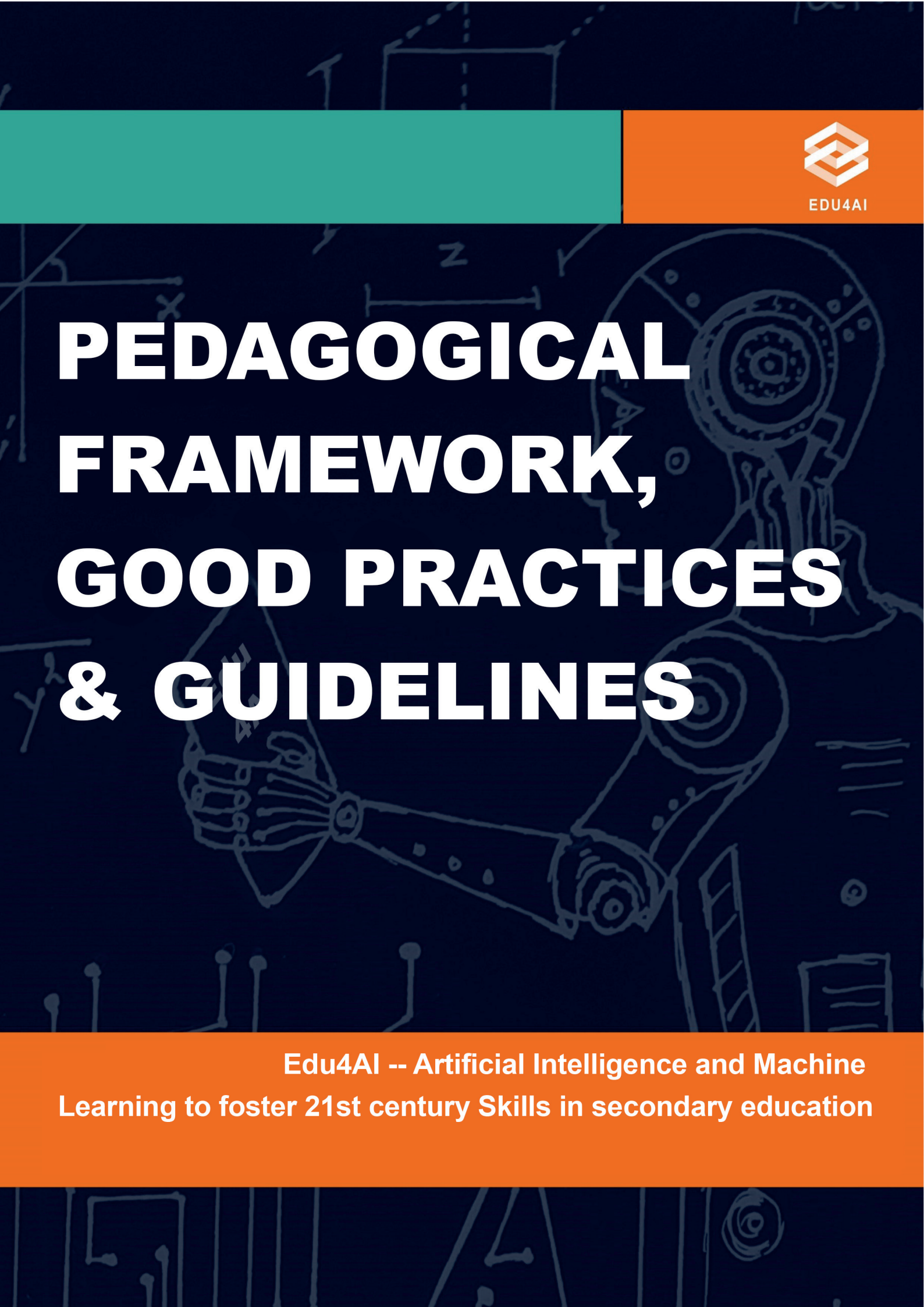

PEDAGOGICAL FRAMEWORK, GOOD PRACTICES & GUIDELINES

Edu4AI -- Artificial Intelligence and Machine Learning to foster 21st century Skills in secondary education

Edu4AI

Pedagogical framework, good practices & guidelines

Edu4AI -- Artificial Intelligence and Machine Learning to foster 21st century Skills in secondary education

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Abstract

"**Pedagogical framework, good practices and guidelines**" can be used as a theoretical and practical compendium for teachers on how to develop an AI curriculum for secondary school. In the **introductory chapter** we discuss the importance of AI in society and the current need for a meaningful pedagogy of AI in order to face fundamental challenges for XXI century education. **Chapters 1 and 2** provide an outline of thirty-two good practices and thirty-one publications, including guidelines, case studies, tools mapping and methods reviews - which helps in understanding how AI is currently applied at school: the two categorization tables included in this chapter contain useful examples of class activities, technologies, pedagogical objectives and learning outcomes. Based on the information retrieved from the analysis of the collected good practices and publications, **chapter 3** presents an overview of AI in education in terms of teaching/learning formats, pedagogical style, learning contents, learning objectives and type of tools. **Chapter 4** contains a proposal of a pedagogical framework to build AI curricula to ensure equal opportunities and to foster students' mind-set toward a more sustainable society. Finally, **chapter 5** delineates instructional materials including AI curricula design workflow, curriculum template, learning units canvas, teaching cards canvas and students worksheet.

Through this compendium, teachers can get a comprehensive view of AI in education, develop a methodological ground for their lessons, get inspiration from international projects, access useful online resources, and contribute to reinforcing the connection between school and society.

Introduction

These guidelines are intended as a methodological and operational document **addressed to** all the teachers who intend to introduce Artificial Intelligence in their didactics with relevant links to the main current fields of application of AI.

Artificial Intelligence is becoming ubiquitous in our society and in our daily life: seeming less integrated in a wide range of domains - scientific research, web development, robotics, marketing, transports, finance, logistic, health, etc. - its development is characterized by exponential rate and astonishing complexity (Taguma et al., 2018). Consequently, a great deal of future **career paths** for the new generations will undoubtedly be AI-related (ibidem). For this reason, AI is increasingly included in **educational programs** as a prerequisite to understand (and operate into) the contemporary world as well as to have access to a significant part of the job market. European networks, national projects, pedagogical research are jointly contributing to define educational standards, didactic patterns and best practices for the introduction of AI at school (Holmes et al., 2019).

However, much has to be done in order to identify effective and rational answers to the "**quest for meaning**" which is presently carried worldwide in the field of AI education in order to define **how AI can "make sense"** at school (e.g., Villani 2018). The reflections, solutions and products that will be illustrated in the present document are based on the idea that, in order to build an effective framework for the integration of AI in didactics, it is of the utmost importance to take into account the following **three challenges**:

- Learning design of AI contents for school should target **educational priorities of the 21st century** which mainly concern **sustainability in different areas** (environment, health, society, and economic development); this implies a special focus on interdisciplinary work through collegial design thinking practices that go beyond single disciplines.
- In order to spread AI in education and prompt inroads towards AI educational standards, teachers need empowering instructional tools to develop and test structured sequences of unit lessons and projects that can allow the building of **AI curricula**.
- AI as a subject of study itself needs to be democratized and made accessible for all learners, supporting in this way **fairness and equal opportunities** in education for all: true innovation does not leave anyone behind.

