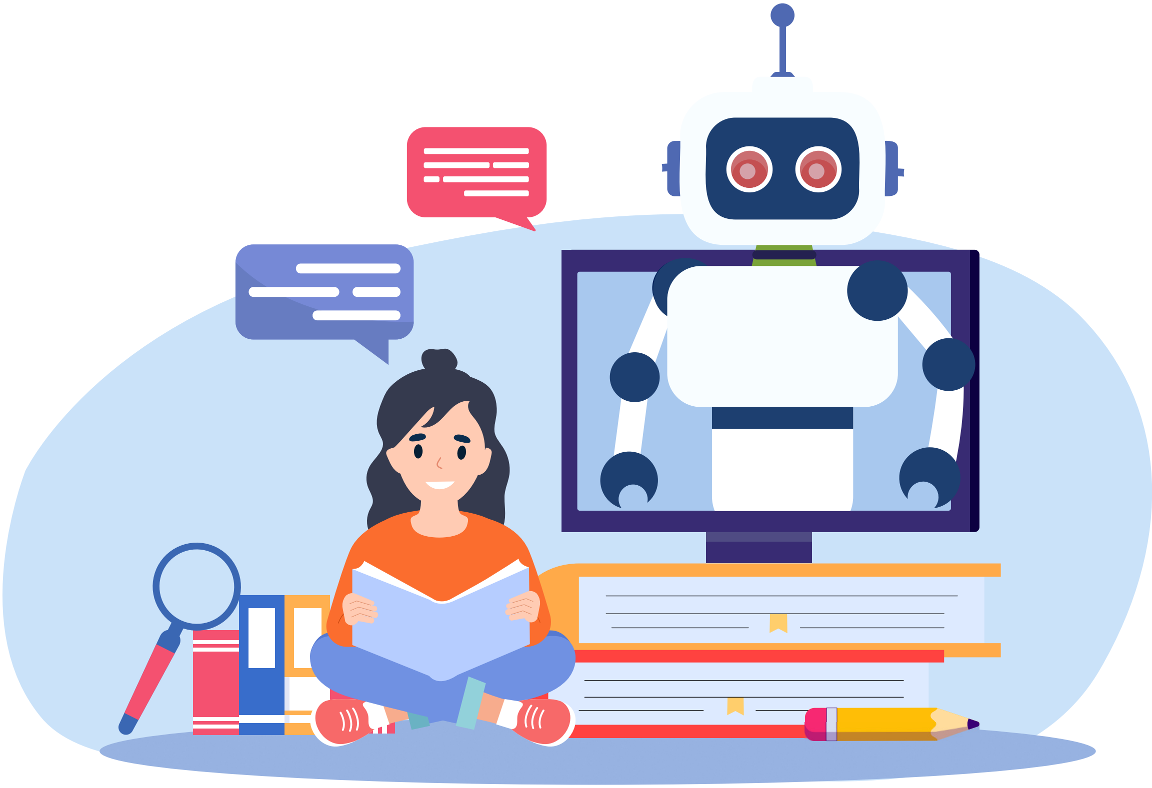
AI competency framework for students



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SHORT SUMMARY

Preparing students to be responsible and creative citizens in the era of AI

Artificial intelligence (AI) is increasingly integral to our lives, necessitating proactive education systems to prepare students to be responsible users and co-creators of AI. Integrating AI learning objectives into official school curricula is crucial for students globally to engage safely and meaningfully with AI.

The UNESCO AI competency framework for students aims to help educators in this integration, outlining 12 competencies across four dimensions: Human-centred mindset, Ethics of AI, AI techniques and applications, and AI system design. These competencies span three progression levels: Understand, Apply, and Create. The framework details curricular goals and domain-specific pedagogical methodologies.

Grounded in a vision of students as AI co-creators and responsible citizens, the framework emphasizes critical judgement of AI solutions, awareness of citizenship responsibilities in the era of AI, foundational AI knowledge for lifelong learning, and inclusive, sustainable AI design.

By 2022, only 15 countries had included AI learning objectives in their national curricula

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"Since wars begin in the minds of men and women it is in the minds of men and women that the defences of peace must be constructed"

AI competency framework for students

Foreword

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The past decade has seen widespread adoption of artificial intelligence (AI) in all areas of human development, with the public release of generative AI tools in November 2022 only accelerating its permeation within social life. The education sector, which is at the heart of the transformation of human societies, has been no exception.

This process of rapid technological change brings multiple opportunities but also risks and challenges for students, teachers and society at large. In the era of AI, school students need to be prepared to become active co-creators of AI, as well as future leaders who will shape novel iterations of the technology and define its relationship with society.

This is exactly the ambition of UNESCO's AI competency framework for students – the first ever global framework of its kind. It aims to support the development of core competencies for students to become responsible and creative citizens, equipped to thrive in the AI era. This will help students acquire the values, knowledge and skills necessary to examine and understand AI critically from a holistic perspective, including its ethical, social and technical dimensions.

The new framework embodies UNESCO's mandate by anchoring its vision of AI and education in principles of human rights, inclusion and equity. This approach seeks to ensure that AI supports the development of human capabilities, protects human dignity and agency, and promotes justice and sustainability.

The publication builds on UNESCO's previous work in the field, such as the *ICT competency framework for teachers, AI and education: Guidance for policy-makers*, and the more recent *Guidance for generative AI in education and research*. It reflects the contributions of a wide range of stakeholders, drawing on UNESCO Member States' insights on developing and implementing AI school curricula, the expertise of an international working group, three international consultation meetings, and multiple rounds of online consultations.

The AI competency framework for students has been developed hand in hand with a competency framework for teachers. It is my hope that these two frameworks will empower students and teachers to shape the digital futures we want.

In a world characterized by rising complexity and uncertainty, it is our collective responsibility to ensure that education remains the central space for transformation of our shared futures.

Stefania Giannini
UNESCO Assistant Director-General for Education

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List of acronyms and abbreviations

AGI	Artificial general intelligence
AI	Artificial intelligence
AI CFS	AI competency framework for students
CCDI	Computing, Creative Design and Innovation
CG	Curricular goal
GAN	Generative adversarial networks
K-12	Kindergarten through 12th grade
ICT	Information and communication technology
IEA	International Energy Agency
IGO	Intergovernmental organization
ITU	International Telecommunication Union
MIT	Massachusetts Institute of Technology
NGO	Non-governmental organization
STEAM	Science, technology, engineering, arts and mathematics
STEM	Science, technology, engineering and mathematics
TVET	Technical and vocational education and training
UNESCO	United Nations Educational, Scientific and Cultural Organization

Chapter 1: Introduction

1.1 Why an AI competency framework for students?

The rapid iterations and proliferation of artificial intelligence (AI) across all aspects of life and all sectors are posing new challenges regarding the nature of machine intelligence, the collection and use of personal data, the role of humans and machines in decision-making, and the impact of AI on social and environmental sustainability. It is essential that education systems prepare students not only with the knowledge and skills to use AI, but also with insight into the potential impact of technology on societies and the environment at large. Given the transformative potential of AI for human societies, it is crucial to equip students with the values, knowledge and skills needed for the effective use and active co-creation of AI.

Education, as a public sector, cannot be reduced to a testing ground for the passive adoption of AI. The role of the education sector is not only to prepare students to adapt to a society that is increasingly being transformed by AI technologies; it also has a key role to play in empowering young people to help co-create sustainable futures by rebalancing our relationships, not only with others, but also with technology and the environment. By defining the core competencies that students are likely to require as we move deeper into the AI era, the ultimate aim of this AI competency framework for students (AI CFS) is to help shape responsible and creative citizens that can co-create these desirable futures.

Governments acknowledged the urgent need to develop AI literacy and more advanced AI competencies as early as 2019, when they adopted the UNESCO *Beijing Consensus on AI and Education*. Indeed, the Beijing Consensus underlined the need to equip people with AI literacy across all layers of society. However, according to a recent survey conducted across 190 countries, only some 15 countries were found to be developing or implementing AI curricula in school education (UNESCO, 2022*b*). The survey also found that there was wide variation in how countries defined AI literacy, skills and competency. The results of the survey therefore underscored the urgency of developing a harmonized approach to integrating AI-related teaching and learning content in school curricula.

Far too often, the definition of AI competencies for students is influenced by training designed and/or provided by private companies, which tends to focus on technical skills to operate profit-driven AI platforms. Such approaches seldom engage with the broader critical issues of the implications of AI for learning and citizenship, more broadly. There is currently a void in too many education systems when it comes to public-approved frameworks for introducing AI-related content and methods to educational curricula. One of the challenges that public education systems are facing in filling this void is the lack of an international reference framework on AI competencies for students. Such an international reference framework can inform the design of national/local AI competency frameworks for students that promote a critical and ethical approach to AI tools, as well as develop the foundational knowledge required for their effective and meaningful use in education. The aim of this AI CFS is to fill this void.

AI technology is a rapidly moving target. It is therefore critical to ensure that all students have a core set of knowledge, skills and values for interacting ethically and effectively with AI in the present. This foundation can enable students to utilize future iterations of AI technology in an appropriate and human-centred manner.

The AI CFS supports educational authorities to respond to these needs by defining a core set of competencies for students that fall under four aspects: Human-centred mindset; Ethics of AI; AI techniques and applications; and AI system design. These four aspects are articulated at three levels of progression or mastery (understanding, application and creation), resulting in a total of twelve competency blocks. For each of these competency blocks, the AI CFS proposes detailed specifications on relevant pedagogical methodologies and strategies for the planning and provision of AI-related curricular content.

1.2 Purpose and target audience

The AI CFS aims to serve as a guide for public education systems to build the competencies required of all students and citizens for the effective implementation of national AI strategies and the building of inclusive, just and sustainable futures in this new technological era.

More specifically, the AI CFS: (1) provides a global reference framework on the core set of AI competencies for students to inform the design of national or institutional AI competency frameworks; (2) specifies typical attitudinal and behavioural performance relating to the key aspects of AI competencies at different levels of mastery to help design AI-related curricular content for school students; and (3) recommends an open-ended roadmap to help plan the learning sequence of AI curricula across grade levels.

As a global reference framework, the AI CFS is to be tailored to the diverse readiness levels of local education systems in terms of curricula, the enabling learning environment for teaching AI, preparedness of teachers, and the prior knowledge and capacities of specific groups of students.

The AI CFS is aimed principally at policy-makers, curriculum developers, providers of education programmes on AI for students, school leaders, teachers and educational experts.

Chapter 2: Key principles

2.1 Fostering a critical approach to AI

Critical thinking is a fundamental skill that students need to meaningfully engage with AI as learners, users and creators. Students also have the responsibility to determine what types of AI should be developed and how they should be used to drive human societies towards inclusive, environmentally sound, shared futures. School students need to be supported to become active co-creators of AI, as well as potential leaders who will define further iterations of AI and its interactions with human society for present and future generations. To support this vision, the AI CFS is designed to foster a critical approach to AI by engaging students with fundamental questions, such as: is AI poised to help solve real-world challenges faced by humans, or does it pose insurmountable threats to humans? Are adverse impacts on climate of training and using AI disproportionate to its anticipated benefits? What social, economic, political and demographic impacts of the use of AI should be carefully reviewed?

The AI-driven transformation across development sectors has profound implications for human agency, human interactions, social equity, economic inclusiveness, and environmental sustainability. Thus, in the first place, school students are expected to be conscious and knowledgeable of the advantages and limitations of existing affordances of AI. The pre-condition for responsible use consists in students' abilities to detect the trustworthiness and proportionality of AI tools. The AI CFS aims to prepare students with the values, knowledge and skills necessary to critically examine the proportionality of AI from an ethical perspective. This includes examining and understanding its impact on human agency, social inclusion and equity, institutional and individual security, cultural and linguistic diversity, the construction and expression of plural opinions, as well as on the environment and on ecosystems. Students are expected to move beyond the misconception that AI is a solution to everything. Rather, they are to become conscious decision-makers on when AI systems and applications should, or should not, be used; what problems they may or may not solve; and when and how AI should be designed and used as one part of a wider solution. The AI CFS aims to nurture students' aspirations to apply and design AI tools to serve meaningful specific purposes or to address real-world challenges and promote sustainable development.

Societies are moving into the era of AI at different paces, but students everywhere are, or will be, citizens in contexts characterized by widespread AI integration. They will not only have to comply with legal regulations and ethical principles, but, as citizens, they will also have to contribute to the adaptation of AI standards and regulations. The framework therefore highlights the importance of supporting students to become responsible and ethical users of, as well as contributors to, AI. It engages students to reflect on key controversies surrounding AI, internalize ethical principles, and become familiar with related regulations.

The AI CFS sets out a forward-looking vision of the type of citizenship required by societies increasingly shaped by AI. It proposes that students be challenged and enabled to make meaningful use of AI for self-actualization; to evaluate its social, economic and environmental impacts; and to contribute, at a level appropriate for their age or grade, to the development of AI regulations, helping to shape our relationship with technology in society at large.

2.2 Prioritizing human-centred interaction with AI

In the era of AI, interaction between humans and AI systems and applications will become an essential constituent element of public service, production and commerce, social practice, learning, and daily life. Establishing the competencies needed to understand and ensure human-centred interaction with AI in these domains is a priority for the AI CFS.

UNESCO's human-centric approach advocates that the design and use of AI should serve the development of human capabilities, protect human dignity and agency, and promote justice and sustainability throughout the entire AI life cycle and all possible human–AI interaction loops. Such an approach must be guided by human rights principles and respect for the linguistic and cultural diversity that defines the knowledge commons. A human-centred approach also requires that AI be used in ways that ensure transparency and explainability, as well as human control and accountability.

As AI becomes increasingly sophisticated and more widely used, a key danger is its potential to undermine human agency and compromise the development of human intellectual skills. While AI can be used to challenge and extend human thought, it should not be allowed to usurp or replace critical thinking. The protection and enhancement of human agency should, therefore, always be a core principle in the design of AI curricula and education programmes. The AI CFS aims to support students to understand the types of data that AI may collect from them, the methods with which the data may be used to train AI models, and the impact that the data cycle may have on their privacy and wider lives. It seeks to stimulate students' intrinsic motivation to grow and learn as individuals and to reinforce their autonomy in contexts in which sophisticated AI systems are increasingly being integrated. Critical AI competencies, as proposed in this framework, can also guide students to understand the unique value of social interaction and of the creative works produced by humans that should not be replaced by AI outputs. By developing competencies for human-centred engagement with AI, the framework aims to prevent students from becoming addicted to or dependent on AI, and to foster behaviours that maintain human accountability for high-stakes decisions.

2.3 Encouraging environmentally sustainable AI

As co-creators and potential leaders of the next generations of AI technology, students need to have a critical understanding of the adverse environmental impact of profit-driven approaches to the design, training and deployment of AI models. Education systems bear the responsibility of ensuring that students understand carbon emissions, analyse the root causes of climate change, and act judiciously to protect the climate and the environment.

In the race to produce increasingly powerful AI models, environmental sustainability is often considered to be of secondary importance. In some instances, it has even been intentionally obscured by claims that AI holds the promise of solving climate change. As global leaders and policy-makers work to consider regulations around the consumption of energy and the protection of the environment, it is imperative that students understand how the training of AI models is contributing to the destruction of the natural environment. Learning about AI should empower them to urgently explore more climate-friendly approaches to the design, training and use of AI models. The AI CFS attends to this by guiding students to design and implement project-based learning activities on the environmental impacts of AI use and training, prompting students to investigate potential solutions to mitigate these impacts.

2.4 Promoting inclusivity in AI competency development

Access to AI and AI competencies represent the two sides of citizens' basic rights in today's world. All students should have inclusive access to the environments required for learning about AI at the basic level, and they should be supported to learn how to embed the principle of inclusivity into the design of AI and be prepared to contribute to an inclusive AI society.

When defining AI competencies, school students should be provided with opportunities to understand and apply the principle of inclusivity across the AI life cycle. This covers the selection of representative data, the choice of bias-agnostic algorithms and anti-discrimination training methods, the design of accessible functionalities, testing for the inclusiveness of AI outputs, and impact assessment of the use of AI on social inclusion. With regard to AI system design, students can deepen their understanding and application skills to assess the needs of users with different abilities as well as those from diverse linguistic and cultural backgrounds.

In selecting the models and categories of technologies as vectors of AI-related teaching and learning, care is needed to avoid favouring certain demographics over others. When recommending specific AI tools for educational purposes, rigorous public validation mechanisms must be applied to avoid algorithms with bias(es) related to gender, ability, socio-economic status, language, ethnicity and/or culture. AI tools that are designed to support individuals with disabilities and promote linguistic and cultural diversity should be given priority. Where such validation mechanisms are unavailable, the recommendation of specific AI tools for use at scale should be avoided.

Turning to delivery of the curriculum, specific measures can be outlined to provide basic enabling conditions for the implementation of the AI CFS-based curriculum. While AI frameworks or educational programmes should be designed to be applicable to all students, including those who live in low-tech settings, engagement with AI without access to the internet and AI tools will limit the scope and mastery level of AI competencies. Governments should commit to promoting inclusive access to basic internet connectivity, updated digital devices, open-source or affordable AI programmes and software, and essential AI devices, with the support of academia or the private sector, where appropriate. Once again, these efforts must pay particular attention to students who have disabilities and/or are from linguistic or cultural minority groups.

