI literacy and competency be tailored to reflect cultural, legal, and socioeconomic differences across different global contexts?
- How can we effectively nurture student AI literacy and competency among diverse populations?
- How can our student AI competency framework be integrated in different subjects?
- How does students' AI competency levels affect their self-regulated learning?

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