Hence, the **objectives of these guidelines** are to i) outline present trends in AI pedagogy; ii) share helpful examples, insights, recommendations and tips for teaching AI at the secondary school; iii) provide material for instructional design of AI curricula.

All the information contained in this document are the result of the research actions carried during the Erasmus+ KA2 project Edu4AI[1] (Artificial Intelligence and Machine Learning to foster 21st century skills in secondary education) whose main objective is to support teachers and educators to build a student-centered engaging techno-pedagogical environment through: the building of an AI community; the design, test and sharing of AI open educational resources (OER); and, the identification of a simple framework to introduce AI at school.

1 https://edu4ai.eu/

1. A selection of K-12 good practices at European, international and national level

The selection of thirty-two good practices available in the Annexes is the result of a review conducted by the Edu4AI partners on projects, pilot studies and networking initiatives around educational AI. The objective of the review was to examine good practices at implementation and/or evaluation stage with the aim of defining a global taxonomy of AI usages at school, selecting useful didactic materials, and pointing out lessons learnt from concrete experiences. The selection focused on good practices at European, international and national level related to the implementation of AI learning intervention in the class (age 13+), related to how students can learn to create AI apps and/or AI artefacts of their own design.

Amongst the thirty-three best practices, twenty-two are teachers-oriented, while eleven are students-oriented.

Teachers-oriented best practices mostly describe co-design processes of didactic materials, opportunities for professional development and set of AI in-class activities. The main outputs of teachers-oriented best practices are AI curricula, published as: i) teachers' or facilitators' handbooks (which includes handouts, rubrics, lessons plans, and ready-to-be implemented projects); ii) AI dedicated platforms with open-access repositories of projects, videos, didactical resources. Curricula often include both technical and social aspects of AI, with a focus on interdisciplinary subjects such as environment. A limited number of these best practices concern authentic or situated learning within project-based framework (e.g. AI in agriculture, AI for sport, AI to solve problems in given communities etc.), and experimental studies on didactics of AI based on robots and visual/text recognition.

Students-oriented best practices are mainly platforms designed for young learners who are willing to discover AI techniques and concrete applications. These platforms host texts and video-courses, dedicated apps and GUI, web-based machine learning exercises, and students' networks. Learning materials are approachable and attractive, mostly related to image and/or sound classification; this helps students acquire basic knowledge on AI (neural networks, decision trees, machine learning workflow, etc.); develop competences on how to build AI training processes; develop AI based digital artefacts (apps, games artworks, chatbots and animations to share); become aware of impacting society positively through AI.

Good practices

Teachers-oriented

LINK	https://www.iste.org/learn/AI-in-education
SHORT DESCRIPTION	Detailed curriculum and lesson plans for teachers who want to teach artificial intelligence at different school levels.
OBJECTIVES	Basic understanding of artificial intelligence and how to implement it using different targets like robots or computer games.
ACTIVITIES	Machine learning as a service, Robotic motion planning, AI powered players in video games.
RESULTS	Understand the basic principles of how artificial intelligence does work in different areas.

LINK	https://www.actua.ca/en/programs/codemakers/#aicodemakers/#ai
SHORT DESCRIPTION	Actua's AI project develops an artificial intelligence (AI) curriculum for high-school students. Working with a team of leading AI experts, the final objective is developing new content that covers the basic principles of AI and how it will influence future careers. As part of the project, teachers trainings are developed, as well as workshops and the AI Education Handbook for teachers, parents, citizens.
OBJECTIVES	– Develop AI for education framework including new contents that covers the basic principles of AI and how it will influence future careers. – Develop materials to support teachers introducing AI in school – Provide K-12 pre-service and classroom teachers with professional development opportunities designed to enhance learning outcomes in their current curriculum. – Develop students awareness about AI and their competences developing AI projects
ACTIVITIES	– Definition of AI for Education Framework (described in the handbook), with workshops for each of the six AI themes. – AI Teacher Training in-person workshops. These are face-to-face, interactive professional development opportunities offered throughout the year by Actua and our network members. – Development of teachers handbook. – Piloting (teachers implementing activities with students).
RESULTS	An AI handbook, freely accessible, has been developed: https://www.actua.ca/en/ai/

LINK	http://cbseacademic.nic.in/ai.html
SHORT DESCRIPTION	Sharpening its focus on STEM (Science, Technology, Engineering, Mathematics, Education) education, Central Board of Secondary Education (CBSE), in collaboration with Intel's AI4Youth initiative, has released its Facilitators Handbooks to provide artificial intelligence (AI) based education to grade 8 and grade 9 students, in order to develop an "AI-Ready Generation". The course is added to the regular school curriculum by 2020 to help students understand AI and develop their interest in it.
OBJECTIVES	Artificial Intelligence Curriculum aims at developing the learner's mind set and skills set towards artificial intelligence (technical and social issues). The handbook framework is organised in units, each of them referring to specific skill sets including conceptual, technical and life skills.
ACTIVITIES	Development of facilitators handbook for grade 8, 9, and 10 combined with courses and workshops to support teachers developing a methodology to introduce AI in class with practical activities through 112-hour curriculum
RESULTS	AI facilitator handbooks have been developed for grade 8 and 9: http://cbseacademic.nic.in/web_material/Curriculum21/publication/secondary/Class10_Facilitator_Handbook.pdf http://cbseacademic.nic.in/web_material/Curriculum20/AI_Curriculum_Handbook.pdf

LINK	https://www.iste.org/learn/AI-in-education
SHORT DESCRIPTION	The International Society for Technology in Education (ISTE) developed the Hands-On AI Projects for the Classroom series, a set of guides for teachers who are seeking instructional and curricular resources about artificial intelligence (AI) for various grade levels and across a range of subject areas. Projects engage students in both unplugged and technology-infused activities that explore key facets of AI technologies.
OBJECTIVES	– Raise awareness about the ethical and societal implications of AI systems and how they are designed and regulated - Challenge students to become increasingly sophisticated consumers of media - Use of chatbots and virtual assistants to support learning and productivity - Use of AI for solving problems related to science and the environment
ACTIVITIES	Teachers and facilitators training on how to introduce AI activities in class; handbook development; piloting and collecting case studies
RESULTS	A set of educational projects has been developed. Each project includes instructions for: • Getting Started activities that hook students' interest, activate prior knowledge, and introduce them to the project's objectives. • Take a Closer Look activities that develop students' AI understanding by providing students with scaffolded, guided learning activities that make connections between AI concepts and subject area content. • Culminating Performances that challenge students to synthesize their learning, complete a meaningful performance task, and reflect on the societal impact of what they've learned.