2.5 Building core AI competencies for lifelong learning

AI-related teaching and learning should serve to build core AI competencies that allow students to accommodate new knowledge, as well as adapt to solving problems in new contexts with novel AI technologies. First and foremost, these core competencies must include values associated with an ethical and human-centred mindset. Students need guidance to progressively deepen their understanding of particular human rights – such as rights to equality, non-discrimination, privacy and plural expression – as well as their implications for varying forms of human–AI interaction. The competencies also reflect the need to understand controversies surrounding AI and the key ethical principles that guide regulation, as well as foster practical skills to combat bias, protect privacy, promote transparency and accountability, and adopt an ethics-by-design approach to the co-creation of AI.

The core competencies are brand-agnostic and product-agnostic, ensuring that students can appropriately engage with a range of tools, as well as with future iterations of AI technologies. It enables them to develop an age-appropriate and progressively deeper understanding of AI data, algorithms, models and system design. Students must be supported to construct this understanding by connecting AI concepts with real-world challenges to develop critical problem-solving skills. Students should be further encouraged to exploit their creativity in an effort to optimize existing AI models or co-create more meaningful AI. These core competencies constitute the foundation for further learning and more specialized use of AI in further education, work and life.

Chapter 3: Structure of the AI competency framework for students

3.1 The framework

The AI CFS specifies twelve competency blocks based on a matrix of two dimensions. The first dimension comprises four interlinked aspects of AI competencies, while the second dimension includes three levels of progression or mastery that students are expected to engage with iteratively.

While the AI CFS anchors the definition of AI competency on three pillars that frame wider core competencies for students – namely, knowledge, skills and values – it also aims to encourage an ethical understanding of human-led methods underlying AI systems. Based on this conceptualization, the framework defines four essential constituent elements of students' AI competency: a human-centred mindset, ethics of AI, AI techniques and applications, and AI system design. These elements focus on fundamental values, social responsibilities to uphold ethical principles, foundational knowledge and skills, and higher-order thinking skills for system design. While different elements can be developed through domain-specific learning and pedagogical methodologies, AI competencies are ultimately a set of interdisciplinary, general abilities and value orientations that extend beyond particular AI domains or tools.

The first aspect positions students' competencies within a human-centred attitude towards the benefits and risks of AI. It also aims to foster a critical understanding of the proportionality1 of specific AI tools for our human needs and for the sustainable development of the environment and ecosystems. Ethics of AI, the second aspect, encompasses the social and ethical components of students' AI competencies, including the social skills to navigate, understand, practise and contribute to the adaptation of a growing set of principles that regulate human behaviour throughout the entire life cycle of AI.

The third aspect, AI techniques and applications, represents an integrated view of the intrinsically linked conceptual knowledge on AI and associated operational skills, using selected AI tools and authentic tasks. The last aspect is AI system design, which covers comprehensive engineering skills that determine the problem scoping, architecture building, training, testing and optimization of AI systems. This aspect aims to challenge and enable students to gain a deeper understanding of AI systems and scaffold their exploratory learning for the pursuit of further study in the field of AI.

The second dimension of the framework outlines three levels of progression: Understand, Apply and Create, which are designed to reflect levels of mastery across all four aspects outlined above. They can be used to furnish AI curricula or programmes of study with a spiral learning sequence across grade levels, to assist students in progressively building a systematic and transferable schema of competencies.

The framework matrix cuts across the four aspects for the three levels of progression or mastery (see Table 1). At the intersection of these levels and aspects are twelve constituent blocks of AI competencies whose characteristics underpin the critical thinking, ethical examination, practical use and iterative co-creation of AI. These competency blocks should be understood as interlinked units for the framing of key components. Rather than considering them as fragmented and disparate topics to be learned in isolation, they can be connected and woven together as the operational organs of AI competency.

The matrix provides a blueprint for learning outcomes at a minimum level of mastery within a certain competency block. More specifically, the matrix is designed to guide: (1) the scoping of main AI-related focus areas and expected mastery levels, tailored to local AI readiness and available instructional time; (2) the identification of AI-related learning content that can be integrated across existing curricula, subject areas, and grade levels; (3) the definition of proficiency levels and the development of assessment criteria to assess students' general AI competencies and progression; and (4) the design and exploration of age-appropriate and domain-specific agile teaching and learning methodologies. Many of these factors will be vital to consider when a country, district or school localizes this framework; the selection of focus aspects and specification of the desired mastery levels, for instance, will depend on students' existing AI competencies, the training and skills of teachers, the availability of learning hours, and local AI readiness, including affordability and infrastructure.

Table 1. AI competency framework for students

Competency aspects	**Progression levels**		
	Understand	**Apply**	**Create**
• **Human-centred mindset**	• Human agency	• Human accountability	• Citizenship in the era of AI
• **Ethics of AI**	• Embodied ethics	• Safe and responsible use	• Ethics by design
• **AI techniques and applications**	• AI foundations	• Application skills	• Creating AI tools
• **AI system design**	• Problem scoping	• Architecture design	• Iteration and feedback loops

3.2 Progression levels

The three levels reflect increasing sophistication, proficiency and ethical consciousness in using and co-creating AI technology. Students are expected to progress through them reciprocally. These levels, and the specifications of each competency block, can guide both the formative and summative evaluations of students' AI competencies, as well as inform the design of contextually relevant and agile pedagogical methodologies.

Level 1: Understand

This first level is designed for all students. All individuals are, or will be, interacting with some form of AI over the course of their lives. It is also true that AI providers have been mining and manipulating data from almost all internet users. All students must therefore develop the human-centred values, knowledge and skills needed to engage in a safe, informed and meaningful manner in their daily interaction with AI in various spheres of life.

At the 'Understand' level, students are expected to foster an understanding of what AI is and construct age-appropriate interpretations of the values, ethical issues, concepts, processes and technical methods underlying AI tools and their uses. They should be able to explain or exemplify their knowledge with connections to real-life or social practices and assimilate novel knowledge by integrating them into their own knowledge schemas.

This level of mastery provides the essential attitudinal, cognitive and practical foundations for the further study of AI. It does not define the exit-level competencies for specific areas or domains of AI overall.

Level 2: Apply

Given that the use of AI has permeated all sectors, as well as all aspects of life, including education and work, students at school should be prepared to become responsible, active and effective users of AI, both for the sake of their own individual interests, as well as to address shared sustainability challenges. The outcomes at the second level, 'Apply', are therefore relevant for all school students and can be used to tailor the scope, breadth and level of difficulty of thematic modules of a formal AI curriculum. Studying at this level requires students to have acquired a basic understanding of the human-centred approach and essential ethical principles for AI, as well as basic AI knowledge and application skills.

At the 'Apply' level, students are expected to enhance, transfer and adapt their learned values, knowledge and skills to new learning processes. They do so by addressing theoretical questions and/or practical tasks in more complex contexts, and by critically examining advanced technical methods behind AI tools. Upon achieving this level, students will have constructed a sound and transferable foundation of conceptual knowledge and associated AI skill-sets. They should also be able to apply the human-centred mindset and ethical perspective to the assessment, study and practical uses of AI tools.

Students at this level may progress to the third, more specialized level, Create. However, it is possible that some students will not have a strong interest in AI, or will lack sufficient time or opportunities to finetune their AI competencies within the formal learning environment at school. For many, 'Apply' at Level 2 will be the point of exit for their AI-related competency development, at least at school.

Level 3: Create

The exponential pace of innovation within the AI sector means that technology providers are defining the terms of the transformation of our societies. Developing critical AI competencies is critical to ensuring that the design, deployment and use of AI responds to the needs of users and benefits the public. School students should be prepared to create trustable AI tools and to take a leading role in the definition and design of the next generation of AI technologies. At the 'Create' level, students are expected to become conscientious AI co-creators, developing human-centred solutions to positively impact the design and use of AI. Study at this level requires the integrated application of the acquired values, knowledge and skills on AI to design, implement and test AI solutions that can help address real-world challenges.

Students will critically leverage their knowledge and skills on data, algorithms and ethical design; actively craft AI applications; and deliberate on the adaptation of AI regulations.

At the 'Create' level, students are expected to reinforce their interest in AI innovation and develop new AI tools based on open-source and/or customizable datasets, programming tools or AI models. Throughout the iterative process of customizing and testing AI technologies, students are expected to reinforce the sense of being an AI co-creator and belonging within a broader community, helping to lead the human-centred design and use of AI. At this level, students are also expected to enhance their capacity to critically assess the social implications of AI and to personalize the responsibilities of being a citizen in AI-driven societies.

Learning at the 'Create' level also aims to foster students' creative problem-solving skills and a proactive attitude to advocating for ethical AI practices. Meeting the requirements of this level in full will require sufficient allocation of learning time and space within the curriculum (e.g. an entire semester or multiple semesters). The learning programme must also provide the necessary AI resources and facilitate age-appropriate innovative pedagogical methodologies. For students who do not have a strong interest in pursuing deeper study in the field, the learning outcomes at this level, in particular under the 'AI system design' aspect, should be offered as elective programmes rather than as compulsory requirements for all students.

3.3 Aspects

The four aspects specify the essential constituent elements of AI competencies that students need to build and continuously update in order to become responsible users and active co-creators of AI, and potential leaders in defining and developing next generations of AI.

Human-centred mindset

Competency aspects	Progression levels		
	Understand	**Apply**	**Create**
• **Human-centred mindset**	• Human agency	• Human accountability	• Citizenship in the era of AI

The 'Human-centred mindset' aspect focuses on students' values, beliefs and critical thinking skills, applied to the examination of whether AI is fit for purpose, whether its use is justified, how humans should interact with it, and what responsibilities individuals and institutions should take on to contribute to the building of safe, inclusive and just AI societies. A human-centred mindset lays the foundation for further engagement with all aspects of AI. The full expression of this aspect also encompasses human identities in relation with AI, assuming social and civic responsibilities, and the pursuit or deepening of personal interests in the AI era. The values and skills that this aspect is intended to nurture can be characterized by the following three competency blocks:

Human agency: Students are expected to be able to recognize that AI is human-led and that the decisions of AI creators influence the way in which AI systems impact human rights, human–AI interaction, as well as their own lives and societies. They are expected to understand the implications of protecting human agency throughout the design, provision and use of AI. Students will understand what it means for AI to be human-controlled, and what the consequences might be when this is not the case.

Human accountability: Students are expected to recognize that human accountabilities are the legal obligations of AI creators and AI service providers, and to understand what human accountabilities they should assume during the design and use of AI. They should also develop an awareness that human accountability is a legal and social responsibility when using AI to assist in decision-making, and that human choice should not be ceded to AI when making high-stakes decisions.

Citizenship in the AI era: Students are expected to critically understand the impact of AI on human societies and to promote responsible and inclusive design and use of AI for sustainable development. They should have an awareness of their civic and social responsibility as citizens in the era of AI. Students are also expected to develop a desire to continue learning about, and using, AI throughout their lives to support self-actualization.

Ethics of AI

Competency aspects	Progression levels		
	Understand	**Apply**	**Create**
• Ethics of AI	• Embodied ethics	• Safe and responsible use	• Ethics by design

The 'Ethics of AI' aspect represents the ethical value judgements, embodied reflections, and social and emotional skills students require to navigate, understand, practise and contribute to the adaptation of a growing set of principles and regulatory rules relative to the entire life cycle of AI systems. Students are expected to understand and apply knowledge on the governance of ethics at the intersection of global implications and local contexts. As the rapid iterations of AI are triggering more profound controversies, the scope of the ethics of AI is expanding, and new regulations, laws and rules are being adopted. The three competency blocks for this aspect outline key steps for students to gradually internalize ethical principles as well as habituate compliance with AI regulations.

Embodied ethics: Students are expected to develop a basic understanding of the issues underlying key ethical debates around AI, including the impact of AI on human rights, social justice, inclusion, equity and climate change within their local context and personal lives. They will have understood, internalized, and adopted the following principles in their reflective practices and uses of AI tools in their learning and beyond:

- **Do no harm:** Students demonstrate an understanding that AI systems should not be used for purposes that might be harmful for humans (such as facial recognition for surveillance or assigning social status, or predictive algorithms for grading examinations). This includes the ability to assess whether a certain AI solution infringes upon human values and rights, particularly data privacy, and to decide on whether a particular AI method complies with global or local regulations.
- **Proportionality:** Students develop the capacity – as appropriate for their age and ability level – to examine whether or not the use of a specific AI system is advantageous in achieving a justified aim, and whether or not a given AI method is appropriate to the context.
- **Non-discrimination:** Students are aware of and are able to detect gender, ethnic, cultural and other biases embedded in AI tools or their outputs. Further, students are aware of AI divides within and between countries, and understand the need to make efforts to address these and ensure greater accessibility and inclusivity.
- **Sustainability:** Students are able to explain and illustrate the implications of AI systems for environmental sustainability.

- **Human determination in human–AI collaboration:** Students are able to demonstrate why humans should bear ethical and legal responsibilities for the use of AI; they are able to exemplify how humans can remain accountable in AI-assisted decision-making loops, rather than cede determination to machines.
- **Transparency and explainability:** Students are aware that users are entitled to request explanatory information from designers and providers on how AI tools work, how their outputs are produced based on algorithms and models, and the degree to which the deployment and application of certain AI tools are appropriate for users of a certain age or ability level.
- **Safe and responsible use:** Students are expected to be able to use AI in a responsible manner in compliance with ethical principles and locally applicable regulations. They are aware of the risks of disclosing data privacy and they take measures to ensure that their data are collected, used, shared, archived and deleted only with their deliberate and informed consent. They are also aware of the specific risks of certain AI systems, and are able to protect their own safety, as well as that of their peers, when using AI.
- **Ethics by design:** Students are expected to adopt an ethics-by-design approach to the design, assessment and use of AI tools, as well as to the review and adaptation of AI regulations. Students are aware that assessing the intent behind AI design involves examining all steps of the AI life cycle, starting with the stage of conceptualization. Students should be able to assess the compliance of an AI tool with ethical regulations, as well as review AI regulations and inform adaptation.

AI techniques and applications

Competency aspects	Progression levels		
	Understand	**Apply**	**Create**
• AI techniques and applications	• AI foundations	• Application skills	• Creating AI tools

The 'AI techniques and applications' aspect represents the intrinsically linked conceptual knowledge on AI and associated operational skills, in connection with concrete AI tools or authentic tasks. This aspect serves as the most important and transferable technical foundation for a concrete understanding and application of a human-centred mindset and its associated ethical principles. The basic knowledge structure and practical skills on data and AI programming is the foundation for the capacity to design and build AI systems, especially for students who have strong interests and abilities in the field. The 'AI techniques and applications' aspect implies that students are expected to look into exemplar AI tools to gain insight on how AI is developed, based on data and algorithms. Students will synchronically acquire skills in AI programming and reinforce the transferability of their knowledge and skills by applying them to the crafting of AI tools. In the stream of the three progression levels, students are also expected to integrate ethical, cultural and social parameters, and solidify the interdisciplinary foundational knowledge and skills in science, technology, engineering, mathematics, arts, languages and social studies.

AI foundations: Students are expected to be able to build basic knowledge and skills on AI, particularly with respect to data and algorithms, understanding the importance of the interdisciplinary foundational knowledge required to gradually deepen understanding of data and algorithms. Students should also be able to connect conceptual knowledge on AI with their activities in society and daily life, concretizing a human-centred mindset and ethical principles by understanding how AI works and how AI interacts with humans.

Application skills: Students are expected to be able to construct an age-appropriate understanding of data, AI algorithms and programming, as well as acquire transferable application skills. Students are expected to be able to critically evaluate and leverage free and/or open-source AI tools, programming libraries and datasets.

Creating AI tools: Students are expected to be able to deepen and apply knowledge and skills on data and algorithms to customize existing AI toolkits to create task-based AI tools. Students are expected to integrate their human-centred mindset and ethical considerations into the assessment of existing AI resources. They are also expected to develop the social and emotional skills needed to engage in creating with AI, including through adaptivity, complex communication and teamwork skills.

AI system design

Competency aspects	Progression levels		
	Understand	**Apply**	**Create**
• AI system design	• Problem scoping	• Architecture design	• Iteration and feedback loops

The aspect of 'AI system design' focuses on the systemic design thinking and comprehensive engineering skills required for problem scoping, design, architecture building, training, testing and optimization of AI systems. This aspect aims to challenge the explainability of AI systems and to enable exploratory learning for students who will pursue further programmes of study in the field. Students are also expected to deepen and practise 'ethics by design'. Although the systemic design thinking methodology, associated human-centred values and ethical principles, and required knowledge and skills on AI may be embedded in all other aspects of students' AI competencies, this aspect mainly targets students who have a particular interest in, and commitment to, deepening their knowledge and skills in this field.

Problem scoping: Students are expected to be able to understand the importance of 'AI problem scoping' as the starting point for AI innovation. They are expected to be able to examine whether AI should be used in particular situations, from a legal, ethical and logical perspective; and to define the boundaries, goals and constraints of a problem before attempting to train an AI model to solve it. Students are also expected to acquire the knowledge and project-planning skills needed in order to conceptualize and construct an AI system, including the ability to assess the appropriateness of different AI techniques, define the need for data, and devise test and feedback metrics.

Architecture design: Students are expected to be able to cultivate basic methodological knowledge and technical skills to configure a scalable, maintainable and reusable architecture for an AI system covering layers of data, algorithms, models and application interfaces. Students are expected to develop the interdisciplinary skills necessary to leverage datasets, programming tools and computational resources to construct a prototype AI system. This includes the expectation that they apply deepened human-centred values and ethical principles in their configuration, construction and optimization.

Iteration and feedback: Students are expected to enhance and apply their interdisciplinary knowledge and practical methods to evaluate the appropriateness and methodological robustness of an AI model and its impact on individual users, societies and the environment. They should be able to acquire age-appropriate technical skills to improve the quality of datasets, reconfigure algorithms and enhance architectures in response to results of tests and feedback. They should be able to apply a human-centred mindset and ethical principles in simulating decision-making on when an AI system should be shut down and how its negative impact can be mitigated. They are also be expected to cultivate their identities as co-creators within the wider AI community.

Chapter 4: Specifications of AI competencies for students

The following specifications of the AI CFS clarify what each competency block entails in terms of curricular goals, desirable pedagogical methods and required learning environments, with consideration given to inclusivity as well as variation in levels of AI readiness.

The specifications outlined below are based on the assumption that students' AI competencies are the result of the integrated interventions of national AI curricula; extracurricular programmes; informal learning through various media, including the internet; and engagement with families and local communities. To guide the development of an AI curriculum, the AI CFS specifies the expected learning and behavioural outcomes of a formal AI curriculum while considering the impact of informal learning in social contexts. AI-related learning – introduced into curricula as a specific subject, or as modules within related disciplines, such as computer science or information and communication technology (ICT) – should be allocated adequate instructional time within a semester, or preferably, across multiple semesters.

The specified curricular goals outline domain-specific values, knowledge and skills that can be applied to students at a range of ages and ability levels, who are exposed to AI-related learning for the first time. It is up to national or institutional curriculum agencies to define concrete learning objectives for specific student cohorts, based on their AI readiness and that of their teachers, available instructional time and local learning environments. The specifications include recommendations for configuring these environments in line with the curricular goals, with regard to inclusivity, the potential of open-source options, and the sharing of AI resources with academic institutes and the private sector.

Finally, the specifications also propose pedagogical methodologies for specific domains of AI at a certain progression level. These may inspire teachers and students to explore agile methods of delivery that are relevant for specific contexts and needs.

4.1 Level 1: Understand

The overall goal of this level is to support all students to acquire an understanding of what AI is and to construct age-appropriate interpretations of the values, ethical issues, concepts, processes and technical methods underlying AI tools and their uses. Students should also be supported to make connections between their knowledge of AI and real-life experiences, and between domain-specific knowledge of AI and knowledge of related learning areas.

The curricular goals outlined in **Table 2** help to map the set of foundational values, ethical principles, knowledge and understanding that can ensure the proper and effective use of AI by students – an ability sometimes referred to as 'AI literacy'. The suggested pedagogical methods are designed to facilitate age- and domain-appropriate teaching and learning practices that can potentially stimulate students' interests and support their learning trajectory on the basis of concrete tools, personal experiences, and real-world use scenarios. The specifications also recommend basic learning settings, which include practising with unplugged and low-tech options.

Table 2. Competency blocks for level 1: Understand

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset	**4.1.1 Human agency** • Students are expected to be able to recognize that AI is human-led and that the decisions of the AI creators influence how AI systems impact human rights, human–AI interaction, and their own lives and societies. They are expected to understand the implications of protecting human agency throughout the design, provision and use of AI. Students will understand what it means for AI to be human-controlled, and what the consequences could be when that is not the case.	• **CG4.1.1.1 Foster an understanding that AI is human-led:** Based on selected AI tools, explain to students that AI is human-led; facilitate students to develop a stepwise and integral comprehension of human agency which may cover principles on data ownership and data privacy, protection of human rights in collecting and processing data, explainability of AI methods, human control in deployment, and human determination in using AI for decision-making. Guide students to understand that AI cannot replace human thinking or intellectual development. • **CG4.1.1.2 Facilitate an understanding on the necessity of exercising sufficient human control over AI:** Expose students to real-world scenarios and guide students to experience the consequences of human oversight in controlling AI (e.g. weak regulations failing to prevent the design and production of harmful AI tools, the institutional use of AI to substitute for humans when making high-stakes decisions, and the absence of human validation of the accuracy of AI outputs). Help students to grasp the necessity of exercising human control over AI	• **Visualizing the abstract concept of human agency throughout the AI life cycle:** Ask students to draw concept maps of human agency in key steps of the life cycle of selected AI tools, including data ownership, respecting data privacy when collecting and processing data, explainability of AI algorithms and AI models, human-controlled evaluation of AI outputs, and human determination in AI-assisted decision-making. The concept maps should also reflect on the potential consequences of a loss of human agency at each step, for the individual and for society. • **Simulating an AI Act courtroom debate to evaluate creators' intents underlying prohibited AI systems:** Based on an age-appropriate interpretation of the definition of AI systems prohibited under the European Union's AI Act, organize students to act as jury members to evaluate selected examples of AI systems that are due to be prohibited under the AI Act, deliberating on what their creators' intents and motivations may have been. Help students understand how these systems can do harm to humans, especially by undermining human agency: for example, an	• Unplugged learning settings like paper-based articles, printed reading materials and worksheets. • Locally available AI tools including mobile phones with AI applications. • Predownloaded or recorded videos and other resources related to specific case studies, or scenarios that present a dilemma. • Search engines, online videos and supplemental online learning courses.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset		systems at regulatory, institutional and individual levels to protect human safety, morality and dignity. • **CG4.1.1.3 Nurture critical thinking on the dynamic relationship between human agency and machine agency:** Expose students to real-world cases in which AI can support human agency and human decision loops, support students to understand how humans can properly interact with AI to enhance human capacities. Guide students in holding conflict-based debates on dynamic boundaries between human agency and AI agency, revealing situations in which a certain extent of machine agency might be needed (e.g. detecting medical patterns that are undetectable for human doctors in diagnosing rare diseases, auto spell check and autocorrection when humans draft reports, auto captioning or automating video-production in the development of course materials, automatic language translation, etc.). Foster a critical view that while human agency must be upheld when using AI to make high-stakes decisions, the relationship between human and machine agency in real-world situations should be examined based on the specific needs and contextual factors involved.	AI system may deploy techniques to weaken a person's awareness or purposefully impair their ability to make an informed decision. • **Scenario-based understanding of human-controlled interaction with AI:** Select examples or scenarios in which AI tools are used in workplaces or daily life, denoting what they and their human users are contributing to the target task units. Encourage students to recognize the contribution AI can make in scenarios where human capabilities and intelligence may have limitations, underlining the importance of using AI to enhance human capacities while ensuring human control. • **Debating the dynamic boundary between human agency and machine agency:** Based on the real-world cases of dilemmas surrounding humans' reliance on machine agency, encourage students to conduct a debate on the changing roles humans and AI may play in AI-supported problem-solving and decision-making processes. Guide student to visualize the abstract boundaries between human agency and machine agency in various contexts.	

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Ethics of AI	**4.1.2 Embodied ethics** • Students are expected to be able to develop a basic understanding of the ethical issues around AI, and the potential impact of AI on human rights, social justice, inclusion, equity and climate change within their local context and with regard to their personal lives. They will understand, and internalize the following key ethical principles, and will translate these in their reflective practices and uses of AI tools in their lives and learning: • Do no harm: Evaluating AI's regulatory compliance and potential to infringe on human rights • Proportionality: Assessing AI's benefits against risks and costs; evaluating context-appropriateness • Non-discrimination: Detecting biases and promoting inclusivity and sustainability	• **CG4.1.2.1 Illustrate dilemmas around AI and identify the main reasons behind ethical conflicts:** Based on concrete AI tools, guide students to surface dilemma decisions that individual or corporate creators need to make in the design and development of AI (e.g. maximizing the scale of data collection versus protecting data ownership, recording users' private data for the training of AI models versus protecting their privacy, promoting machine control to generate profit versus guaranteeing the primacy of human agency, and prioritizing AI safety versus accelerating the iteration of AI). Support students to associate perspectives on these dilemmas with the reasons behind ethical conflicts around AI. • **CG4.1.2.2 Facilitate scenario-based understandings of ethical principles on AI and their personal implications:** Offer students opportunities to discuss age-appropriate real-world cases around the six core AI ethical principles: (1) 'do no harm', 2) proportionality, (3) non-discrimination, (4) sustainability, (5) human determination, and (6) transparency and explainability. Guide students to build a knowledge framework on the ethics of AI and practice	• **Case studies on scenarios containing controversies around AI:** Present age-appropriate real-world or simulated scenarios, and guide students to surface controversies surrounding the AI tools and their uses. Discuss the main reasons behind such ethical conflicts and facilitate students to draw infographics or concept maps illustrating the core AI ethical principles. • **Individual or group reflection on the personal implications of ethical dilemmas:** Engage students in group discussion and opinion taking on ethical dilemmas that may arise from uses of AI in daily life and learning in local contexts (e.g. whether large language models should use the data of local communities in their training or not; to what extent AI has a negative environmental impact or mitigates climate change; how much of their privacy users should forego to exchange benefits of AI services). Guide students to present their opinions through age-appropriate formats such as essays, posters, drawings or storyboards. • **Searching for and validating examples of 'AI for the public good':** Organize individual or group scoping of examples of AI tools or approaches to the use of AI that	• Unplugged learning settings and materials including print stories or case studies, worksheets and posters. • Locally available AI tools including those available through mobile phone apps. • Predownloaded or recorded videos and other resources related to specific cases or scenarios that present a dilemma. • Search engines, online videos or resources related to case studies.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Ethics of AI	(understanding AI's environmental and societal impacts) • Human determination: Emphasizing human agency and accountability in AI use • Transparency: advocating for the rights of users to understand AI operations and decisions	them in evaluating the AI tools being used in their lives and schools. • **CG4.1.2.3 Guide the embodied reflection and internalization of ethical principles on AI:** Guide students to understand the implications of ethical principles on AI for their human rights, data privacy, safety, human agency, as well as for equity, inclusion, social justice and environmental sustainability. Guide students to develop embodied comprehension of ethical principles; and offer opportunities to reflect on personal attitudes that can help address ethical challenges (e.g. advocating for inclusive interfaces for AI tools, promoting inclusion in AI and reporting discriminatory biases found in AI tools).	support the public good, including promoting equity and inclusion for people with disabilities, preserving linguistic and cultural diversity, and increasing social justice and environmental sustainability. Guide students to collect evidence on and discuss examples that genuinely serve the public good; validate and categorize these examples.	
AI techniques and applications	**4.1.3 AI foundations** • Students are expected to develop basic knowledge, understanding and skills on AI, particularly with respect to data and algorithms, and understand the importance of the interdisciplinary foundational knowledge required for gradually deepening	• **CG4.1.3.1 Exemplify the definition and scope of AI:** Based on examples of AI tools (e.g. for facial recognition, social media recommendations, pattern analyses underlying scientific data, medical diagnoses, self-driving cars and predicting the risk of loan defaults), facilitate students to understand what AI is and is not; guide students to find and share exemplar tools under the main categories of AI technologies and explain	• **Example-based definition and scope of AI:** Investigate and experiment with examples of AI tools (e.g. in the medical field using supervised learning and image classification for cancer diagnosis, or in business contexts using natural language processing and generative AI for automated minute-taking and composing literature reviews). Based on selected examples, help students to understand what AI is and is not, and the main categories of AI technologies adopted in daily life, as well	• Unplugged learning settings and resources, including textbooks, essays, worksheets and printed materials. • Online or downloaded videos and other media introducing AI innovations or tools. • Locally available AI tools including basic AI-assisted

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI techniques and applications	understanding of data and algorithms. Students should also be able to connect conceptual knowledge on AI with their activities in society and daily life, concretizing a human-centred mindset and ethical principles through an understanding of how AI works and how AI interacts with humans.	their main functions and techniques in an age-appropriate manner. • **CG4.1.3.2 Develop conceptual knowledge on how AI is trained based on data and algorithms:** Foster students' example-based abstraction of conceptual knowledge on how machine-learning models are trained using data and algorithms; help students to develop an age-appropriate understanding of the three types of AI algorithms, namely, supervised learning, unsupervised learning and reinforcement learning. This should include how data behind the three types of AI algorithms are acquired and labelled. Debunk the claims that AI will automate the programming of algorithms and that humans do not need to learn about algorithms. • **CG4.1.3.3 Foster open-minded thinking on AI and an interdisciplinary foundation for AI:** Enable students to gain appropriate knowledge on AI methods and research topics such as the uses of artificial neural networks and the difference between strong AI and weak AI. Offer extended learning opportunities on data and algorithms to students who have strong interests and abilities in AI. Guide students to understand the interplay between knowledge	as in economic and social activities. Guide students to explore the key steps of the AI life cycle; where appropriate, draw a diagram of the cycle for particular AI systems and label the key AI techniques used. • **Spiral learning from examples to abstract concepts and from concepts to specific techniques:** Use selected examples to guide students to abstract how a machine learning model is trained, including the steps of problem definition, data collection, data processing, training, evaluation, deployment and iteration based on tests and feedback. Support students' development of age-appropriate knowledge about (and where possible, basic operational skills on) the use of AI techniques involving datasets, algorithms, AI architectures, setting up of computing environments, design of functionalities and interfaces, and planning of deployment scenarios. • **Case analysis of innovative AI tools and innovative uses of AI:** Organize students to search for potential innovative AI tools and/or innovative uses of AI; guide students to identify the key techniques and main categories of AI used in these applications. Facilitate them to write an argumentative essay or provide an oral defense on the extent to	applications installed on smartphones. • Online AI tools, for example image and/or video creators, generative AI model and video recommendations on social media.

	STUDENT COMPETENCY	CURRICULAR GOALS (AI curricula or programmes of study should…)	SUGGESTED PEDAGOGICAL METHODS (Institutions and teachers can consider and adapt the following learning methods.)	LEARNING ENVIRONMENTS (The following learning settings can be provided and adapted.)
AI techniques and applications		on AI and knowledge in STEM, languages and social studies, and invite them to solidify related interdisciplinary knowledge and the reflections on the reciprocal impact of AI on related subjects. • **CG4.1.3.4 Concretize human-centred considerations in the design and use of AI:** Organize tool-based reflections on AI to give form to students' understanding of its impact on life, work and societal relationships. Highlight humans' roles in the key steps of the AI life cycle (e.g. researchers, architecture engineers, data engineers, data workers, beta testers, regulators of ethics and safety, specialists in human–AI interfaces and auditors of system compliance). Guide students toward a deep familiarity with the main ethical issues related to the use of data for training AI systems.	which these AI technologies may help humans engineer innovations in their personal practices, economic or business models, or social services, and/or the risks that specific AI technologies may pose to ethical principles and human agency. • **Solidifying multidisciplinary foundation for AI with a specific focus on mathematics:** Based on lectures and problem-based inquiry, help students grasp that modern AI systems are rooted in mathematics, and learning about data and algorithms requires a strong command of mathematics and a multidisciplinary knowledge set. Nurture students' essential mathematical and interdisciplinary skills for AI development, including relevant material on algebra, probability and statistics, data structures and algorithms such as K-nearest neighbours, K-means clustering, linear regression and CART/decision trees. Cultivate students' higher-level knowledge on linear algebra for complex data representation and matrix mathematics, calculus for back propagation and gradient descent for understanding machine learning and neural networks. Support students to solidify and extend their other multidisciplinary foundational knowledge as well, especially in science, technology and engineering.	

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design	**4.1.4 Problem scoping** • Students are expected to be able to understand the importance of 'AI problem scoping' as the starting point for AI innovation. They are expected to be able to examine whether AI should be used in certain situations from legal, ethical and logical perspectives; students are able to define the boundaries, goals and constraints of a problem before attempting to train an AI model to solve it; students are also expected to acquire the knowledge and project-planning skills needed in order to conceptualize and construct an AI system, including by assessing the appropriateness of different AI techniques, defining the need for data, and devising test and feedback metrics.	• **CG4.1.4.1 Scaffold critical thinking skills on when AI should not be used:** Drawing from examples, guide students to develop critical analysis skills to examine reasons why AI should or should not be used to address certain real-world challenges (e.g. improving institutional productivity, the sustainable development of communities, or the precision and efficiency of human decision-making) with reference to human and environmental implications. Provide clarity on when, and under what conditions, AI cannot and/or should not be applied to problems (e.g. where non-AI solutions would offer the same performance with lower ethical risk and environmental impact, or where the use of AI would weaken human consciousness or manipulate human actions). • **CG4.1.4.2 Support the acquisition and reinforcement of skills in scoping a problem to be solved by an AI system:** Based on a simulation project, support the learning and practice of skills to identify and scope a problem that should and could possibly be solved by building a new AI model (e.g. training an AI model on a minority language to better serve its community, or building a model for	• **Simulating the review of project proposals:** Organize students to simulate the review of a project proposal and justification process. The proposals could, for example, be on building or selecting an AI system. Conduct a debate on whether AI should or should not be used in the project to solve the problem, considering factors such as the availability of sufficient training data, ethical implications, environmental impact and whether non-AI solutions could achieve similar outcomes with fewer risks. Guide students to outline a checkbox for the review. • **Simulating the problem-scoping and justification for the design of new AI system:** Facilitate students to research problems in their daily lives or communities (e.g. at school or in volunteer work) and identify a problem that could potentially be addressed by AI (e.g. automatic watering the school garden or helping a hard-of-hearing grandparent to detect alarms). Support students to scope and define the problem by anticipating the key features including AI algorithms and datasets, and produce a corresponding problem statement. • **Data preprocessing lab:** Using a basic dataset and the architecture of an existing AI model, organize experiments on training the model	• Unplugged learning settings including worksheets, paper-based case studies, and printouts of prototypes or plans for AI system design. • Digital devices with an internet connection. • Selected online AI systems.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design		the automated tracking of migration across target regions). Students can sharpen their analytical skills by formulating problem statements that can help avoid wastage of time and effort on poorly defined problems. • **CG4.1.4.3 Develop skills on assessing AI systems' need for data, algorithms and computing resources:** Offer opportunities for students to develop planning skills by assessing the need for data, algorithms and programming languages, software, computing capabilities and hardware; study the feasibility of an AI project in terms of the data available given the regulatory and ethical restrictions and the total costs of the required processing and engineering of data, computing capabilities and hardware.	based on variations of the dataset (e.g. a challenge of classifying mystery images). Support students to apply various data preprocessing techniques, such as adjusting the coding (e.g. data augmentation, handling outliers and analysing dataset skew/imbalance). Support them to train the model based on the modified datasets and observe how the data preprocessing has affected the model's performance.	