LINK	http://aiplus.udc.es/
SHORT DESCRIPTION	The development of an Artificial Intelligence curriculum adapted to high school education in Europe using the student's mobile phone (smartphone) as a central technological element to all educational material to be developed.
OBJECTIVES	Provide initial training in AI to foster students' basic knowledge about how AI systems operate.
ACTIVITIES	Artificial Intelligence (AI) curriculum is developed for students from 14 to 18 years old, with some previous basic knowledge of technology, mathematics and programming. It covers a two-year period prior to their incorporation to tertiary education. This curriculum is focused on technology or science students (not arts or humanities).
RESULTS	he main results of the project correspond to four intellectual outputs: 1. A book (digital and printed) with teaching units for the teacher 2. A book (digital and printed) with activities for the student 3. AI Libraries and programming environments that allow high school students to develop the teaching units 4. A Best Practice Guide encompassing all the intangible results and conclusions extracted from the activities carried out during the project, both from a technical and from a social perspective.

LINK	http://ai-4-all.org/open-learning/
SHORT DESCRIPTION	AI4ALL Open Learning empowers high school teachers of all subjects to bring AI education to their classrooms through a free, adaptable AI curriculum and teacher resources. It is designed to equip educators and community members to empower high school students with relevant and approachable AI education. The program can be incorporated into the classroom, a club, or a workshop and provides 60+ hours of free curriculum with facilitator guides.
OBJECTIVES	Through the proposed curricula, students will learn: a) What AI and Machine Learning are b) Who some role models in AI are c) The benefits and risks of AI and Machine Learning to the world and to themselves d) How they can be involved in the world of AI and Machine Learning
ACTIVITIES	The proposed activities revolve around Machine Learning methods, programming image recognition, data collection and issues related to ethics, as well as designing AI-enhanced education apps. Through the proposed activities different subjects are addressed, such as art, science, environmental strategies and many more.
RESULTS	Students are getting familiar with methods of AI and Machine learning. By getting involved in different projects they are progressively able to design their own AI-enhanced educational apps.

LINK	http://aiinschools.com/
SHORT DESCRIPTION	The aim of the AI inSchools programme is to demystify the topic of Artificial Intelligence and to provide free, accessible resources for teachers for usage within the classroom. Specifically, it contains an in-depth curriculum pdf download with daily lesson plans, supporting handouts and rubrics, and live links, as well as supplementary teacher resources—all classroom-tested and ready for implementation.
OBJECTIVES	Students will gain knowledge and skills while considering the social, moral, and ethical impacts of AI systems and their usage, as well as gaining an understanding of how a Neural Network functions. They explore practical daily applications of AI that are likely to have an impact on their lives. Students design smart cities, homes, and schools and share them with the group. Students also learn to build, train, and test an AI system through a NVIDIA platform. Students are also encouraged to look at how "the message of AI" is communicated to each of us through images and narratives.
ACTIVITIES	The proposed lessons include activities such as: a) Identify the AI being used in different industries, such as Image recognition, speech recognition, translation and apply this knowledge to a fictional Smart City. b) Gain an understanding of how a Neural Network functions, and how Maths is used in a neural network c) Train an AI system, gain an understanding of datasets and test the AI system d) Explore the impact of AI on society and in fields such as agriculture, cooking, transport including driverless cars, medical diagnosis
RESULTS	Throughout the unit students are encouraged to come up with their own designs for areas such as smart cities, homes, and schools and to share them with the group. Students also learn to build, train, and test an AI system. Students are also encouraged to look at how "the message of AI" is communicated to each of us through images and narratives.

LINK	https://ai4k12.com/
SHORT DESCRIPTION	The mission of AI4K12 is to develop national guidelines for teaching AI in K-12, modeled after the CSTA (Computer Science Teachers Association) standards for computing education. The guidelines revolve around two fundamental questions, namely “what should students know?” about AI, and “what should students be able to do?” through the implementation of AI technology. Another goal of this initiative is the development of a curated AI resource directory for K-12 teachers, as well as fostering a community of K-12 AI resource developers. The guidelines are based on five Big Ideas: a) perception, b) representation & reasoning, c) learning, d) natural interaction and e) societal impact. A number of different types of resources – in the form of interactive links – are provided (https://ai4k12.com/resources/list-of-resources/), such as suggested books and reports, curriculum materials, Demos, Online Courses, reference sources and tutorials, software packages, as well as videos.
OBJECTIVES	Through the use of transparent AI demonstrations, students will be able to understand the fundamental concepts of AI (i.e. shift from a black box to a white box paradigm). They will also be able to understand the mechanisms of AI application through building mental models. Moreover, they will be encouraged to develop their own AI application by using AI services.
ACTIVITIES	Depending on the age group, the activities that can be included to a curriculum vary. Some of the proposed activities are a) experimentation with AI agents to investigate their behavior, b) hand simulated AI algorithms, c) building AI applications, as well as d) exploring case studies of AI-related societal issues from multiple perspectives.
RESULTS	The included/proposed activities promote understanding of: a) how AI works, b) what are the limitations of AI, c) systems thinking, d) sources of bias in AI, as well as e) societal impacts of AI systems.

LINK	https://ecraft2learn.github.io/ai/
SHORT DESCRIPTION	This good practice is about a set of extensions to the Snap! programming language to enable children (and non-expert programmers) to build AI programs, that were developed during the eCraft2Learn project. The blocks are available as projects with examples of using the blocks as well as libraries to download and then import into Snap! or Snap4Arduino.
OBJECTIVES	Students will learn how to apply speech synthesis and speech recognition through block-based programming methods. They will also learn how to add image recognition to their programming projects. They will also learn how applying training machine learning models to their programs as well as creating machine learning neural nets.
ACTIVITIES	The proposed projects include activities such as: a) Enabling sprites to speak in over a hundred languages. b) Enabling sprites to listen to speech in over a hundred languages as well as to recognize sounds. c) Enabling sprites to see using the camera. d) Enabling projects to do arithmetic on words. e) Enabling projects to create, train, and use deep learning neural networks. f) Miscellaneous AI blocks (style transfer, image embedding, and using Wikipedia and Yahoo Weather).
RESULTS	Students will be able to create their own projects through speech synthesis as well as speech and image recognition, understand machine learning models, and also to create, train and use deep learning neural networks.

LINK	https://www.media.mit.edu/projects/ai-ethics-for-middle-school/overview/
SHORT DESCRIPTION	This project seeks to develop an open source curriculum for middle school students on the topic of artificial intelligence. Through a series of lessons and activities, students learn technical concepts such as how to train a simple classifier - and the ethical implications those technical concepts entail, such as algorithmic bias.
OBJECTIVES	Throughout the curriculum students learn to think of algorithms as opinions, are taught to consider direct and indirect stakeholders in a system, and engage in design activities to reimagine familiar artificial intelligence systems.
ACTIVITIES	Development and piloting of An Ethics of Artificial Intelligence Curriculum for Middle School Students: the document includes a set of activities, teacher guides, assessments, materials, and more to assist educators in teaching about the ethics of artificial intelligence.
RESULTS	The ultimate goal is to enable students to see artificial intelligence as manipulable - from a technical and societal standpoint - and to empower students with tools to design AI with ethics in mind.

LINK	https://www.hkedcity.net/goelearning/sites/default/files/upload/5e1d1c4d0da87e5202adf7c6/1578966276_16_Dr%20Thomas%20Chiu%20Kin-fung.pdf
SHORT DESCRIPTION	Project initiated from the CUHK (Chinese University of Hong Kong) in collaboration with selected schools and AI companies and supported by the government. A team of 14 professors with expertise in engineering and education collaborated with 17 principals and teachers from 6 secondary schools to co-create the curriculum. 335 students have participated in total.
OBJECTIVES	– Define main features of an AI curriculum through co-creation process. – Improve the students' perceived competence in, as well as attitude and motivation towards AI. – Better understand teachers' perceptions of the co-creation process, accommodate and foster teacher autonomy.
ACTIVITIES	The program intended to foster students' communication skills about technical AI matters, learn from experience and failure and suggest new solutions and implement various machine learning techniques. As a result an AI curriculum has been designed. The project had two stages: a) A curriculum development phase b) An implementation phase In the implementation stage, teachers considered their school culture, environments and resources, and selected and fine-tuned the relevant content to create learning activities related to the AI technologies, in ways that are most fitting for their students' needs and interests. Three hundred and thirty-five students in total, aged 12-16, and 8 teachers from the pioneering schools have been involved to evaluate the curriculum and its co-creation process.
RESULTS	As major result was that he co-creation process can effectively connect the AI and education experts in the university with secondary school teachers. The proposed curriculum had significant effects on enhancing perceived competence and intrinsic motivation towards AI. The co-creation process has been shown to be an empowering and enabling process for teachers in supporting their efforts to bring AI into their classrooms. The curriculum has been assessed on AI knowledge, readiness, confidence, relevance and intrinsic motivation

LINK	https://www.exploreaiethics.com/
SHORT DESCRIPTION	The Artificial Intelligence (AI) for K-12 initiative (AI4K12) is jointly sponsored by AAAI and CSTA. Check out the following information to learn about this initiative. This website has a special focus on ethics.
OBJECTIVES	https://www.exploreaiethics.com/
ACTIVITIES	Articles, videos, curricula on AI ethics.
RESULTS	Students acquire knowledge, competences and skills on responsible computing, risks and ethics of AI.

LINK	techgirlz.org/topic/artificial-intelligence-computers-learn/
SHORT DESCRIPTION	Useful and well defined lessons for students to make them learn how k-nearest-neighbour algorithm and neural networks work.
OBJECTIVES	Students acquire an in-depth view of two different artificial-intelligence algorithms
ACTIVITIES	Neural Networks: Unplugged activities. K-nearest-neighbour: Usage of a Jupyter-Notebook to classify oranges and apples.
RESULTS	Students acquire basic knowledge how machine-learning algorithms work.

LINK	appsforgood.org/courses/machine-learning-std/launch
SHORT DESCRIPTION	On this platform students can explore a wide range of machine learning applications and assess the social, legal and ethical impact of the use of AI algorithms.
OBJECTIVES	Classification, Neural Networks, facial recognition, chatbots, driverless cars, modeling & evaluation
ACTIVITIES	Students use machine learning algorithms with Python, make presentations to fellow students, prepare the data and train a given m.l.-model
RESULTS	Understand how machines learn, what neural networks are, what is bias in a neural network; evaluate ethical impacts, be able to improve a machine learning model

LINK	https://www.media.mit.edu/groups/personal-robots/overview/
SHORT DESCRIPTION	Democratizing the development of artificial intelligence (AI) technologies is the purpose of the Personal Robots group at MIT Media Lab, in Boston (USA). Through the PopBot robot, which is a programmable and 'intelligent' social robot that plays with children to help them learn AI. It is a learning companion that uses tools such as the smartphone, LEGO blocks, Arduino and a tablet or computer. AI activities are developed around this technological ecosystem that allow children to create their own algorithms.
OBJECTIVES	The purpose is to train minors to understand and grow knowing AI, in addition to understanding how their attitude towards technology evolves as they learn how it works.
ACTIVITIES	All the activities he proposes to children have to do with games and art, and the playful robot character makes the experience especially attractive for the little ones. Children become creative designers: they learn by designing, training and interacting with the robot.
RESULTS	Know what AI is, how it works and know how to develop games or applications with it. Publications of the research group available hre: https://www.media.mit.edu/groups/personal-robots/publications/ For example, Text classification for Ai Education: https://dam-prod.media.mit.edu/x/2021/03/29/06_text_class.pdf

LINK	cs.uef.fi/sipu/pub/KoliPaper.pdf
SHORT DESCRIPTION	This practice describes a plain vanilla html and javascript app for training a classifiyng algorithm from scratch.
OBJECTIVES	Practice image recognition based on different filter applications on standard images and performing basic mathematical transformations to those filtered images. The motto of these exercises is NBB, meaning “No Black Box” programming.
ACTIVITIES	• M1 - introduction to video images (15 min) • M2 - method description (20 min) • M3 - group work (30 min) • M4 - assembling the app (15 min) • M5 - experimentation (20 min)
RESULTS	Students learn to write a javascript-version of a simple image recognition algorithm from scratch.

LINK	http://sessinger.com/Publications/Introduction_to_Machine_Learning.pdf
SHORT DESCRIPTION	Two sample scenarios for learning the basic principles of k-means clustering, starting from problem formulation, feature extraction, model selection, implementation and evaluation. The scenarios cover waste recycling and bacteria classification.
OBJECTIVES	Building a model for classification, implementing and evaluating it to improve performance.
ACTIVITIES	K-Means-Clustering algorithm is predefined. The students have to train the algorithm with self-formulated attributes. After training, the model is tested and evaluated by the students
RESULTS	Students have learned the basics of m.l. by implementing and exercizing a specific machine learning algorithm.

LINK	https://modeling-languages.com/multi-platform-chatbot-modeling-deployment-xatkit/
SHORT DESCRIPTION	Implementing a chatbot as an application embedding a recognition engine to extract intentions from user inputs, and an execution component performing complex event processing represented as a set of actions.
OBJECTIVES	Creating a multi-platform chatbot aiming to assist newcomers in the definition of issues on the Github platform, a reported concern in the open source community.
ACTIVITIES	Develop a chatbot using Xatkit Framework that provides a set of Domain Specific Languages (DSLs) to specify not only the chatbot’s conversation logic, but also the integration of third-party action
RESULTS	Users learn to create a chatbot designed in a platform-independent way, and deployed over multiple messaging platforms and NLP engines.

LINK	https://www.researchgate.net/publication/330476102
SHORT DESCRIPTION	This project addresses problem solving through integration of technological solutions such as AI in the social context (with a focus on agriculture products). Students have been divided into groups of six and worked in challenges splitted in three phases. Their performance and level of satisfaction has been assessed before and after the workshops.
OBJECTIVES	Engage students with little or no AI/computer engineering background in AI social context problem solving.
ACTIVITIES	Workshops and project-based works of applied machine learning methods in order to promote student's engagement through creative learning experiences
RESULTS	The results of the workshops and projects deployed helped students adopt interdisciplinary thinking as well as having awareness of the integration of new technological solutions in other contexts such as agriculture. Students had more fun, engagement, and hands-on interactivity in the workshop compared to their regular classroom, even though the topic of AI is much more complex and challenging.