4.2 Level 2: Apply

The overall goal of the 'Apply' level is for students to construct a solid and transferable conceptual knowledge structure and associated skill sets on AI and to habituate their application of the human-centred mindset and ethical principles to guide the assessment, learning and practice of AI tools. The curricular goals in **Table 3** aim to guide the charting of a core set of value orientations, practical ethical principles and methodological knowledge that can be used to tailor curricular modules and specify exit competencies for all students. The suggested pedagogical methods are intended to catalyse problem-based inquiry of conceptual knowledge and task-based appreciation of operational skills while integrating strategies to maintain students' curiosity for further study. Providing desirable learning environments at the 'Apply' level involves setting up hardware, software and applications to support practices of AI operation and co-creation, with considerations of open source options.

Table 3. Competency blocks for level 2: Apply

	STUDENT COMPETENCY	CURRICULAR GOALS (AI curricula or programmes of study should…)	SUGGESTED PEDAGOGICAL METHODS (Institutions and teachers can consider and adapt the following learning methods.)	LEARNING ENVIRONMENTS (The following learning settings can be provided and adapted.)
Human-centred mindset	**4.2.1 Human accountability** • Students are expected to be able to recognize that human accountabilities are the legal obligations of AI creators and AI service providers, and understand what human accountabilities they should assume during the design and use of AI. They should also foster an awareness that human accountability is a legal and social responsibility when using AI to assist decisions on that affect humanity	• **CG4.2.1.1 Develop a view that human accountability is a legal obligation of AI creators and AI service providers:** Leveraging prior knowledge on the human-led AI life cycle and real-world lawsuits, guide students to understand that human AI creators and service providers, and institutions deploying AI tools, are accountable for legal issues, violations and infringements that the AI system or service may cause. Explain how to hold AI creators, providers and institutional users to assume human accountability for safety incidents, ethical risks in designing and training AI, and misuses of the AI service to control users. Guide students to understand what human accountabilities they should	• **Writing guidelines on human accountability for AI creators and service providers:** Facilitate students to play the roles of AI creators and data owners and discuss their key legal and ethical accountabilities in terms of maintaining human control of the collection and processing of data, training AI models, designing functionalities and interfaces, deployment of AI systems, and monitoring and feedback loops. Guide them to write self-discipline guidelines for their studies on the design, training and iteration of AI systems, holding AI creators to account for protecting the rights of data owners and AI users.	• Unplugged and/or offline learning settings and resources, including print-based case studies, role-play scripts, videos, worksheets and flipcharts. • Online AI tools, for example learning management systems, social media platforms and generative AI platforms.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset	and uphold the principle that humans should not cede the determination to AI when making high-stakes decisions. They are also expected to enhance their judgement on, and attitudinal resilience to, the illusive claims on about the use of outputs and as well as predictions that AI can usurp humans' thinking and decision-making.	assume themselves when learning how to create AI tools or design AI systems. • CG4.2.1.2 **Generate the understanding that human accountability is a legal and social responsibility when using AI in making decisions about humanity:** Guide students to analyse the capabilities of AI tools used to assist decision-making. Critically interrogate the genuine capabilities of certain AI tools and debunk the hype around AI's supposed ability to make decisions. Assist students to evaluate the consequences of the institutional use of AI to make decisions about humans in complex situations such as profiling the aptitude of students to take up further learning opportunities or determining the employability of job candidates. Lead discussions on why human accountability in using AI is essential to safeguard human rights and human dignity. Facilitate students to understand why we should not use AI to replace humans when making high-stakes decisions, for example to assess the values, infer the emotions or predict the aptitudes of a natural person. AI algorithms should not be used to assign students'	• **Investigating the impact of AI-assisted decisions on humans and avenues of redress within AI regulations:** Ask students to find examples in which decisions about humans are determined or greatly influenced by AI (e.g. an AI-assisted assessment system used by a bank to approve or deny a student loan application, or a profiling system used by a hotel to predict a person's socio-economic background based on their location and the device they were using when they made their booking). Facilitate students to reveal the roles of humans and AI in the key steps of decision loops, and check whether human accountability for the decisions is in compliance with locally applicable or international regulations (e.g. the EU AI Act). • **Scenario-based practices of using AI with purpose:** Engage students in activities where they use AI tools to purposefully practise their writing skills and foster their inquiry-based learning, higher-order thinking and creativity. Lead students to discuss how the use of AI without human accountability (e.g. handing in an essay produced by AI) may reduce human intellectual development. Prompt them to outline concrete actions to protect themselves and their peers from the use of AI outputs	

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset		scores (as happened during COVID-19) or decide on university admissions. • **CG4.2.1.3 Nurture the personal attitude that human accountability requires personal competencies to steer the purposeful use of AI:** Guide students to interrogate how the automation of literature reviews, writing and artistic creation may undermine human thinking processes and intellectual development. Guide students to discuss concrete actions that they can take to protect themselves and their peers from the use of AI outputs or predictions to usurp human thought, intellectual practices and continuous capacity enhancement.	or predictions to usurp thinking processes, and give them insight into the competencies that students need in order to steer the use of AI toward serving human capability development.	
Ethics of AI	**4.2.2 Safe and responsible use** • Students are expected to be able to carry out responsible AI practices in compliance with ethical principles and locally applicable regulations. They are expected to be conscious of the risks of disclosing data privacy and take measures to ensure that their data are collected, used, shared, archived and	• **CG4.2.2.1 Foster self-awareness and habitual compliance with ethical principles for the responsible use of AI**: Illustrate the ethical principles or regulatory articles concerning the responsible use of AI, drawing on concrete AI tools and real-world use scenarios. Support students to iteratively build and update a checkbox of ethical principles for ensuring their own lawful and responsible practices when engaging with AI systems. Guide students to practise and habituate their compliance with these principles, such	• **Designing an 'ethics kit' for the self-disciplined, responsible use of AI:** Design simulated scenarios containing potential ethical conflicts (e.g. sharing private data or protected content when chatting with AI systems, putting AI-generated content in a school assignment, creating a video using images of other people, or distributing misinformation, disinformation or hate speech). Organize the drafting of an 'ethics kit' that users need to habitually check when using AI, including articles drawn from locally applicable	• Unplugged learning settings and resources, including paper-based worksheets, posters and checklists of ethical principles. • Predownloaded privacy policies and AI regulations, and examples of legal or ethical cases concerning AI safety, data privacy and forms of consent. • Locally available AI tools including smartphone apps.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Ethics of AI	deleted only with their deliberate and informed consent. They are also expected to be conscious of typical AI incidents and the specific risks of certain AI systems, and be able to protect their own safety and that of their peers when using AI.	as protecting personal data and privacy, respecting copyright, clearly marking where AI-generated content appears, and avoiding inputs or interactions in AI systems that involve disinformation, misinformation, hate speech or sensitive details about identifiable individuals. • **CG4.2.2.2 Offer opportunities to reinforce self-discipline in the responsible use of AI**: Provide students with opportunities to gain an age-appropriate understanding of their personal, legal and ethical responsibilities when using AI; highlight the consequences of violating regulations; and build and reinforce self-disciplined behaviours, especially with regard to sensitive personal data, copyrighted materials, images depicting identifiable people, content that is AI-generated or digitally synthetized, and the spread of misinformation, disinformation and hate speech. • **CG4.2.2.3 Deepen practical knowledge on the safe use of AI and awareness of locally applicable regulations:** Facilitate students to categorize the general safety risks of AI, potential safety risks of specific AI tools, and typical AI incidents. Guide students to deepen	regulations and personal responsibilities in making legal and ethically proper use of AI tools. Guide students to practice the compliance with the principles when using AI without supervision. • **Simulation of typical AI incidents and risk management**: Expose students to simulated AI incidents that directly harm humans or AI hazards that threaten harm. Familiarize them with precautionary and interactive strategies for ensuring their personal data is collected, used, shared, archived and deleted only with their informed consent. Suggest tips for the safe use of AI, and promote awareness of the regulations that can protect their privacy and well-being and/or mitigate negative impacts in the case of AI incidents. • **Users' reviews of AI creators' policies on data privacy:** Encourage students to search for and download examples of AI creators' policies on data privacy. Guide them to leverage their knowledge on the rights of data owners and legal responsibilities of AI creators to check whether the policies comply with relevant regulations. When they discover a violation, ask them to draft a complaint to the regulatory agencies and/or a recommendation for the AI creator to improve the conformity of their policies and practices.	• Online AI tools especially platforms containing recommender algorithms and content generators.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Ethics of AI		their knowledge on human rights to data protection and privacy and the legal responsibilities of AI creators to collect data with consent, and guide them to practise strategies for ensuring their personal data is collected, used, shared, archived and deleted only with their informed consent. Expose students to simulated scenarios containing typical AI incidents, so they can practise precautionary and interactive strategies for the safe use of AI and become familiar with regulations that can protect their safety or mitigate the negative impacts of AI incidents.	• **Debate the ownership of AI-generated content and outputs from human–AI interactions:** Organize a debate to trigger students' reflections around the ownership of content created using AI. Examine the availability and applicability of regulations on the recognition of copyright for AI-generated content and resources, and how relevant regulations recognize intellectual work that integrates different extents of AI-generated content.	
AI techniques and applications	**4.2.3 Application skills** • Students are expected to be able to construct an age-appropriate knowledge structure on data, AI algorithms and programming, and acquire transferable application skills. Students are expected to be able to critically evaluate and leverage free and/ or open-source AI tools, programming libraries and datasets.	• **CG4.2.3.1 Offer opportunities to strengthen knowledge and skills on data modelling, engineering and analysis**: Provide students with task-based learning opportunities to acquire age-appropriate knowledge and skills on datasets, including applying age-appropriate tools or programming languages to acquire, clean and transform data into a suitable format for storing, processing, and analysing databases (e.g. SQL, NoSQL, SparkSQL or Apache Flink). • **CG4.2.3.2 Provide opportunities to acquire age-appropriate technical skills in AI programming**: Explain examples of AI systems that use different	• **Data biases lab:** Provide students with sample datasets with and without outliers, guide students to conduct hands-on experimentation on how the outliers impact the model (e.g. in regression or clustering examples). For image classification, ask students to conduct an experiment on how class imbalance (e.g. significantly more data in one class than the other) affects model performance per class. Guide students to learn age-appropriate skills in data engineering to remove identifiable biases and compare the results. • **Tailored optional modular courses on various AI algorithms to support cohort-based learning:** Tailor free and/or open-source	• Computers with internet connection. • Computer-based samples of datasets or locally accessible public datasets. • Computer-based applications for AI programming or locally accessible online open-source AI programming libraries. • Computer-based or locally accessible online AI tools.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI techniques and applications		categories of AI algorithms to scaffold students' age-appropriate understanding of AI algorithms including supervised learning, unsupervised learning and reinforcement learning. This should include how they scrape and process data, how they're trained, how they function, and the concrete types of algorithms that underlie these categories. Where appropriate, provide students with task-based learning opportunities to cultivate methodological knowledge on selected AI algorithms. • **CG4.2.3.3 Encourage students to develop analytical and synthesis skills to leverage open-source datasets and AI tools**: Organize problem-based learning to facilitate students' acquisition of skills to critically evaluate and leverage open-source AI datasets (e.g. MNIST[12] CIFAR,[13] or ImageNet)[14] and tools from free and/or open-source AI algorithm libraries (e.g. Teachable Machine,[15] MIT App Inventor,[16] PyTorch,[17] or Keras)[18] to address authentic tasks. Drawing on variations of problems, guide students to practise and enhance the transferability of their knowledge and skills on data and algorithms into complex contexts.	AI datasets and AI algorithm libraries according to the age and prior knowledge of target students. Develop optional modular courses on various AI algorithms and support cohorts of students to choose the courses that align with their interests, to acquire methodological knowledge and skills in applying AI algorithms. • **AI hackathons based on variations of authentic tasks:** Schedule a significant amount of continuous learning hours to challenge interested students to conduct task-based hackathons. Design a series of tasks with variations to enable students to practise their transferable AI programming skills. • **Debunking claims that AI will automate coding and human students don't need to learn AI programming:** Facilitate students' research into the professional knowledge and skills demanded by the creation and iteration of AI systems, especially the foundation of methodological knowledge necessary to explore more human-centred and innovative AI algorithms and methods. Challenge students to contemplate how using AI to replace humans' programming skills will lead to fewer people acquiring these foundational skills, and exacerbate the inequality between those with and without AI-related knowledge.	

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design	**4.2.4 Architecture design** • Students are expected to be able to cultivate basic methodological knowledge and technical skills to configure a scalable, maintainable and reusable architecture for an AI system covering layers of data, algorithms, models and application interfaces. Students are expected to develop the interdisciplinary skills necessary to leverage datasets, programming tools and computational resources to construct a prototype AI system. This includes the expectation that they apply deepened human-centred values and ethical principles in their configuration, construction and optimization.	• **CG4.2.4.1 Scaffold the acquisition of methodological knowledge and technical skills on AI architecture:** Facilitate students to acquire and practise the necessary engineering thinking and operational skills to evaluate a variety of AI architectures with an aim to choose an appropriate solution based on a defined problem statement, while considering open-source options. Provide project-based learning opportunities to support their acquisition of methodological knowledge on the configuration of a prototype AI architecture encompassing an anti-bias data structure, an energy-efficient AI model to minimize the negative environmental impact, the human-centred design of performance and services, and metrics to test and improvise the maturity of the configuration. • **CG4.2.4.2 Support the preparation of advanced technical skills and project management competencies needed by AI system building:** Offer project-based learning opportunities to facilitate students to acquire and apply the interdisciplinary technical skills demanded by the building of a prototype AI system designed for a simple specific task (e.g. a chatbot imitating the responses of	• **Simulating the evaluation of frameworks and components for AI architectural configuration:** Based on the problem statement and feasibility study, facilitate students to evaluate a variety of frameworks for AI architectures (e.g. TensorFlow, PyTorch, or Scikit-learn). Simulate the evaluation and selection of solutions to the components of the architecture (e.g. data layer, algorithm layer, AI model layer and interface layer) based on the selected framework. Configure a prototype architecture encompassing the required datasets, algorithm tools, AI model and required computational resources, the design of main functionalities and interface, and the plans for deployment. Guide students to communicate the configuration through abstractions such as flowcharts, diagrams or pseudocode. • **Simulating the leveraging of resources to build an AI system:** Facilitate students to build the simulated AI system based on locally hosted computing devices or locally accessible cloud computing platforms (e.g. Hadoop or Spark), and the operating systems (e.g. GNU) and software needed to train the machine-learning models. Guide students to conduct trade-offs between cost and computing capability needs, and between the robustness	• Videos and metrics showing how to conduct ethical and technical evaluations of AI models. • Computer-based or locally accessible online examples of AI systems. • Computer-based samples of datasets or locally accessible public datasets. • Computer-based applications for AI programming or locally accessible online open-source AI programming libraries. • Locally hosted or open-source cloud computing and other resources shared by institutions through cloud platforms.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design		an experienced teacher). Explore the leveraging and normalization of datasets, assembling of virtual computational resources, and selection and enhancements of AI models (e.g. hyperparameter optimization). Guide students to simulate the training of a machine-learning model, including the practical use of computational resources and calling of data to train the models based on the selected and preprocessed datasets. Design and arrange opportunities for students to acquire project management skills including balancing the scope of the AI systems with the resources available, coordinating the division and sharing of responsibilities, and critically evaluating and leveraging AI resources.	of the AI models and their environmental impact, aiming to optimize efficiency and minimize the waste of computational resources. Simulate the enhancement of the architecture including the optimization of hyperparameters and/or fine-tuning of existing AI models to solve simple problems (e.g. transfer learning on top of a pre-existing model, or apply novel neural networks or non-trivial modifications to foundational models). Practise using computational resources and calling data to train machine-learning models based on the selected and preprocessed datasets.	

4.3 Level 3: Create

The overall goal of the 'Create' level is to challenge and enable students to develop advanced competencies to configure AI solutions or craft new AI tools based on customizable datasets, programming tools or AI models, with consideration of open-source options. Students will also be supported to reinforce a sense of belonging to a broader community of AI co-creators and enhance their intellectual engagement with the social responsibilities that are required for being a citizen in AI societies. The curricular goals shown in Table 4 aim to inspire the outlining of a set of high-level competencies composed of advanced methodological knowledge on AI, engineering skills for AI system design, and adaptivity in compliance with personal and corporate social responsibilities when creating and testing AI systems. The suggested pedagogical methods and approaches are designed to help solve ill-structured problems and nurture higher-order thinking, including through project-based learning, problem-based exploration of methodological knowledge, and multi-faceted ethical assessments. The suggested learning environments present recommendations on the configuration of datasets, AI programming tools and necessary computational devices to support complex learning with consideration of sharing AI resources and critically leveraging open-source options.