LINK	https://www.edsurge.com/news/2018-10-08-what-students-learned-when-they-made-robotics-relevant-to-their-lives
SHORT DESCRIPTION	Design of robotic modules to inspire students in a secondary school designing meaningful applications for robots helping in agricultural works
OBJECTIVES	Enhance students motivation designing meaningful robotic applications.
ACTIVITIES	This project implements a PB3 approach (student-centered teaching Problem-Based, Place-Based, Project-Based Learning). Students define their own problems - like how to automate chores over the weekend and are given freedom to find and implement solutions via robotics and STEM classes. The students developed collaboratively a robot feeder for chickens in a farm.
RESULTS	Participants learned to apply STEM competencies on solving everyday problems

LINK	https://dl.acm.org/doi/pdf/10.1145/3331071
SHORT DESCRIPTION	Sports and Machine Learning: How young people can use data from their own bodies to learn about machine learning. In order to foster interest in machine learning among young people, this practice present simple and effective ways to engage kids using sensors on their own bodies.
OBJECTIVES	“This personalization allows learners to work within a domain they already understand, and explore new concepts, such as collecting data, curating a training set, and rapidly iterating to improve a model”.
ACTIVITIES	Students “build” a model, next they “test” that model, then they “evaluate” the results of their test, and “refine” the model. Students repeat this process as needed until the model meets their expectations.
RESULTS	This practice allows learners to work within a domain they already understand, while exploring new concepts, such as collecting data, curating a training set, and rapidly iterating to improve a model.

Student-oriented

LINK	https://code.org/ai
SHORT DESCRIPTION	The platform includes courses, projects and information on AI for education.
OBJECTIVES	Facilitate students understanding of AI in terms of technical functioning, social and ethical implications
ACTIVITIES	Videos and educational resources on how AI works (data train and bias, etc), ethics and AI (algorithm bias and equal access; privacy, etc.)
RESULTS	Students learn fundamental concepts of Ai; they also lear to create AI-based videogames, apps, artworks, animations, etc.

LINK	https://edsquare.co/
SHORT DESCRIPTION	Edsquare aims at creating accessible AI & data science educational content. The Edsquare founder Maor Amer is also the author of “Nuts About Data” – a simple way to understand data science.
OBJECTIVES	Playful introduction to AI & data science for young students.
ACTIVITIES	Children learn through videos, animations and printable activities, no coding involved.
RESULTS	Thanks to this platform, students will be able to reflect upon the following 3 ideas: Idea #1 (Perception) Idea #2 (Machine Learning) Idea #3 (Societal Impact)

LINK	https://appinventor.mit.edu/explore/ai-with-mit-app-inventor
SHORT DESCRIPTION	MIT App Inventor is a block-based programming tool that enables the creation of applications. Enhanced with tools related to AI it also enables even beginning students to create original AI applications, creating new opportunities for them to explore the possibilities of AI, while empowers them as creators of the digital future. AI with MIT App Inventor includes tutorial lessons as well as suggestions for student explorations and project work. Each unit also includes supplementary teaching materials: lesson plans, slides, unit outlines, assessments and alignment to the Computer Science Teachers of America (CSTA) K12 Computing Standards.
OBJECTIVES	Students will learn about the basics of machine learning and create their own apps that implement these concepts through image classification. They will also learn how to create and train their own image and audio classification models to correspondingly identify and classify images and audios.
ACTIVITIES	The proposed lessons include activities such as: a) creating apps that implement machine learning concepts through image and audio classification; b) creating a Voice User Interface (VUI) by building a voice-driven calculator that can do basic arithmetic operations; c) tracking key points of the body to create a skeletal model and develop some basic methods to quantify, measure and identify some dance moves; d) creating a program that allows the machine to observe and learn from its user's game choices (using a Markov Model) to quickly become intelligent enough to repeatedly beat the user at the game.
RESULTS	Students will be able to create their own apps that implement machine learning concepts through image or/and audio classification. They will also be able to create more complex and intelligent programs that can identify bodily postures or can even beat a user at a game.

LINK	http://cognimates.me/home/
SHORT DESCRIPTION	Cognimates is a project started at MIT media lab revolving around the idea of creating inclusive AI literacy for kids around the world. Cognimates site provides free access to Gognimates GUI, an AI education platform for building games, programming robots and training AI models. The Gognimates GUI platform is a block-based programming tool that facilitates the creation of AI applications such as applications for image recognition, voice recognition, translation etc. This practice can be also implemented in school classes 13+
OBJECTIVES	Students are able to build their own AI projects and understand the process of training and coding an AI model.
ACTIVITIES	The proposed projects and tutorials are based on methods related to image recognition, voice recognition, translation of speech to text, text to speech. Some ideas are: a) creating a stuffed toy, a robot or a cartoon like character to react to meassages b) learning the computer to play rock, paper, scissors game c) creating a project/program that recognizes and reacts to feeling (tweets mood, a person's mood etc.) d) creating a program/project that can match a well-known sentence to a person
RESULTS	Students are able to build their own AI projects and understand the process of training and coding an AI model.

LINK	https://experiments.withgoogle.com/collection/ai
SHORT DESCRIPTION	AI Experiments is a showcase for simple experiments that make it easier for anyone to start exploring machine learning, through pictures, drawings, language, music, and more. Through the site of AI experiments users can have access to a number of experiments on AI created by other users worldwide, explore an overview of each experiment, get the source code of the proposed activity, as well as launch each experiment to their computer. Moreover, AI Experiments site allows users to upload and share (to the community) their own AI experiments.
OBJECTIVES	Users (i.e. students, teachers, hobbyist etc.) can learn about the concept of machine learning and the creation of machine learning models through different interactive online paradigms.
ACTIVITIES	Through the included experiments a number of different scenarios/ideas on AI are proposed. Some of them are: a) creation of an app that recognizes images detected from a live camera b) creation of an app that can guess a drawing produced in real time c) creation of an app that recognizes voices and compares user's singing abilities to those of famous singers d) creating live animations through a process of mapping bodily postures and assigning them to a digital character e) creating apps for people with speech and motor impairments
RESULTS	Users are able to understand the general concept of Machine Learning systems and to build their own machine learning models or/and AI applications, and share them with/to a wider audience.

LINK	https://www.elementsofai.com/ie
SHORT DESCRIPTION	The Elements of AI is a series of free online courses created by Reaktor and the University of Helsinki to encourage as broad a group of people as possible to learn about AI.
OBJECTIVES	Basic knowledge, introduction to AI; Building AI enhancing AI practice
ACTIVITIES	Free on line courses on basic knowledge of AI. The courses combine theory with practical exercises and can be completed at one's own pace.
RESULTS	Students learn what AI is, what can (and can't) be done with AI, and how to start creating AI methods.

LINK	https://machinelearningforkids.co.uk/
SHORT DESCRIPTION	Machine Learning for kids is a useful tool for introducing children to how Machine Learning systems are trained, how they are used, and some of the real-world implications of AI applications. This free tool provides hands-on experiences through an easy-to-use guided environment for training machine learning systems and models to recognize text, numbers, images, or sounds, as well as building things with them. It is entirely web-based. The tool is compatible with Scratch 3 block-based programming environment. It provides an admin page for teachers or group leaders to be able to manage and administer access for their students.
OBJECTIVES	The platform was designed for classroom activities and volunteer-run coding groups for children. The objective is to guide students building their own AI projects and understand the concept of machine learning through training and coding/instructing their own machine learning models.
ACTIVITIES	Several projects that can be programmed through the combined implementation of machine learning online tool and Scratch 3 (or in some exceptional cases, Python) are proposed. The projects are divided in 5 categories, namely: train a computer to recognize text, train a computer to recognize images, train a computer to recognize numbers, train a computer to recognize sounds, and train a computer to recognize faces. Here are some scenarios/ideas: a) creation of a game that learns when a glass is described as half-full or half-empty b) creation of a smart assistant that controls virtual devices c) creation of a virtual chameleon that changes color to match background d) training the computer to sort photos into groups and teach it to recognize pictures of objects e) teaching computer to make predictions in order to assist a virtual character to escape from a zombie horde f) learning about how computers can be confused and make mistakes (addressing bad training issues)
RESULTS	Students are able to build their own machine learning models and understand the general concept of Machine Learning systems.

LINK	experiments.withgoogle.com/quick-draw
SHORT DESCRIPTION	Open source doodles data set useful to learn training new neural networks, detecting patterns in how people around the world draw, and helping artists create new things.
OBJECTIVES	This project aims at making students become familiar with a.i. workflow: acquiring and labeling training data, testing the training status of the algorithm and furthermore improving the model.
ACTIVITIES	Students can teach an artificial intelligence algorithm to classify their drawings. It can be implemented in classroom activities.
RESULTS	Students develop a key understanding of a machine-learning workflow.

LINK	classifier.appinventor.mit.edu
SHORT DESCRIPTION	On this platform students art train an image-recognition-algorithm using a web interface called “PIC interface”; afterwards, they use Appinventor blocks to access the PIC data for acquiring and classifying image data using their laptop webcam.
OBJECTIVES	Get familiar with AI workflow: acquiring and labeling training data, testing the training status of the algorithm and furthermore improving the model.
ACTIVITIES	Students can learn how to train an an image-recognition-algorithm
RESULTS	Studnets aquire understanding regarding the mage-recognition-algorithm mechanism

LINK	https://www.curiositymachine.org
SHORT DESCRIPTION	This project proposes challenges to families to learn foundations of AI technology by solving a problem in their communities.
OBJECTIVES	Foster basic understanding of machine learning classification based on target attributes.
ACTIVITIES	Create data set by collecting objects of daily use (marbles, figurines, pipe cleaners, etc) and implement classification and sorting on the basis of specific characteristics (color, size, shape, etc.) to understand how neural network function and build/test a network of nodes.
RESULTS	Students and families acquire basic understanding of a neural network / decision tree

LINK	https://edu.readyai.org/
SHORT DESCRIPTION	The ReadyAI Curriculum is built for on line classes (primary and middle school), divided in units that include exercises, customizable AI lessons and a showcase event.
OBJECTIVES	To teach AI for social good - that is, impacting society positively through AI - emphasizing both technical and non-technical components of learning, combining art and multimedia.
ACTIVITIES	Project-based Learning dedicated to: define basic concepts in the field of AI; describe functions of AI as well as current limitations; apply principles of coding to demonstrate understanding of AI concepts; evaluate applications of AI technologies; build up ideas with teammate
RESULTS	Students learn computer science in the context of their interests and power and of STEAM education, infusing their work with what makes us human. They create a project that uses AI to solve real-world problems. They also learn soft-skills such as presentation techniques, leadership, and collaboration.

2. A selection of K-12 international publications

The following selection is the result of a literature review conducted by the Edu4AI partners. The objective of the review was to collect, analyse and interpret results that serve not only to define the state of the art but to point out the future directions of AI activities integration in the school programs. The selection focused on international publications in English about methodological and applied use of AI at school (age 12+), particularly related to conceptualization frameworks and pedagogical settings.

The following sections contain the main elements of the selected materials, to provide a concise indication of the content, which can be viewed in full by simply using the links provided. The aim is to provide a collection of reference publications.

PUBLICATIONS

Articles presenting a literature review

TITLE OF THE PUBLICATION	Taguma, M. F. (2018). Future of Education and Skills 2030: Conceptual Learning Framework. OECD. https://www.oecd.org/education/2030/Education-and-AI-preparing-for-the-future-AI-Attitudes-and-Values.pdf
KEYWORDS	Learning Framework; AI
ABSTRACT OR SHORT DESCRIPTION	This paper reviews the existing literature to find out what knowledge and skills will remain for human in a time of increasing AI. It addresses some of the issues surrounding the use of AI in education, and discusses how AI can be harnessed to improve the education and opportunities of students as they prepare to enter the workforce. It also stresses the need for students, employees and society to develop the awareness and understanding that they will need in order to be effective, engaged and active citizens in a world in which AI will play an increasing role.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The framework is grounded in an appreciation that societies face environmental, economic and social challenges. As a result, educational goals must be broader and they must drive individual and collective well-being. In order to ensure that all students are well prepared for the future and that they themselves can act as change agents, the framework identifies a broad set of knowledge, skills, attitudes and values. In particular, it identifies three additional categories of competencies, also known as the "Transformative Competencies": Creating new value, reconciling tensions and dilemmas and taking responsibility.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Examples of curricula and didactic units http://www.exploringcs.org/for-teachers-districts/artificial-intelligence