Table 4. Competency blocks for level 3: Create

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset	**4.3.1 AI society citizenship** • Students are expected to be able to build critical views on the impact of AI on human societies and expand their human-centred values to promoting the design and use of AI for inclusive and sustainable development. They should be able to solidify their civic values and the sense of social responsibility as	• **CG4.3.1.1 Foster awareness of being a critical AI citizen:** Enable students' to gain evidence-based insights into the pervasive adoption of AI as a supporting infrastructure of social activities in human societies. Foster their awareness and critical views on challenges that human societies are facing, such as prioritizing the acceleration of AI innovation while sacrificing safety and inclusivity, or prioritizing safety first, or and inclusive access. Develop students' skills in critiquing AI-amplified biases against females, marginalized	• **Case studies on conflicts between an inclusive and just AI society and the threats AI poses to inclusion, justice and sustainability:** Organize case studies or project-based learning on the typical conflicts between an inclusive and just AI society and the risks AI poses to human-centred values. Organize a discussion of what is meant by sustainable, inclusive and just societies. Ask students to analyse cases where AI has been pervasively embedded into the infrastructure of societies, and interrogate how AI may amplify biases, widen economic and social	• Unplugged learning settings and resources, including worksheets, flipcharts, reports or videos on jobs and career development in AI societies, and print-based analytical case studies on the societal implications and environmental impact of AI. • Online AI systems or locally available AI tools for experiential and analytical

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset	a citizen in an AI society. Students are also expected to be able to reinforce their open-minded attitude and lifelong curiosity about learning and using AI to support self-actualization in the AI era.	ethnic groups and socio-economically disadvantaged people, and the effects of AI on social relationships, norms and structures. Help reveal the reasons behind AI's profound impact on societies and assess how legal, ethical and social rules should be adapted to respond to the challenges. • **CG4.3.1.2 Nurture personal and social responsibilities in AI societies:** Encourage students to share their views on what desirable AI societies would look like and delineate the main responsibilities and obligations that citizens need to undertake in order to build an inclusive, sustainable and just AI society, from the perspectives of both users and designers of AI. Support students to continuously refine their personal responsibilities as AI society citizens. Challenge students to examine challenges in upholding ethical principles for the design and use of AI in complex authentic situations with an aim to reinforce the resilience of their human-centred mindset. • **CG4.3.1.3 Nurture the sense of self-actualization as an AI citizen and the lifelong learning attitude to AI:** Guide students to dynamically review the impact of the adoption of AI across sectors and the	inequality, undermine human agency and worsen climate change. Challenge students to take and defend positions on how existing AI technology can be regulated and how the design of the next generations of AI could be steered to make positive contributions to the building of inclusive and just societies. • **Inquiry on the personal social responsibilities of being an AI society citizen:** Arrange for students to conduct group discussions on the rights of citizens in an AI society, and jointly outline the main obligations and responsibilities that citizens should assume, taking into consideration both global and local contexts, as well as the perspectives of inclusion, equity, social justice, human-centred purposes and impacts on the environment and ecosystems. This includes ensuring humans have control and accountability over all key steps of the AI life cycle. Allow students to conduct and share their self-reflections on personal social responsibilities in an AI society. • **Case studies on self-actualization in AI societies and their implications for lifelong learning:** Organize case studies for students on the adoption of AI in work, life and social practices, and challenge them to review the implications of the adoption of AI for their personal goals, career development	tests including applications on smartphones that provide personal assistants, chatbots, and intelligent tutoring systems.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Human-centred mindset		competency sets that living and working in an AI society may require. Reflect on personal goals in a society where AI is pervasive, and evaluate the roles of AI in relation to self-actualization. Support students to build an adaptive and persistent attitude towards the lifelong study of AI to support their self-actualization and personal contribution to the sustainable development of societies.	and self-actualization. Guide students to build an adaptive and curious attitude to the lifelong study and use of AI to support their self-actualization and personal contribution to the sustainable development of societies.	
Ethics of AI	**4.3.2 Ethics by design** • Students are expected to be able to adopt an ethics-by-design approach to the design, assessment and use of AI tools as well as the review and adaptation of AI regulations. Students are expected to be aware that the assessment and ratification of the intent of the AI design should start from the conceptualization stage and cover all steps of the AI life cycle. Student should be able to apply parameters to assess the compliance of an AI tool with ethical regulations and use an ethical matrix of	• **CG4.3.2.1 Build awareness and understanding on 'ethics by design':** Provide conflict-based learning opportunities so students can apply an integral set of ethical principles throughout the life cycle of the design and creation of AI. Guide students to assess the ethical properness of AI tools when they are under conceptualization, anti-bias measures in data collection and engineering, discrimination-free methods for training machine learning, human-centred 'guardrails' for generating AI outputs, and the inclusive testing and auditing of AI tools. • **CG4.3.2.2 Develop a critical attitude to the ethics-by-design principles behind existing AI systems and algorithms:** Provide students with opportunities to take a holistic approach	• **Simulating the due diligence of a 'chief ethics officer' in an AI development team:** Design project-based learning practices, ask students to simulate the role of a chief ethics officer of an AI company, including drafting a checklist of ethical criteria for auditing key steps of AI system design, and defining the key due-diligence procedures to follow when overseeing the safety and ethics of the AI system being designed by a team or company. • **Simulating the use of 'ethics label' to audit selected AI tools or algorithms:** Organize students to undertake a mock audit of 'ethics by design' in selected AI tools or systems. Provide lectures on this and support students to research ethics labels for AI systems (an ethics label for AI systems is analogous to a nutrition label for food	• Unplugged learning settings and resources, including worksheets, flipcharts and print-based examples of due diligence checks and reports, ethics labels and matrices, privacy policies of AI creators and regulations on AI. • Locally available AI tools including smartphone apps. • Online AI systems for ethical analysis. • Websites sharing regulations on AI and lawsuits or court cases.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
Ethics of AI	multi-stakeholders to review AI regulations and inform adaptation.	to applying principles and regulations to the evaluation of the 'ethics by design' of specific AI systems or tools. Develop their critical thinking skills by requesting them to propose recommendations to the creators of AI systems to remedy any identified violations of ethical principles or regulations, and mitigate any harms their AI tools have caused. • **CG4.3.2.3 Cultivating social responsibilities to uphold 'ethics by design' in regulations on AI:** Drawing on selected AI regulations, guide students to evaluate how they align with the ethics-by-design approach and the extent to which corresponding measures are sufficient in monitoring and regulating typical ethical risks embedded in algorithms and AI systems. Enhance students' awareness of, and skills in carrying out, their social responsibilities by guiding them to recommend modifications of existing local regulations or draft proposals on the development of regulations to govern ethics by design in their communities.	items). Guide students to construct or adapt an ethical label to audit the intent of the designers of selected AI systems and services, including collecting information beyond their published statements (e.g. the creators of a shopping-recommendation platform state that its intent is to help customers find the most appropriate products, while the hidden purpose may be to make users dependent on or addicted to using the platform). Write reports on the findings of the audit. • **Simulating the use of an ethics matrix to review regulations on AI and suggest adaptations:** Invite students to research an ethics matrix for involving relevant stakeholders in regulations on AI. Support them to construct an adaptive ethics matrix with core ethical principles forming its columns and relevant stakeholders forming the rows (e.g. AI creators, regulators, institutional deployers and individual users). Students can apply their matrix to analyse relevant articles of a selected regulation and draft reports or reviews including recommendations for further adapting or iterating the regulations. Where local regulations are not available, write a proposal on the creation of a new AI regulation with an outline of articles for relevant stakeholders.	

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI techniques and applications	**4.3.3 Creating AI tools** • Students are expected to be able to deepen and apply knowledge and skills on data and algorithms to customize existing AI toolkits to create task-based AI tools. Students are expected to integrate their human-centred mindset and ethical considerations into the assessment of the existing AI resources and the test of self-created AI tools. They are also expected to foster social and emotional skills needed to engage in creation with AI including adaptivity, complex communication and teamwork skills.	• **CG4.3.3.1 Challenge and enable advanced skills to develop task-based AI tools:** Provide task-based learning opportunities so students can transfer their values, knowledge and skills to crafting an AI tool based on existing AI models or toolkits. Support their mastery of advanced skills in critically analysing the relevance of existing AI tools to specific tasks, assessing its data collection and processing needs, deciding on whether a low-code approach will be adopted or AI algorithms and programming language are required, and carrying out the operational customization and/or programming. • **CG4.3.3.2 Enhance students' creativity in applying AI knowledge and skills to customize AI toolkits and coding:** Design tasks around customizing AI tools to solve authentic tasks. Guide students to acquire skills in leveraging AI-development platforms or toolkits, enhancing datasets, and modifying programming codes, including those based on open-source options; challenge and support students to explore and test creative ideas on the design of AI tools to solve variations of problems.	• **Task-based enhancement of datasets and programming codes for crafting an AI tool:** Organize students to modify a dataset or create a new one for real-world contexts, by drawing on an authentic task such as monitoring the energy consumption of local schools or households, forecasting weather for a specific location or route, or tracking an epidemic disease. Teach and facilitate students to leverage automatic data-collection tools (e.g. BeautifulSoup[19] for scraping information from webpages); apply AI programming skills to clean, encode and preprocess the data; and use the data to customize AI models or craft AI tools. • **AI application performance test lab:** Guide students to search for and adapt a free and/or open-source performance matrix for the testing of AI applications (e.g. accuracy, precision, F-1 score, confusion matrices and ROC curves). Let students experience the use of adapted tools to test the performance and technological robustness of the crafted AI application, and simulate users' feedback on ethical compliance. Use automated tools to generate visualized reporting and summarize recommendations on the optimization of the AI application.	• Locally accessible free and/or open-source online datasets, AI tools and programming libraries. • Locally accessible free and/or open-source data analytics tools. • Locally accessible cloud-based computing resources, locally hosted computing resources (e.g. a school server), or computing resources shared by trustable institutions or industry agencies.

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI techniques and applications		• **CG4.3.3.3 Equip students with skills to test and optimize their self-crafted AI tools:** Support students to customize assessment methods and instruments for the testing of their self-crafted AI tools for robustness and ease of use, learn how to organize peer assessments and share feedback, and build collaborative skills as co-creators.	• **Comparing the creation of AI tools through customizing datasets and programming codes with the building of AI applications based on low-code development platforms:** Organize students to search for information on the steps and skills required to create AI tools by customizing the open-source datasets and programming codes of AI toolkits. Guide them to study skills in building AI applications based on low-code development platforms. Organize discussion on the difference between the two approaches in terms of human agency and human determination, the inclusion of data from local communities and reflection of local cultural diversity, and the scalability and reusability of the resulting tools. Discuss how to choose between the two approaches according to specific needs and situations.	
AI system design	**4.3.4 Iteration and feedback** • Students are expected to enhance and apply their interdisciplinary knowledge and practical methods to evaluate the humanistic appropriateness and methodological robustness of	• **CG4.3.4.1 Develop the skills to critique AI systems:** Provide project-based learning opportunities for students to practise skills in critically testing the technological robustness and critiquing the ethical appropriateness of an AI system through auditing whether the model enhances human capacities, agency and consciousness, or weakens them; checking the extent of its explainability and	• **Simulating the performance-test of an AI system:** Organize students to use adapted metrics to weigh whether an AI model enhances or weaken human capacities, agency and consciousness, and evaluate the extent of explainability of its method. Adapt performance metrics on machine learning and associated visualization tools including open-source options (e.g. the F1 score in machine learning, confusion	• Locally accessible online free and/ or open-source AI tools including data analytics tools and programming libraries. • Locally hosted or locally accessible cloud computing resources. • Downloaded and adapted instruments for the ethical auditing

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design	an AI model and its impact on individual users, societies and the environment. They should be able to acquire age-appropriate technical skills to improve the quality of datasets, reconfigure algorithms and enhance architectures in response to results of tests and feedback. They should be able to apply human-centred mindset and ethical principles in simulating decision-making on when an AI system should be shut down and how its negative impact can be mitigated. They are also be expected to cultivate their identities as co-creators in the larger AI community.	protection of data privacy; measuring the performance of the AI system; and studying users' feedback to evaluate its broader societal and environmental impact. • **CG4.3.4.2 Support the building of technical skills and social responsibilities in optimizing, reconfiguring or shutting down an AI system:** Offer simulation activities for students to understand corporate social responsibility and acquire interdisciplinary skills to make decisions on the iteration of an AI system based on the results of testing and users' feedback. The activities should involve development of students' technical skills for three possible scenarios: (1) optimization: optimizing the datasets, algorithms, model, design functionalities and/or interface; (2) reconfiguration: revisiting problem scoping and reconfiguring the AI system; and, (3) shutting down: where it is proven that the AI system violates human rights or harms vulnerable groups, students should learn to make decisions to shut down the AI model and quickly put remedial strategies in place. • **CG4.3.4.3 Foster students' self-identities as co-creators in the AI era:** Guide students to nurture the responsibilities of being	matrices and ROC curves) to measure the performance of the AI system. Design and apply research methods (e.g. gathering age-appropriate qualitative and quantitative market data) including feedback from (simulated) end users to study the societal implications and environmental impact of the adoption of the AI model. Synthesize the results and report them in a visual format. • **Simulating AI engineers' corporate decision-making on the iteration of an AI model:** Organize students to play the roles of AI engineers to integrate and interpret results from feedback, considering both AI system design and corporate social responsibility. Make an appropriate decision from multiple choices on the iteration of the AI model: (1) optimization, where the problem scoping is validated and the datasets, algorithms, AI model or interfaces may need to be optimized; (2) reconfiguration, where fundamental flaws are discovered through tests and/or users' feedback in the problem scoping and/ or configuration of the architecture; or (3) shutdown, where it is proven that an AI model violates human rights or harms vulnerable groups. Support students to acquire technical skills for optimization and reconfiguration, and learn	and performance testing of AI models. • Access to applicable regulations on AI or governance frameworks. • Locally accessible online collaborative platforms to support resource sharing, peer learning, and the collaborative design and creation of AI tools (e.g. GitHub, arXiV or forum groups).

	STUDENT COMPETENCY	**CURRICULAR GOALS** (AI curricula or programmes of study should…)	**SUGGESTED PEDAGOGICAL METHODS** (Institutions and teachers can consider and adapt the following learning methods.)	**LEARNING ENVIRONMENTS** (The following learning settings can be provided and adapted.)
AI system design		a co-creator of AI tools and the 'driver' of the design of the next generation of AI technology. Develop their sense of belonging to the larger AI community, and encourage them to critically analyse the long-term impacts of AI systems on social relations and individual behaviours by drawing on real experiences of designing and building AI systems. Discuss how regulations or policies should be adapted or created to enhance the governance of AI.	to negotiate and make decisions about shutting down the AI model and what are the possible remedy strategies. • **Engagement with communities of AI creators:** Facilitate interested students to join local or online communities of AI co-creators. Encourage them to participate in online discussions or collaborative development of AI tools, and share open-source datasets and examples of algorithms or AI toolkits.	

Chapter 5: Applying the framework

This chapter provides some further guidance on the types of considerations that can feed into the successful development and deployment of curricula.

5.1 Aligning AI competencies as the foundation for national AI strategies

The development and implementation of national strategies for AI vary across countries. Around 70 countries have released strategy documents on AI, which often position education as the sector to build local human resources and talent in AI.

In countries with well-entrenched national strategies, the AI CFS can be aligned with existing policy frameworks as a foundation to foster the human-centred mindset and values needed to implement regulations on the ethics of AI, prepare people to be responsible AI users and citizens, and develop local communities of AI co-creators at scale.

Box 1: Recommendation on the Ethics of Artificial Intelligence

Member States should promote the acquisition of 'prerequisite skills' for AI education, such as basic literacy, numeracy, coding and digital skills, and media and information literacy, as well as critical and creative thinking, teamwork, communication, socio-emotional and AI ethics skills, especially in countries and in regions or areas within countries where there are notable gaps in the education of these skills.

Member States should promote general awareness programmes about AI developments, including on data and the opportunities and challenges brought about by AI technologies, the impact of AI systems on human rights and their implications, including children's rights. These programmes should be accessible to nontechnical as well as technical groups.

Source: UNESCO, 2022*a*, pp. 33–34

If a national strategy for AI is released and well-implemented, the implementation of the AI CFS and AI curricula for students should be planned and supported administratively and financially within the broad framework of the AI strategy. Such national strategies are usually triggered by policy responses to the wide-ranging and disruptive impact of AI on work, in terms of both AI-driven job displacement and AI-supported job creation, as well as the prospect of new employment skills that the adoption of AI may require. The foremost policy response to this disruption is system-wide strategies on AI competency development that are comprised of funding and incentive mechanisms as well as specific courses on AI that streamline different trajectories as appropriate for each sector, including school education, technical and vocational education and training (TVET), higher education, upskilling and reskilling for employees, and lifelong learning programmes for citizens. For countries without an adopted strategy, the AI CFS can serve as a trigger to raise awareness about the importance of national policies on AI in general, and on the development of AI competencies in particular.