TITLE OF THE PUBLICATION	Xuesong Zhai, Xiaoyan Chu, Ching Sing Chai, Morris Siu Yung Jong, Andreja Istenic, Michael Spector, Jia-Bao Liu, Jing Yuan, Yan Li, "A Review of Artificial Intelligence (AI) in Education from 2010 to 2020", Complexity, vol. 2021, Article ID 8812542, 18 pages, 2021. https://doi.org/10.1155/2021/8812542
KEYWORDS	Artificial Intelligence; Education.
ABSTRACT OR SHORT DESCRIPTION	This study provides a content analysis of studies aiming to disclose how artificial intelligence (AI) has been applied to the education sector and explore the potential research trends and challenges of AI in education. A total of 100 papers including 63 empirical papers (74 studies) and 37 analytic papers were selected from the education and educational research category of Social Sciences Citation Index database from 2010 to 2020. The content analysis shows that the research questions could be classified into development layer (classification, matching, recommendation, and deep learning), application layer (feedback, reasoning, and adaptive learning), and integration layer (affection computing, role-playing, immersive learning, and gamification). Moreover, four research trends, including Internet of Things, swarm intelligence, deep learning, and neuroscience, as well as an assessment of AI in education, are suggested for further investigation.The research conducts further frequency comparisons on the associations between the research purposes and some factors such as AI technology adoption as well as time periods to predict the trends and challenges of AI in education.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The results provide insights into an overview of the AI used for education domain, which helps to strengthen the theoretical foundation of AI in education and provides a promising channel for educators and AI engineers to carry out further collaborative research. Two main categories were investigated: research questions and technology adoption. Firstly, with regard to research questions, previous research has found three basic models of AI in knowledge processing: knowledge representation, knowledge obtaining, and knowledge derivation. The research questions were classified into three dimensions: (a) development, focusing on the knowledge presentation model; (b) extraction, centering on how to obtain knowledge from data mining; and (c) application, emphasizing the human-computer interaction through information derivation. Secondly, with regard to technology adoption, the focus was on the types of technology that the study adopted, which were further categorized into software (e.g., algorithms and programs) and hardware (e.g., sensors and devices such as virtual reality).
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Hierarchy of artificial intelligence in educational implementation https://downloads.hindawi.com/journals/complexity/2021/8812542.pdf

AI education dimentions and pedagogies

TITLE OF THE PUBLICATION	Radu Mariescu-Istodor and Ilkka Jormanainen. 2019. Machine Learning for High School Students. In Proceedings of the 19th Koli Calling International Conference on Computing Education Research (Koli Calling '19). Association for Computing Machinery, New York, NY, USA, Article 10, 1–9. DOI:https://doi.org/10.1145/3364510.3364520
KEYWORDS	Machine Learning; Education.
ABSTRACT OR SHORT DESCRIPTION	This study presents a machine learning method for object recognition that can be implemented using knowledge that high school students attain during their normal math and IT classes. Observations from this workshop suggest wider applicability of the tool, as well as further research questions on machine learning in K-12 settings.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The machine learning method for object recognition was tailored within a two-hour interactive lesson in which the students were divided into groups to implement solutions to six distinct problems required by the method. The solutions were later put together by the teacher into a working web application (HTML + JavaScript). The lesson was taught on three occasions in schools to students between 13 and 19 years old. The students were excited about the lesson, and the collected data measuring students' intrinsic motivation suggests that the given tasks and the type of instruction were motivating them. The students also found the lesson achievable regardless the level of their previous programming background. The students were even able to suggest viable improvements to the method.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Short minute YouTube video presenting the lesson

TITLE OF THE PUBLICATION	J. Estevez, G. Garate and M. Graña, “Gentle Introduction to Artificial Intelligence for High-School Students Using Scratch,” in IEEE Access, vol. 7, pp. 179027-179036, 2019, doi: 10.1109/ACCESS.2019.2956136.
KEYWORDS	K-12; Computing.
ABSTRACT OR SHORT DESCRIPTION	This paper focuses on innovative ways to introduce studnets to the fundamentals and operation of two of the most popular AI algorithms. It describes the elements of a workshop suitable for K-12 students where is provided an academic use-create-modify scaffolding where students work on the Scratch partial coding of the algorithms so they can explore the behavior of the algorithm, gaining understanding of the underlying computational thinking of AI processes. Section II, presents some methodological background. Section III gives the research question, along with the concrete questions that will provide some light on the effect of the worshop. Section IV describes the workshop design and the mathematics. Section V details the methodological aspects of the workshop. Section VI presents the results of the pilot workshop. Section VIII gives conclusions, limitations of the experiment, and some future directions of work.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	Design based research (DBR) provides the methodological framework for this endeavor. In this direction, encompasses a collection of simple educational exercises aimed to promote understanding and learning of AI at high schools using Scratch as the transmission medium. Full fledged DBR pedagogical projects are long term efforts involving big pedagogical research teams, carrying out several iterations of the problem formulation and solution design, and have a direct connection with the teaching professionals that are in direct contact with the students. Experimental evaluation with a group of high school students is reported, assessing the improved understanding of the technology and its implications after the hands-on workshop was carried out. Before and after the workshop, students must fulfill a questionnaire to check the level of achievement of the planned objectives. The two concrete contributions of the paper towards the answering the main research question are: (1) the design of a learning intervention grounded on experiential learning theory (ELT) approach to teach CT topics, and (2) its validation with a population of high-school students to see the impact on their learning of AI concepts and also the understanding of societal implications of AI.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Workshop design and evaluation process details https://dl.acm.org/doi/10.1145/3364510.3364520

TITLE OF THE PUBLICATION	Steinbauer, G., Kandlhofer, M., Chklovski, T. et al. A Differentiated Discussion About AI Education K-12. Künstl Intell (2021). https://doi.org/10.1007/s13218-021-00724-8
KEYWORDS	AI ; K-12; Education.
ABSTRACT OR SHORT DESCRIPTION	This paper discusses AI education along four dimensions: (1) formal versus informal education, (2) cooperation of researchers in AI and education, (3) the level of education, and (4) concepts and tools. The article gives an initial overview on the very active field of AI education for K-12. The article highlights: 1) Recently the research on the topic exploded, providing tools and the teaching initiatives. This explosion is not only caused by the increased interest but also by the fact that informal approaches are more agile and allow the flourishing of a huge number of ideas and tools. 2) Repositories with material that assess for some quality criteria are needed, to allow educators to find good material more easily. 3) The need to develop a good mixture of formal and informal attempts. What is definitively missing is data of deployments of concepts with larger groups of participants and for a longer period of time (i.e. the entire grades). In order to judge the quality of proposed methods and tools and to extract best practice examples more founded evaluations are needed.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The study presents an excursus on the methods and approaches focusing on teaching AI concepts at K-12 level, which comprises a wide age range from usually 6 to 18 years. It furthermore presents educational means used depending on the individual goal of an education activity, the scope of the activity, and the technical and content depth: (1) unplugged activities, (2) videos, simulations or interactive presentations, (3) partly-finished projects or programming skeletons, and (4) full-fledged projects. The section closes with some highlighted AI K12 education activities and tools.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Tools for creation of artefacts in the context of AI education https://doi.org/10.1007/s13218-021-00724-8

TITLE OF THE PUBLICATION	Phoebe Lin and Jessica Van Brummelen. 2021. Engaging Teachers to Co-Design Integrated AI Curriculum for K-12 Classrooms. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21). Association for Computing Machinery, New York, NY, USA, Article 239, 1–12. DOI:https://doi.org/10.1145/3411764.3445377
KEYWORDS	AI curriculum; Artificial intelligence,; K-12 education; Co-design workshop.
ABSTRACT OR SHORT DESCRIPTION	This paper reports the path applied to co-design with K-12 teachers AI curriculum that is integrated with core subjects., with the aim to empower all teachers to incorporate AI into their classrooms and leverage learners' interests for other subjects workshop. The article sets out to understand what is necessary and valuable to K-12 teachers to effectively implement integrated AI curricula, and co-create lesson plans that address those needs and values
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The study takes a Value-Sensitive Design approach to understanding the role of teacher values in the design of AI curriculum and tools, and identifying opportunities to integrate AI into core curriculum to leverage learners' interests. The co-design workshops with 15 K-12 teachers is presented, where teachers and researchers co-created lesson plans using AI tools and embedding AI concepts into various core subjects. The paper highlights K-12 teachers need additional scaffolding in AI tools and curriculum to facilitate ethics and data discussions, and value supports for learner evaluation and engagement, peer-to-peer collaboration, and critical reflection. Exemplar lesson plan is presented that shows entry points for teaching AI in non-computing subjects and reflect on co-designing with K-12 teachers in a remote setting.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Description and schedule of co-design workshops DOI:https://doi.org/10.1145/3411764.3445377