The implementation of such strategies and policies is expected to start with the assessment of readiness and programme gaps. The processes and outcomes of the implementation are usually monitored and evaluated, and policy-makers should establish early and regular monitoring of AI competency development programmes when setting up overall mechanisms and methodologies to track implementation. To evaluate AI curricula or agile education programmes, it is particularly important to formulate criteria that cover: the readiness of students and teachers; deficiencies in training and support for teachers' professional development; gaps in curricular goals and content that need to be addressed to support the national AI vision; additions needed to the curricular content to meet immediate and near future needs of the markets; mechanisms for the mobilization and validation of intersectoral support; the degree of curriculum integration; readiness of learning environments; and the quality of the implementation of the curriculum.

Box 2: Supporting human resource development: The Republic of Korea's *National Strategy for Artificial Intelligence*

The Republic of Korea's *National Strategy for Artificial Intelligence* has three main focus areas: (1) Establish reliable AI infrastructure, including to support human talent and improve technology; (2) expand the utilization of AI throughout the industrial and social sectors; and (3) respond proactively to social changes, including labour market needs. The strategy seeks to develop an AI ecosystem that results in the full-scale utilization of AI, and establishes the Republic of Korea as a global leader in people-centred artificial intelligence.

To support the achievement of this goal, the Republic of Korea has focused on revising regulations to create a more industry-friendly environment and nurture the productive use of data and AI innovations, the use of AI to streamline governance, the establishment of regulations on AI ethics, and the building of human capital in AI from as early as primary school. The strategy proposes an interdisciplinary AI curriculum and the definition of AI competencies based on the needs of four categories of populations: (1) the general public, who need to be able to use AI, as well as acquire basic AI and data literacy, including knowledge of AI ethics; (2) AI practitioners, who apply AI and software tools in 'AI + X' environments in the labour market; (3) AI professionals, who develop AI platforms and systems; and (4) AI talents, who will resolve AI issues and develop new AI models and algorithms.

In alignment with competency development for these four categories, the strategy suggests regulations to upskill and upgrade industry professionals to the level of professorships in AI, support the expansion of existing AI departments, and mobilize more departments to offer programmes related to AI, including through expanding the scale and diversity of education and research programmes in AI at the master's and doctoral levels and through creating interdisciplinary majors on AI.

As for school level, the strategy seeks to expand learning opportunities on AI with a focus on computational thinking. At the lower grades of primary school, students are offered experiential engagement with AI to foster their interest and curiosity; at the higher primary grades, students are supported to extend their knowledge and skills through applying AI in the learning of core subjects. Secondary-level students have the opportunity to attend AI-centred schools to complete a more advanced AI curriculum. Teachers are also supported to enhance their knowledge and skills on AI through integrating AI in their initial training programmes and providing new degrees on AI pedagogy integration.

Source: Ministry of Science and ICT, Republic of Korea, 2019

5.2 Building interdisciplinary core and cluster AI curricula for AI competency

The development of students' AI competency needs to integrate varied channels for learning and practice, including formal courses within the framework of the national curriculum, extracurricular programmes, and informal learning through engagement with families and local communities. While promoting the development and implementation of a national AI curriculum as the main channel for the implementation of the AI CFS, it is also important to consider whether the study programmes provided by the private sector or non-governmental channels are in compliance with the human-centred vision and ethical principles. Reviewing and steering the impact of informal learning channels including digital platforms is also essential, and can be enacted by mandating providers' accountability for safety and ethics if their programmes target students, especially children.

AI has an interdisciplinary nature and complex intrinsic conceptual and practical connections with mathematics, science, engineering, languages, social studies, art, civic and citizenship education, and history as well as various combinations of these subjects. AI also represents both an iterative step and a technological leap in the continuum of digital technologies. In this context, the AI CFS is built upon multidisciplinary knowledge and skills on data, programming, computing structures and the internet as well as the integrated set of conceptual knowledge and skills based on computing and engineering thinking, and scientific reasoning. In parallel, the fostering of a human-centred mindset and the ethics of AI are anchored in students' broad social and emotional skills.

It is therefore necessary to align the AI CFS to countries' general competency frameworks for students, and examine whether the latter need to be adapted or reformed to respond to the new requirements of the AI era. In countries where national digital or ICT competency frameworks for students have been adopted and implemented, an adaptive approach can be considered to integrate AI aspects into them. This requires a redefinition of digital competencies to cover the uncharted values, knowledge and skills required for new iterations or novel domains of AI, and their connections with previous generations of digital technologies.

A set of core AI curricula within formal education programmes is usually considered to be the main channel for providing inclusive opportunities for all students, particularly those who may not have access to AI other than at school. This will require the reconfiguration of national curricula to accommodate the time to be committed to AI courses. The cluster curricula related to AI should be adapted or reformed to enhance their connections with AI competencies, without losing their focus on students' other core competencies. These interdisciplinary core and cluster AI curricula can be integrated into agile structures that are appropriate to national or local educational contexts.

The UNESCO report *K-12 AI curricula: A mapping of government-endorsed AI curricula* (2022*b*) identified four main strategies for integrating AI curricula into K-12 education systems. These include the implementation of AI as a discrete subject; the integration of AI into other existing subjects (usually

ICT); cross-curricular approaches in which AI outcomes are integrated into multiple cluster subjects; and AI as an optional, extracurricular or co-curricular activity (e.g. for an extra-curricular club). AI as a discrete subject may be mandated for all students and can be supported by a series of complementary courses in science, technology, mathematics, engineering and design, to meet the diverse abilities, backgrounds and learning needs of students. Under any one or combination of these approaches, the interdisciplinarity has double implications: the core AI curriculum should mobilize students' multidisciplinary values, knowledge and skills in relevant subjects, especially science, technology, engineering, arts and mathematics (STEAM), to act as the foundation of the AI curriculum as exemplified by the United Arab Emirates' Computing, Creative Design and Innovation curriculum (UNESCO, 2024); and the cluster AI curriculum should promote the intrinsic integration of key aspects of the AI competencies into the learning outcomes and navigate them at corresponding progression levels.

Box 3: The United Arab Emirates' interdisciplinary approach to K-12 AI curricula

'By covering computer science, engineering, design, sustainability and visual communication, the Ministry of Education's Computing, Creative Design and Innovation curriculum offers a comprehensive and concise educational framework. It prepares students to thrive in the dynamic and interconnected world by nurturing critical thinking, problem-solving abilities and innovation.'

The United Arab Emirates takes an interdisciplinary approach to its AI curriculum for K-12 schools by integrating it into a curriculum called Computing, Creative Design and Innovation (CCDI). By including a focus on AI, the CCDI curriculum encourages students to develop their creativity and problem-solving skills; build an awareness of ethics and ethical impacts; learn and rehearse fundamental AI principles and concepts; and cross-fertilize their knowledge across fields. The curriculum was first established in 2016 as a technology-focused subject area, over and above the already-existing computer science curriculum.

Since then, and with the recent developments in the field of AI, the CCDI has progressively integrated robotics, programming, 3D-modelling and electronics. In 2020 the curriculum was revised to cover five domains: (1) computer science, with a focus on computer systems, networks and the internet, data and analysis, algorithms and programming, and the impacts of computing; (2) engineering principles and systems, with a focus on electricity and electrons, robotics and systems, and embedded systems; (3) design and innovation, including entrepreneurship and the engineering design process; (4) sustainability, with an emphasis on the sustainable society; and (5) visual communication, concentrating on graphics for design, computer-aided design and design realization.

Source: UNESCO, 2024

5.3 Framing future-proofing and locally feasible AI domains as carriers of the curriculum

After determining the interdisciplinary alignment structure of core and cluster AI curricula, curriculum developers will need to integrate the AI CFS into national or institutional core AI curricula. The framing of the core AI curriculum is built on interlinked key aspects of the AI competencies, subdomains of AI under each aspect, and specific AI systems to act as carriers of the curriculum. Decisions about making the curriculum compulsory or elective is framed by at least three factors: the foundational value of different aspects, the future-proofing potential of AI knowledge and skills, and the feasibility of implementation in local schools. The feasibility of AI domains and systems is determined by the AI readiness of teachers and students, and the local availability and affordability of generic AI systems and specific hardware, software, programming languages and essential applications for the majority of schools.

As explained in Chapter 4, the human-centred mindset, AI ethics, and AI techniques and applications are crucial to all students' lives and work in the AI era, and thus should be included in all AI curricula. Some domains, such as AI system design, may be more appropriate for students who have a strong interest and ability in AI. Assessing the extent of local AI readiness can inform decisions on whether AI system design should be defined as a set of thinking skills that can be merged into other aspects or should be taught as a discrete domain if the necessary databases, computing resources and AI models are available.

Within the framework of a selected aspect or domain of AI, the next step is the scoping of the subdomains of AI techniques and technologies to be covered, and the specific AI systems to recommended as carriers of the curriculum or learning practices. This is more pronounced for the aspect of AI techniques and applications. The range of techniques is vast, including logic systems or algorithms crafted from general deductive principles to solve specific problems (e.g. human-coded decision trees, alpha-beta pruning and minimax), as well as models trained on large amounts of data (e.g. deep learning and generative AI). Curriculum developers need to choose subdomains from a large list of exemplar AI techniques and specify their relations, such as classical AI or 'rule-based AI', machine learning, deep learning and generative AI models. The range of AI technologies and human-facing products and services is expanding rapidly, and it's more challenging to choose from AI technologies being developed across sectors, including from the categories of computer vision, natural language processing, automated speech recognition, and automated planning and scheduling (AI planning). Following the selection and scoping of subdomains of AI techniques and technologies, examples of AI systems and tools should be considered, with a view to being agnostic towards commercial brands or products as much as possible. As stated in Principle 5 of Chapter 2, rigorous public validation mechanisms should be applied to prevent the use of AI systems that discriminate against marginalized groups or produce bias(es) related to gender, ability, socio-economic status, language and/or culture. The principle of inclusivity should be upheld when choosing AI tools.

Furthermore, which AI domains should be defined as compulsory and which can be elective will be determined by the national context, including the aims and ambitions of relevant policies and readiness as stated above. The depth and breadth of domain-specific AI knowledge and skills should be defined based on the typical readiness and abilities of the target cohorts of students. It is imperative for all students to reach the first two levels of Human-centred mindset, Ethics of AI, and AI techniques and applications, but it is less necessary for them to reach the third level, 'Create', especially for AI system design. Therefore, it might be useful to consider an agile or contextualized implementation strategy, in which both compulsory and elective subjects or courses will be designed and offered to students for different AI techniques and key domains of AI knowledge.

By anchoring AI competencies in a human-centred mindset and embodied and social knowledge and skills in ethics, the AI CFS aims to prepare students to collaborate with future-oriented AI in a range of contexts. The systemic AI design thinking, knowledge and skills are intended to foster an open knowledge schema that can support students to understand, use and create future generations of AI systems. The AI CFS emphasizes the importance of transferable knowledge and skills under the aspect of AI techniques and applications that can help the majority of students to be ready for the further iterations of AI tools. While efforts have been made to ensure that this curriculum framework responds to emerging technologies, new tools and innovations will emerge after it is published, and the example tools and activities may become obsolete or dated. The curriculum itself will need to include content that can be adjusted going forward in order to remain relevant and 'future-proof'. A modular curriculum design is suggested, in which multiple modules based on AI domains or different AI systems or tools can be developed and recommended to local educational institutions. A modular structure allows the curriculum to be reviewed and updated more dynamically, as it is not necessary to change the entire curriculum to add or remove a specific tool, domain concept or other content. On the other end of the spectrum, future-proofing can involve schools and students co-designing AI curricula. This means encouraging the drafting of school-based AI curricula and teachers' contextual adaptations of specific domains or tools selected for general competency development. To enact this framework, curriculum developers should consider the dynamism of an AI curriculum and make efforts to future-proof the learning process.

5.4 Tailoring age-appropriate spiral curricular sequences

The AI CFS naturally entails a paradigm shift towards competency-based education. A competency-based education aims to transition from models of fixed time and flexible learning (implying completing instruction within a fixed curricular schedule regardless of whether all students have reached the expected mastery level) to more flexible time and fixed learning (implying that flexible learning schedules are allowed so that students of all abilities can reach the expected mastery level). With competency-based education, students are expected to demonstrate performance-based knowledge, skills and values that constitute the competencies, and students who do not meet these minimal standards are provided with additional support until they do (Patrick and Sturgis, 2017).

This framework does not break down the progression of learning or activities by grade level, focusing instead on the exit-level outcomes which systems should seek to achieve for all students. Curriculum developers will therefore need to leverage the framework and its components to develop a scaffolded spiral learning pattern across all four aspects, allowing for students to start the learning of AI with the domains and difficulty level that match their abilities and the readiness of their schools. The spiral curricular pattern should provide spaced and iterated engagement with a set of foundational AI knowledge that will encourage both memory retrieval and cyclically upgraded practices to deepen their understanding and associations with problem-solving contexts. This design helps ensure a transfer of information from the working memory to the long-term memory to support sustained learning gains, as well as enable students to leverage existing schemas to learn novel AI knowledge, or adapt application skills to solve problems in varied contexts. Conversely, a curriculum developed and delivered as a one-off over a short period of time (e.g. for hackathons or bootcamps) may spark interest but is less likely to lead to sustained AI competency.

The work of curriculum developers will be to outline the main elements of AI ethics, foundational knowledge and skills as well as system design thinking, and then identify appropriate levels of difficulty, breadth and depth of these elements for different grade levels. This will enable them to create spiral iterations of lessons and project-based tasks that help students to progressively advance and expand their learning and practice.

Box 4: The spiral curricular sequence of 'Day of AI' courses

The AI curriculum developed by MIT's RAISE[2] initiative, Day of AI, adopted the spiral design approach by clustering curricular content around key topics such as 'What AI is, and what AI does well and what AI does not do as well', 'How AI works', 'How a machine learns' and 'How a machine creates'. Students at different ages were given opportunities to continuously engage in topics such as 'What is AI?', while being gradually exposed to novel or upgraded knowledge and skills such as algorithms and AI programming, teachable machines and generative AI. Cross-cutting topics around ethics, including AI biases, human rights, human–AI interaction and the social impact of AI were tailored to students at different age levels.

For more information: https://dayofai.org

5.5 Building enabling learning environments for AI curricula

While the required resources for the implementation of AI curricula may vary depending on the breadth and depth of expected curricular goals and overall digital readiness in local schools, a basic learning environment is required to meet minimum standards for effective study of the essential aspects and domains of AI to the basic mastery level. According to UNESCO's report *K-12 AI curricula: A mapping of government-endorsed AI curricula* (2022*b*), implementation for school students requires the following essential conditions, ranked by importance: teacher training and support, teaching resources on AI, needs analysis and school-based research, updated digital infrastructure in schools, and the provision of AI resources including through procurement of hardware and software as well as engagement with the private or third sector to share AI devices and systems. If these conditions are not provided, the curriculum is unlikely to be implemented as intended or achieve its anticipated learning and competency objectives. The report highlighted typical learning environments that had been set up by the 11 countries that were implementing their own governmental K-12 AI curricula as of 2022, detailed below.

Box 5: Typical enabling learning environment set up by governments' AI curricula

- **Hardware and robotics:** The hardware needed for AI curricula may include computers, tablets, laptops and internet access. Not all AI curricula include content on robots or robotics. When the learning on robots is required, curricula can leverage free online virtual applications or locally affordable kits. Devices like Raspberry Pi are used by some curricula that require students to create programs and test them using low-cost devices.

- **Software:** The Ubuntu[3] open-source operating systems were used by some curricula as less expensive alternatives to other operating systems.

- **Programming languages:** National AI curricula have often leveraged free programming languages such as HTML, Javascript, Python, Micropython, NumPy, R and Scratch.

- **Tools for learning AI techniques:** A number of tools have been developed or made accessible free of charge to facilitate understanding and allow the exploration of complex concepts and AI techniques, with the following mentioned in the 11 governmental AI curricula: MachineLearningForKids (an educational tool for teaching kids about machine learning by letting them train a computer to recognize text, pictures, numbers, sounds or other inputs),[4] Teachable Machine (a platform developed by Google to train a computer to recognize the user's own images, sounds and poses),[5] TensorFlow (an end-to-end platform for machine learning),[6] and Keras (deep learning for humans).[7]

Source: UNESCO, 2022*b*, p. 47

To provide enabling learning environments for AI competency development and the implementation of an AI curriculum in particular, governments should commit to universal access to internet connectivity for all schools and students, including through agile 'online + offline' solutions, to engage with online or mobile AI systems, customizable applications, basic and extendable learning resources, and peer learners or co-creators. The prerequisite digital infrastructure also includes a modest number of well-functioning digital devices with basic connectivity as well as a minimum amount of software or applications for students to learn operational skills, practise programming, and train virtual machine or AI models.

Where these essential conditions are not yet realized, but the government is determined to initiate an AI curriculum at the earliest possible stage, alternative options should be considered in the provision of enabling learning environments. With regard to the AI CFS, most objectives under the first two aspects, Human-centred mindset and Ethics of AI, can be engaged with, at least partially, through online and offline solutions, which are also defined as unplugged solutions. For the aspect of AI techniques and applications, some well-designed unplugged activities have been made available by academic and non-profit organizations to demonstrate conceptual knowledge on AI tools and the understanding of AI techniques (e.g. the unplugged AI activities designed by Everyday AI,[8] AI Unplugged,[9] and the International Society for Technology in Education).[10] Even in fully connected learning settings, unplugged solutions have value by providing students with opportunities to retreat from algorithm-controlled information cocoons and interactions with digital platforms to practise independent, autonomous contemplation, which is critical for the progressive construction and deepening of conceptual knowledge on AI.

5.6 Promoting the professionalization of AI teachers and streamlining their support

As stated above, the most important preconditions for the implementation of AI curricula for school students are teacher training and support as well as the provision of teaching resources on AI. The achievement of the goals outlined by the AI CFS will require teachers, particularly those in ICT or AI, to continuously develop and update their subject knowledge and pedagogical capacities in designing and facilitating age-appropriate learning activities on AI. National and institutional strategists need to plan and implement an integrated approach to the reform of pre-service programmes to prepare qualified AI teachers, design and provide competency-based training and long-term support for in-service ICT or AI teachers, and enhance upskilling for teachers in other core subjects to foster interdisciplinary AI competency. All these training and support programmes aim to strengthen the competencies of teachers who are tasked with teaching AI or implementing the national AI curriculum, implying a trend toward the professionalization of AI teachers. This professionalization includes setting up frameworks specifically for AI teachers, or alternative and more agile mechanisms, that define and develop a set of professional competencies to fully realize the goals of the AI curriculum for students. As ICT and AI are often categorized as marginal subjects in school curricula, the professional status of ICT and AI teachers has not been fully recognized. The professionalization of AI teachers also means that AI should be classified as one of the core subjects and AI teachers should be entitled to the same professional status as teachers in other core subjects, with their teaching hours and performance being equally recognized in personnel management systems.

Box 6: An AI competency framework for AI subject teachers in China

In China, an AI competency framework for AI subject teachers was developed by the National Institute for Education, East China Normal University and Tencent. Even though it's not a government-driven national AI competency framework, it is a clear indication of the professionalization of AI teachers. It defines a comprehensive set of competencies for AI teachers, which encompasses six dimensions: understanding and awareness, basic knowledge, basic skills, problem-solving capability, teaching practices, and ethics and security. Accordingly, teachers must grasp AI's foundational conceptual logic and societal impact, appreciating the distinctions between human and machine intelligence, and the significance of human-machine collaboration, with a view to AI's educational roles. Unlike the UNESCO *AI competency framework for teachers*, the framework is aimed at AI teachers; the aspects of human-centred mindset and professional development are not covered, and no progression levels are provided.

For more information: http://www.jyb.cn/rmtzcg/xwy/wzxw/202203/t20220325_686401.html

In countries where public teacher education institutions do not have sufficient capacities to upskill teachers to keep pace with the rapid changes of AI technologies, public–private partnerships for the development and provision of AI curricula are often mobilized to leverage the human and material resources of the private AI industry or NGOs to partly or fully substitute for a public AI curriculum and ICT or AI teachers. As these resourceful AI companies and NGOs have a strong interest in reinforcing their presence and dominance in the teaching of AI based on their own brands, this approach risks the de-professionalization of public AI teachers. It is recommended that public–private partnerships are mobilized with a clear purpose of contributing to the preparation of upskilling public AI teachers and supporting their continuous professional development. Moreover, the comprehensive competency frameworks for AI teachers to meet the needs of implementing the AI CFS and national AI curriculum should be used to define a rigorous set of criteria to validate whether the AI courses and trainers developed by the AI industry are trustworthy, anti-bias, relevant for AI competency development and sufficiently brand-agnostic. Such frameworks should also help verify how the AI courses can be properly integrated into school curriculum systems to supplement rather than replace the public curriculum. The accountability of public schools for continuously improving teachers' capacities in implementing the AI curriculum should be prioritized instead of being weakened.

To promote the professionalization of public AI teachers, it is also important to adopt the requirement of implementing the AI CFS as a benchmark to streamline pre-service and in-service training and continuing support for teachers' professional development, to ensure they are aligned with a set of clearly defined competencies and are complementary in scaffolding teachers' progressive improvement throughout their career. Special attention should be given to the engagement, review and adaptation of continuing education initiatives for teachers and school-based support for their professional development according to the value orientation, knowledge and practical skills required to teach the national AI curriculum.

5.7 Guiding the cohort-based design and organization of pedagogical activities

AI competency development is a three-helix bundle spanning the social and emotional learning of values and ethical principles, self-directed and collaborative construction of conceptual knowledge on AI, and practical skills to apply and co-create AI tools. A combination of innovative pedagogical methodologies is required in order to help students progress through the three helixes of competencies altogether, bridging between what they know and what they can do as well as transferring their prior knowledge and skills to novel concepts and new problem-solving contexts in the AI-rich workplaces and social spaces of the future.

The pedagogical innovations that are tailored to the particularities of AI domains and varied abilities of students can be unlocked through the design and organization of activities based on a cohort of students who are enrolled in a certain AI course or share an interest in the same domain of AI. In this cohort-based approach to the design and organization of learning scenarios or projects, a certain cohort of students may be grouped together from different classes and grade levels. This approach does not represent any particular learning theory, and typically involves a wide range of pedagogical methods and practice-orientated learning scenarios including interactive activities, collaborative projects and peer support. Students build a community of practice and their learning often follows a curricular schedule where they share accountability and motivate and coach each other, and work with their teachers to get feedback. In this way, they deepen their understanding and tackle challenging questions together; collaborate in hands-on projects to apply knowledge and skills in practical ways; and exchange views and engage in debates on the societal impact and ethical issues of AI to enhance social construction.

When choosing or designing pedagogical methodologies for the understanding, application and creation of different aspects of the AI CFS, it is also important to consider the domain-specific needs for pedagogical practices:

- The nurturing of human-centred values and mindset, by nature, is built upon social and emotional learning processes, and requires conflict-based opinion-taking, social construction and social interactions.
- The learning of ethics is a process of understanding abstract principles and regulatory rules through practical

case studies, scenario-based critical evaluations, contextual application and collaborative rule-making.

- AI techniques and applications represents a domain that seamlessly blends the practice-oriented construction of conceptual knowledge on AI with authentic task-based application, and requires real AI tools as the basis for constructing knowledge schema on AI techniques and technology, problem-based learning and practices of transferable application and scenario-based inquiry, and a deepened understanding of the values and ethics underlying AI tools and their uses.
- AI system design simulates real-world engineering projects, involving the life cycle of the creating, realizing and iterating AI systems to practise engineering thinking processes and foster integrated problem-solving skills. It requires teachers to design and organize project-based learning to allow students to identify and delineate the problems that can and should be solved by AI; assess needs for data and plan methods of data collection; configure the architecture of AI models; and train AI models or create prototypes, tests and iterations of them.

As AI competency is a three-helix bundle, specific pedagogical practices can potentially cover multiple aspects of AI competency within one lesson or unit. This requires instructional planners or teachers to infuse and navigate various pedagogical methods so students can engage with multiple aspects of the learning and practice of AI. The real-world research and development of AI technology and applications often leverages intensive and continuous conceptualization of AI methods and iterative programming, configuration and optimization. This prerequisite for developing practical AI competencies has been validated by the effectiveness of the pedagogical methodologies practised at hackathons and bootcamps using AI applications. To improve the efficacy of pedagogy in schools, opportunities should be scheduled for students to be engaged in more intensive units of lessons or activities that align with the formal AI curriculum.

The national or institutional AI curriculum should frame recommendations or guidance on pedagogical methodologies around the principles of engaging shared accountability and peer learning in the target cohort of students and the specificity of the AI domain and expected learning outcomes. When updated or novel pedagogical methodologies are introduced in AI curricula, sufficient training, practical guidance and instantly responsive services (e.g. online chatbots) should be made available for teachers. Locally relevant incentive mechanisms should be planned and implemented to review, validate and recognize practices in pilot testing and scaling up pedagogical innovations.

Box 7: Pedagogical methodologies in the MIT curriculum on the ethics of AI for middle school students

An ethics of artificial intelligence curriculum for middle school students was created by Blakeley H. Payne with support from the MIT Media Lab Personal Robots Group, directed by Cynthia Breazeal (Payne, 2019). The curriculum is designed to be implemented online and/or offline with students aged 12 to 14 who are early in their AI learning journeys. The curriculum focuses on improving students' understanding of AI and the relationships between humans, technology and society. Parts of this curriculum have also been integrated into the MIT DAILy Curriculum,[11] and into How to Train Your Robot: A Middle School AI and Ethics Curriculum. Research into the latter demonstrated the potential for such a curriculum to be delivered even by teachers with a limited computer science background (Williams et al., 2021).

This curriculum exemplifies a student-centred and inquiry-based approach, with learning outcomes that are aligned to enable a cycle of: initial orientation or information-gathering that supports students to build knowledge schemas on a new topic; conceptualization, where students begin to form a hypothesis around the purpose(s) of AI; investigation, in which students delve deeper into the different perspectives, benefits, values and risks of AI for different populations, and design potential solutions for the problems that emerge; and finally, the development of a potential solution prototype using a project-based approach. Throughout, discussion and reflection are leveraged to deepen understanding and thinking about the problem.

The curriculum includes six core goals, which are pursued through different online or offline activities depending on the context. The chart below outlines the goals as well as example activities for teachers or other facilitators that can help to achieve them

Learning outcomes	Example activities and pedagogical advantages
Understand the basic mechanics of artificial intelligence systems. This learning outcome includes sub-outcomes such as recognizing AI uses in everyday life; understanding algorithms as a process of input, changes to input and output; and understanding AI as a specific type of algorithm with a dataset, learning and prediction.	**Play 'AI Bingo' with AI systems**. Using a worksheet, each student tries to find another classmate who has used or experienced various AI applications (for example, a tool that suggests emojis to replace words or an app that maps a route to a destination). Together the pair must determine the dataset used and prediction made by each different type of AI system until one student has completed five in a row. This represents an example of gamification, which can increase student interest and motivation, and is designed to support recall in order to begin building knowledge schemas around core AI concepts.

Learning outcomes	Example activities and pedagogical advantages
	Write an algorithm to make the 'best' peanut butter and jelly sandwich (or noodle, rice or tamale dish, or another locally-relevant food the children are familiar with). This can be undertaken individually or as a group. The core of the activity requires students to practise recall through accessing knowledge on what an algorithm is and how it is structured, and apply this to a specific mandated problem framed in a familiar context. **Identify the AI systems on the YouTube platform as a group**. In this recall-and-identification activity, students engage in recalling, reflection on and building of knowledge schemas. In this curriculum, this activity forms foundational schemas for more advanced reflective and creative collaborative problem-solving in the later stages in the curriculum. **Build a classifier in Google's Teachable Machine**. In this activity, students are asked to build an AI in Teachable Machine that will sort pictures of cats and dogs, but are given a biased dataset that does not yield consistent results. This is an example of facilitated experiential learning, where students leverage a knowledge base about AI and develop practical skills through hands-on, guided exploration. They need to reflect on the outcome of their work and determine the causes of the inconsistencies (bias). Confirmation design, in which students are provided with a question and methodology to confirm a known result, can be used. At more advanced levels, students can generate explanations of their results.
Understand that all technical systems are socio-technical systems, and that socio-technical systems serve political agendas and are not neutral sources of information. Students engage concepts such as the stated and hidden goals of algorithms, algorithmic bias and human agency.	**Create an ethical matrix of the stakeholders and their values invested in the student's peanut butter and jelly sandwich (or other food item)**. Undertaken as a group or individual activity, this builds on earlier recall/identification tasks by requiring students to engage in reflection and early critical analysis as they identify different stakeholders and their potentially conflicting interests and values. This enables students to develop procedural knowledge that can then be applied to more complex challenges and even ill-defined problems.

Learning outcomes	Example activities and pedagogical advantages
	Using YouTube as an example, students construct an ethical matrix around the YouTube Recommender Algorithm. This activity exemplifies a student-centred critical thinking exercise which pushes students to connect classroom learning (both procedural and content) to their lived realities.
Recognize that there are many stakeholders in a given socio-technical system and that the system can affect these stakeholders differently. Students identify AI stakeholders and their values, and the goals that systems should have in order to meet those stakeholders' needs.	**Students reflect on the stakeholders for a range of technologies such as generative adversarial network (GANs), emotional recognition and speech-to-text software**. In this exercise, students demonstrate the ability to transpose the procedural knowledge gained from the ethical stakeholder matrix example for the food item and YouTube to other technologies, an important step in developing translational skills.
Apply both technical understanding of AI and knowledge of stakeholders in order to determine a just goal for a socio-technical system.	**Students brainstorm and redesign the YouTube algorithm to support new goals. They identify the datasets and design features necessary to reflect the new goals they have set**. This project-based group learning approach leverages constructivist principles as well as technical knowledge gained from the course to date, in order to work through the early stages of a design thinking process (up to the prototype stage) and co-create a solution to, in this case, a given problem of creating a different ethical stakeholder profile for YouTube. Sharing designs facilitates co-learning and reflection across groups, and a second cycle of iteration can be used to give students opportunities to leverage feedback or knowledge gained from peers.
Consider the impact of technology on the world.	**Students interact with different technologies and respond to creative writing and/or discussion prompts, reflecting on their direct and extended impacts**. In addition to following an inquiry approach and leveraging design thinking for project-based learning, the curriculum seeks to engage learners experientially in a range of AI technologies, and foster debate, discussion and reflection on the interactions between the technology, people who use it, broader society and the environment.

Source: Adapted from Payne, B. H. 2019. Available under CC BY-NC 4.0

5.8 Constructing competency-based assessments on the progression of key AI aspects

The assessment of students' AI competencies naturally requires the use of competency-based assessments that need to be adapted to the specificity and integration of multiple aspects of AI. Methodologies and instruments designed for such assessments are essential to benchmark students' starting point, measure their mastery levels of the key aspects of AI, and provide references for evaluating the effectiveness of teaching practices and overall implementation of the AI curriculum. However, few attempts have been made to develop these sorts of instruments for assessing comprehensive AI competencies cross-cutting multiple progression levels. Therefore, the implementation of the AI CFS or the local AI curriculum needs to include the construction of a competency-based assessment system encompassing purpose and objectives, authentic tasks and methodologies, benchmarking standards or indicators, and domain-appropriate criteria associated with a corresponding grading scale.

Frame criterion-referenced assessments to measure the mastery of AI competencies

The primary purpose of competency-based assessments is to measure students' mastery level against predefined standards or benchmarking frameworks, implying the use of criterion-referenced assessments. As stated above, competency-based education aims to support all students to achieve the minimum mastery level of competencies, meaning the fixed learning outcomes with more flexible time schedules. Under these models, students who do not meet the minimum standards within a certain timeframe should be given additional support until they can reach them. To support this aim, a set of reference criteria should be defined to diagnose students' mastery levels compared with the predefined standards, and to recommend further learning experiences. In the context of the cohort-based design and organization of pedagogical activities, the criterion-referenced ipsative assessment of a single student or a target cohort of students should be implemented to diagnose the gaps between their mastery level and the minimum standard as well as their progressive performance over time. While the ipsative assessment of learning may help tailor students' personalized experiences, the emphasis on the criterion reference can prevent the loss of targeted achievement of AI competencies. This can be extended to students' self-assessment and setting of personal curricular goals.

The AI CFS interprets AI competencies into measurable learning outcomes and outlines expected exit-level behavioural performance for each competency block. These can be used as a basis for framing predefined benchmarking standards, against which a repository of criterion-referenced assessment items can be created to measure the mastery level of the cohort of students, including, more specifically, the aspects, domains or specific topics they have mastered and any areas in need of improvement.

Norm-referenced assessments, which compare individual students to the rest of the cohort on the same course, are not the main focus of the competency-based assessments in the AI curriculum. However, national or institutional agencies in charge of AI curricula may consider building a set of dynamically adjusted norms of students' competency development in key aspects or domains of AI through the long-term tracking of students' performance. The norm-referenced assessments can also provide a comprehensive view of a student's abilities compared to their peers, and a benchmarking of local students' competencies compared to same-age students in other countries. The mean of the norm should be measured against the predefined standards of AI competencies to monitor whether the learning outcomes of the majority of students exceed, meet or are below the minimum standards. Finally, the performance of different groups of students compared to the norms should be disaggregated and analysed by age, gender or demographic background, to help provide evidence for policies or strategies that enable remedial or supplementary support for students who are disadvantaged in learning AI.

Adapt performance scenarios to assess overt performance and latent competencies

AI technology is designed to address real-world problems, and its practice-orientated nature requires the use of real-world scenarios and authentic tasks to measure students' performance in applying their mindset, ethical principles, skills and knowledge, and to psychometrically validate students' development of multiple aspects of AI. The competency-based assessment should fully leverage tasks showing students' measurable or overt behavioural performance (what they can do), which is often termed 'performance-based assessment'. However, to fully meet the needs of assessing both observable behaviours and latent competencies involving the human-centrality of mindset and ethics, transferability of conceptual knowledge, adaptivity of practical skills, and creativity in AI system design, the objectives and methods for assessing performance should be adapted as follows:

- **Assess both observable performance and latent competencies:** Move from pure assessment of observable behaviours (what students already do) to the psychometric testing or validation of students' latent knowledge schema on AI techniques and application abilities (what they can potentially do), human-centred critical thinking and ethical evaluation and selection of AI tools to serve specific purposes (how they apply ethics to their use of AI).
- **Shift from assessing rote learning to testing transferability, adaptivity and creativity:** Assessment methods should move from the measurement of fixed, repetitive operations to the design and use of varied tasks to assess how students can transfer knowledge and skills across contexts (how students can transfer knowledge and skills) and adapt to novel situations. Methods should also shift (how students can adapt); move from a limited focus on the fluency of operating existing AI tools to how students can critically evaluate existing tools and collaboratively craft or co-create new AI tools (what students can co-create).
- **Balance domain-specific and integrative AI competency assessments:** Building upon the domain-specific assessments of

mindset, understanding and practices of ethics, knowledge and skills, design and use authentic project-based testing to assess students' integral competencies to blend and integrate ethical principles, AI knowledge and skills, and computational and engineering thinking to critically evaluate AI tools, redesign algorithms or co-create AI systems. These project-based assessments of how students can integrate AI competencies to solve problems require curriculum developers or teachers to design open and authentic tasks; the breadth of the required competencies should be adapted to the different progression levels, and appropriate grading scales need to be designed to reflect the measurement of open and multilayered competencies.

- **Configure authentic assessment tasks and grading scales for AI competencies:** The design of assessment items can be framed by the detailed specifications of each competency block provided in Chapter 4. The configuration of assessment tasks, methods of administering assessment and formats of responses should be aligned with the requirements of each domain (mindset, ethics, conceptual knowledge on AI, operational AI skills and comprehensive AI system design). This means the specific assessment tasks should be tailored according to the cognitive and behavioural performance that can psychometrically validate the mastery of 'Understand', 'Apply' and 'Create'. For the 'Understand' level, the tasks may focus more on the comprehension of the concepts and ethical principles underlying performance, with less focus on concrete practical skills, while tasks at the 'Apply' level can centre on problem-based practical skills and adaptivity in coping with task variation. For 'Create', the measurement tasks might be more about synthesis and algorithmic programming on the conceptualization of new ideas, design of virtual or physical prototypes of new AI tools or systems, the knowledge and skills to test and optimize AI models, the comprehensive computational skills and engineering demonstrated in the co-creation of AI, as well as the human-centred mindset and ethical principles underlying the design and testing.

The focuses of domain-specific assessments divided by three progression levels are recommended as follows for further deliberation, and a non-exhaustive list of examples of assessment items is provided in **Table 5** to inspire configurations of assessment instruments that cover all topics and progression levels of the local curriculum.

1. Human-centred mindset:
1.1 Conflict-based opinion taking
1.2 Conflict-based critical evaluation
1.3 Conflict-based social actions

2. Ethics of AI:
2.1 Scenario-based ethical value orientation
2.2 Scenario-based ethical behaviour
2.3 Scenario-based rule-making

3. AI techniques and applications:
3.1 Problem-based AI knowledge and understanding
3.2 Tool-based conceptual insights and transferable operation
3.3 Task-based tool crafting

4. AI system design:
4.1 Project-based design thinking
4.2 Project-based system configuration
4.3 Project-based iteration

The three forms of assessment under AI system design are based on the virtual environment of Teachable Machine and a simulation project on the design, training, testing and optimization of an AI system. The project should be defined around themes relating to the real-world needs of promoting social inclusion, and using data on local languages or cultural features when training AI models. One critical aspect of the integrated AI competency is the comprehensive ability to iterate AI systems based on feedback, and therefore traditional methods such as paper-based testing should be expanded upon to include metrics that capture a student's ability to conduct technological conceptualization, and create prototypes and processes for improvements, together with their technical expertise demonstrated in the projects.

Table 5. Examples of assessment tasks

COMPETENCY ASPECTS	PROGRESSION LEVELS		
	Understand	**Apply**	**Create**
Human-centred mindset	**1.1 Conflict-based opinion taking** **1.1.0** An integral paper and/or computer-based test on the main points of 'Human agency'. **1.1.1** Can AI be used in supporting human decisions on values and social issues? Name a weakness of current AI technologies in supporting decisions in relation to values, social issues and personal emotional reactions. **1.1.2** What will happen if humans don't take accountability in the conceptualization and design of AI systems? **1.1.3** Will machine agency become stronger than human agency, and take over more and more human agency? Explain your opinion.	**1.2 Conflict-based critical evaluation** **1.2.0** An integral paper and/or computer-based test on the main points of 'Human accountability'. **1.2.1** The media reported that artificial general intelligence will arrive by 2030 and will overpower humans in almost all areas, while some AI experts have said AGI may never emerge. Who is correct? Evaluate whether some selected media reports of AI go beyond the genuine capabilities of AI technologies. **1.2.2** In the future, will all minutes of daily meetings and administrative reports be drafted by AI? Do the next generation of students still need to learn how to synthesize materials and draft reports? Assess whether a particular problem in life or subject learning can and/or should be solved with AI methods.	**1.3 Conflict-based social interactions** **1.3.0** An integral paper and/or computer-based test on the main points of 'Social responsibility'. **1.3.1** Will AI eventually help humans remove the drivers of climate change and protect the planet's well-being? Should human societies mobilize all resources to unlimitedly train AI models? Or has the training of AI models generated irreversible impacts on climate change? Analyse how some AI systems can affect environments and climate change, and how their methods could be optimized. **1.3.2** Will AI become indispensable and trustworthy co-workers of humans or will AI threaten the safety, inclusion, equity, justice and other social norms of human societies? Critically reflect on the potential impact of AI on human societies. **1.3.3** Will AI create jobs for all groups of people equally or will the deployment of AI cause more inequality in economic development in the connection of global markets and your local context? Critically evaluate why AI has become increasingly important and how it may affect your local economy and job market. **1.3.4** AI companies have claimed that they are developing AI tools for all. Will AI enhance or threaten inclusion and equity? Critically evaluate the implications of the wide adoption of AI for inclusion and equity in your local context.

COMPETENCY ASPECTS	PROGRESSION LEVELS		
	Understand	**Apply**	**Create**
Ethics of AI	**2.1 Scenario-based ethical value orientation** **2.1.0** An integral paper and/or computer-based test on the main points of 'Ethical principles'. **2.1.1** You have never expressed consent to the use of your personal data to train AI models, so are your personal data protected and safe? Describe how personal online data have been collected and used without consent. **2.1.2** You have only entered your personal data in the prompt to request a 'trustworthy' generative AI system to help you draft a recommendation letter. Can you be sure your private data won't be disclosed? Describe how sensitive personal data may be collected through prompts or interactions with AI systems. **2.1.3** Video-sharing platforms such as YouTube and TikTok look as if they can understand what sorts of videos the users may like and know how to recommend videos that will be of interest to users. Please identify ethical issues around the video-recommendation algorithms used by video platforms.	**2.2 Scenario-based ethical behaviours** **2.2.0** An integral paper and/or computer-based test on the main points of 'Safe and responsible use'. **2.2.1** Explain why data security must be considered when developing and using AI applications. **2.2.2** If we want to benefit from the useful services offered by an AI system, is it necessary to forego some of our personal privacy to enjoy the benefits? Explain why data privacy must be considered when developing and using AI applications. **2.2.3** 'I have tried many AI platforms and they always provided service exceeding my expectations, so I don't need to be provided with the explanation on how these AI models work?' Evaluate this statement and describe the concept of explainable AI. **2.2.4** 'I used a photo of one of my friends to generate a video using a generative AI tool and it looks very real, and I posted it online for fun; I used a generative AI system to author essays based on my 'creative' prompts and I published them in my name.' Evaluate one or both of these statements and describe potential legal problems that may arise when using AI-generated content or claiming it as 'your' work.	**2.3 Scenario-based rule-making** **2.3.0** An integral paper and/or computer-based test on the main points of 'Co-creating ethical rules'. **2.3.1** Has your country or school (district) developed regulations on the use of AI (or generative AI)? If yes, critically evaluate the regulations against core principles of UNESCO's *Recommendation on the Ethics of AI* and/or with the EU AI Act. If no, develop a proposal to justify the necessity of regulations and outline the main points they should cover. **2.3.2** Co-create ethical guidance for yourself and your peers on the use of video-recommendation platforms or generative AI systems. **2.3.3** Co-create a set of ethical rules for the safe and responsible use of AI in your schools and at home. **2.3.4** Co-create regulatory rules for the brain-computer interface (BCI) technology

COMPETENCY ASPECTS	PROGRESSION LEVELS		
	Understand	**Apply**	**Create**
AI techniques and applications	**3.1 Problem-based AI knowledge and understanding** **3.1.0** Competency-based or criterion-referenced examination on key conceptual knowledge on AI. **3.1.1** Describe or exemplify (using tools) what AI is and is not; or exemplify personal, school-based or public tools that are supported by AI. **3.1.2** Explain the difference between strong AI and weak AI. **3.1.3** Describe the basic concept of big data; give a couple of examples of misusing big data. **3.1.4** Explain how machine-learning models are trained, tested and optimized; explain why data play an important role in the training, development and further iterations of an AI model. **3.1.5** Explain how deep learning relates to machine learning. **3.1.6** Define the term 'artificial neural network' (or other key concepts applicable for the 'Understand' level).	**3.2 Tool-based conceptual insights and transferable operation** **3.2.0** Criterion-referenced, computer-based examination on the fluency, transferability and adaptability of operational skills on data, algorithms and programming. **3.2.1** Exemplify applications which use any of the following: natural language processing, computer vision, speech recognition, image recognition, autonomous agent systems, emotion detection, data-based prediction or generative AI. **3.2.2** Explain how supervised learning, unsupervised learning and reinforcement learning work on a basic level. **3.2.3** Exemplify typical AI algorithms under the categories of supervised learning, unsupervised learning and reinforcement learning; exemplify tools that use some of these typical algorithms. **3.2.4** Explain what AI algorithms are used and integrated by a given generative AI system. **3.2.5** Exemplify two to three open-source datasets and libraries of AI algorithms; explain the advantages and limitations of open-source datasets and algorithm libraries.	**3.3 Task-based tool crafting** **3.3.0** Computer-based individual or group work to customize existing AI toolkit(s) to create a task-based AI tool. **3.3.1** Explain how sensors, crawling software, and other tools are used by AI researchers and designers to collect data that can be used to train AI models. **3.3.2** Explain and/or demonstrate by operation how to find and reuse open-source datasets and libraries of AI algorithms; evaluate the benefits and risks in comparison with AI options from proprietary enterprises. **3.3.3** Draft a design-and-development plan on a task-based AI tool to address real-world needs in and beyond the local context. The plan should cover the following criteria on an age-appropriate level: critical analysis of existing AI tools, assessment of need for data, methods to collect and process data, appropriate AI algorithms and programming languages, open-source AI tools or systems that can be customized or fine-tuned, and parameters for the testing of the AI tools.

COMPETENCY ASPECTS	PROGRESSION LEVELS		
	Understand	**Apply**	**Create**
AI system design	**4.1 Project-based design thinking** **4.1.0** Simulated tests on problem-scoping for AI system design. Request that students produce a report and/or oral defence on problem scoping or on a project proposal. The report can be evaluated according to the following criteria: why AI should be used for the problem based on a checklist; and the problem statement including key requirements or features of the AI systems such as algorithms, datasets and functionalities. **4.1.1** Explain why a specific real-world challenge (given by teachers) should not be solved by an AI tool. **4.1.2** Computer-based test on data preprocessing techniques, drawing on open-source datasets including adjusting the data augmentation, handling outliers, analysing dataset skew or imbalance, training the model based on modified datasets, and observing how data preprocessing affects the model's performance compared to the given dataset.	**4.2 Project-based system configuration** **4.2.0** Computer-based tests on the architectural configuration of AI. The simulated operation can be evaluated using the following criteria: assessment and selection of frameworks for AI architectures; evaluation and choice of solutions for the layers and components of the AI architecture; the configuration of a prototype architecture; and the presentation of the configuration. **4.2.1** Explain how open-source datasets and libraries of AI programming can be leveraged to build an AI system including locally accessible cloud computing platforms or operating systems, and software needed by the training of machine-learning models. **4.2.2** Explain what criteria should be considered to optimize for efficiency and minimize computational resource waste when configuring AI architecture. **4.2.3** Calculate the selected AI model's consumption of computing resources, and design strategies for improving the efficiency of AI methods to reduce its environmental impact.	**4.3 Project-based iteration** **4.3.0** Computer-based simulated optimization of a simple AI model, including operational optimization of the datasets, algorithms and parameter adjustment, and the design of functionalities and interfaces; and/or reconfiguration of the architectures, including modifying the problem-scoping. **4.3.1** Design a set of metrics for the performance-testing of an exemplar AI system. Explain what metrics can be designed or adapted to support the measurement of the system's performance and to collect feedback from end users on the societal implications and environmental impact. Exemplify open-source tools that can conduct and report on the performance-testing of an AI system. **4.3.2** Draft a report to explain what decision should be taken on an AI system and why, based on the findings of simulated performance tests and user feedback. Include explanations of decisions to optimize, reconfigure and shut down the system; present the plan for optimization or reconfiguration, or for mitigation strategies if the AI system has the potential to cause harm. **4.3.3** Exemplify locally accessible online communities of AI co-creators; explain what a student can do in these communities.

Agile formats of concrete assessments and corresponding grading scales that fit neatly into different assessment items and objectives should be designed, tested and optimized. These may include formative and peer assessments in the form of reflective essays, oral presentations or reports of users' tests of AI tools; and summative examinations on paper and/or via computer-based or unplugged design, including prototypes of AI tools or drawing of algorithms, essays about case studies on AI's ethical issues, technical reports on the design and development of AI tools or systems, the fine-tuning or simulated training of AI models, and the assembling or creation of hardware.

This large array of concrete methods should be examined in a nuanced manner against the specific needs of aspects and infused flexibly in the implementation of the AI CFS.

The use of AI tools for assessments also emerges as a new supplementary method of assessment, for example automating the collection of data on learning processes and formative mastery directly from students or learning management systems, personalizing assessments for students according to their ability or linguistic and cultural background, or facilitating teachers' decision-making on teaching strategies. While the opportunities being enabled by AI to enhance assessments should be dynamically reviewed and properly leveraged, it is critical to examine and regulate ethical issues concerning the collection and use of students' data; the risks of using AI recommendations and predictions in assessments, especially those with high stakes; and the reduction of teachers' agency in assessments, particularly the opportunities for teachers to gain insights from analysing learning processes.

Conclusion

The *AI competency framework for students* charts an action-oriented programme based on three basic assumptions about the role of education in responding to the pervasive adoption of AI in today's world. The first is that the education sector, rather than merely adapting to AI systems and tools, must be proactive in developing the competencies required to shape ethical and environmentally-friendly AI. Second, that students should be equipped with the competencies to act both as critical and responsible users and co-creators of AI, as well as leaders in defining and designing the next generation of AI technologies. The third assumption is that students' AI competencies are to be constructed around the convergence of a human-centred mindset and attitudes, internalized ethics of AI, transferable conceptual knowledge and skills on AI, as well as future-proof thinking relative to AI system design. As AI competency development goes far beyond mere technical skills associated with learning to code or to operate AI tools, the integration of AI-related learning requires an interdisciplinary approach to curricular integration spanning subjects related to science, technology, engineering, art and mathematics, to social studies and citizenship education.

This AI competency framework for students is the first attempt to provide a global blueprint to steer a human-centred integration of AI-related learning in curriculum. Informed by expertise and consultations at the international level, the framework serves as a global reference to be adapted across diverse local educational contexts. It is only through adapting and testing the framework among teachers and teacher educators in diverse settings, and surfacing insights from their contextualized practice, that the global framework can be further refined. As such, the framework is a living document which will need to be continuously reviewed on the basis of analysis of practice in a diversity of contexts, as well as in response to new iterations of AI technologies that will emerge.

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Endnotes

1 The principle of proportionality in AI encompasses the idea that AI systems should be designed and deployed in a manner that appropriately balances risks and benefits, respects human rights, and aligns with societal values and interests. See the *Recommendation on the Ethics of AI* (UNESCO, 2022*a*) for more on the proportionality of AI.
2 RAISE stands for 'Responsible AI for Social Empowerment and Education'
3 See https://ubuntu.com
4 See https://machinelearningforkids.co.uk
5 See https://teachablemachine.withgoogle.com
6 See https://www.tensorflow.org
7 See https://keras.io
8 See https://everyday-ai.org/resources/search?f%5B0%5D=tools%3A201
9 See https://www.aiunplugged.org
10 See https://iste.org/blog/3-unplugged-activities-for-teaching-about-ai
11 See https://raise.mit.edu/daily
12 See http://yann.lecun.com/exdb/mnist
13 See https://www.cs.toronto.edu/%7Ekriz/cifar.html
14 See https://www.image-net.org/index.php
15 See https://teachablemachine.withgoogle.com
16 See https://appinventor.mit.edu
17 See https://pytorch.org
18 See https://keras.io
19 See https://pypi.org/project/beautifulsoup4

unesco

United Nations
Educational, Scientific
and Cultural Organization

AI competency framework for students

The *AI competency framework for students* presented here is based on an ambitious vision that extends well beyond popular notions of AI literacy. It aims to support students to grow towards being not only effective and ethical users of AI tools, but also co-creators in the design of more inclusive and environmentally sustainable AI. The framework defines the values, as well as the foundational knowledge and transferable skills, required to critically understand and use AI systems in a safe, effective and meaningful manner at different levels of mastery. The framework also proposes detailed specifications on what AI topics can be covered and what pedagogical methods may be deployed to facilitate students' understanding, application, and creation of AI. It further provides guidance for the curricular integration of AI-related learning, the organization of learning sequences, and the design of competence-based assessments. Seen as an integral set of capabilities required for responsible citizenship in the era of AI, the competencies outlined in this framework are based on principles of inclusivity, the centrality of human agency, non-discrimination, and respect for linguistic and cultural diversity.

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4 QUALITY EDUCATION

Sustainable Development Goals