TITLE OF THE PUBLICATION	Li, Li, “A Comparative Study on Artificial Intelligence Curricula” (2020). Electronic Thesis and Dissertation Repository. 7496. https://ir.lib.uwo.ca/etd/7496
KEYWORDS	Artificial Intelligence, curriculum; K-12,; Constructivism; Constructionism.
ABSTRACT OR SHORT DESCRIPTION	This research is a comparative analysis of four K-12 AI curricula to recognize and interpret their basic elements and pedagogical approaches. Guided by (socio) constructivist and constructionist theories as the theoretical framework, qualitative document analysis is applied as the research methodology. Schwab’s four commonplaces serve as the initial analytical framework. A (socio) constructivism and constructionism lens is also used to compare the curricula. The major findings are 1. The four curricula are different in their coverage of subject matters with the curriculum from the UK covering the widest and most balanced range of subject matters. 2. The four curricula apply, to different extent, student-centered (socio) constructivist and constructionist pedagogical approaches. The curriculum from the US fits best for constructionism, while the curriculum form India is most inclined to use traditional approaches. This study will form part of the data on AI educational practices useful to educational researchers, practitioners, and governments.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	Guided by (socio) constructivist and constructionist theories as the theoretical framework, qualitative document analysis is applied as the research methodology. Schwab’s four commonplaces serve as the initial analytical framework. A (socio) constructivism and constructionism lens is also used to compare the curricula.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence
TYPES OF ATTACHED MATERIALS	Article and guidelines https://ir.lib.uwo.ca/etd/7496

TITLE OF THE PUBLICATION	Southgate, E., Blackmore, K., Pieschl, S., Grimes, S., McGuire, J. & Smithers, K. (2018). Artificial intelligence and emerging technologies (virtual, augmented and mixed reality) in schools: A research report. Newcastle: University of Newcastle, Australia. https://docs.education.gov.au/system/files/doc/other/aiet_final_report_august_2019.pdf
KEYWORDS	Artificial Intelligence; Education; Computer assisted instruction; Pedagogical agent; Professional development; Smart classroom.
ABSTRACT OR SHORT DESCRIPTION	This report provides the teaching profession with an accessible, evidence-based, and practical set of documents on the role and potential scope of these technologies in schools: 1) Literature reviews on: (i) Artificial intelligence and school education; (ii) Virtual reality and school education; and, (iii) Augmented reality and school education, with a brief section on mixed reality (MR). 2) A Quick Guide to Artificial Intelligence, created for teachers and older secondary school learners; a Quick Guide to Artificial Intelligence, created for younger secondary and primary school students. 3) A comprehensive mapping of quality online curriculum and professional learning resources related to each technology. 4) A checklist tool to assist teachers in exercising professional judgement regarding the quality of online resources related to the technologies. 5) A set of case studies, written by teachers, which are designed to illuminate the potential of the technologies for learning across a range of areas. 6) A summary of key findings from a targeted national consultation with experts on the implications of AI and emerging technologies in schools.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The Report starts introducing the field of AI, its terminology, historical roots and branches of interest, then offer a classification framework for different types of AI designed for newcomers to deepen their understanding of AI capabilities as they relate to human thinking and perception. Follows an introduction to the field of machine learning before providing a focused review of literature on the actual and potential application of the technology in school education. This includes a discussion of intelligent tutoring systems, pedagogical agents and the role that intelligent systems can play in assisting teachers to provide personalised learning. Smart classrooms are then considered, with a future-focus on how sensing technology may be used with AI to provide more intelligent physical learning spaces. It also included a window into the use of AI in adaptive learning and learning analytics, or how data gathered from learning contexts can be used to provide more individualised approaches and deeper insights into learner behaviour. Finally, presents and unpack an original ethical framework that highlights the key areas for attention and provides a basis for educators to think through and ask critical questions about the benefits and risks of AI for school communities.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners)
SUBJECTS	Science, technology, engineering, the arts and mathematics
TYPES OF ATTACHED MATERIALS	Quick guides and checklist tool to assist teachers ìì https://docs.education.gov.au/system/files/doc/other/aiet_final_report_august_2019.pdf

TITLE OF THE PUBLICATION	Druga, S. (2018). Growing up with AI: Cognimates: from coding to teaching machines. https://dam-prod.media.mit.edu/x/2018/08/29/Growin_up_with_AI_Stefania_Druga_2018.pdf
KEYWORDS	Programming; AI teaching; Cognimates.
ABSTRACT OR SHORT DESCRIPTION	The thesis explores how to best prepare and educate a generation that is growing up with Artificial Intelligence, and how do children perceive and interact with smart technologies that are becoming more embedded in their daily lives. The study starts focusing on how 26 children (3-10 years old) interact with: Amazon Alexa, Google Home, Anki's Cozmo, and NDI Development's Julie Chatbot. After playing with the agents, children answered questions about trust, intelligence, social entity, personality, and engagement. Findings showed that children saw the agents as friendly and truthful, and especially the older children would consider them to be more intelligent than they were. In a second phase the study explores a Cognimates platform for AI education for 7 to 12 years old children that would allow young people to program and train these computational objects and thus, better understand how their "intelligence" works. To probe the effects of programming and training AI, longitudinal user studies in low, medium and high SES schools and community centers were conducted.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The study shows how 107 children from 4 countries, who are 7 to 14 years old, develop a better understanding of AI concepts and change their perception of smart agents by programming and teaching them with the Cognimates platform developed. Overall children developed a rich grasp of AI concepts through play and coding with our platform, they also became more sceptical of the agents 'smarts and truthfulness even if they continued to perceived them as friendly and exciting. International children were overall more critical of these technologies and less exposed to them. The way children collaborated and communicated influenced significantly their progress in learning and understanding these new concepts. Students in low and medium SES schools and centers were better are collaborating initially, but had a harder time advancing because they were less exposed to programming and these new technologies. The students in high SES schools and centers did not have a fluent collaboration initially, but overtime developed a strong understanding of AI concepts and started to teach and help each other.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Computing, Programming
TYPES OF ATTACHED MATERIALS	Unit plans https://dam-prod.media.mit.edu/x/2018/08/29/Growin_up_with_AI_Stefania_Druga_2018.pdf

TITLE OF THE PUBLICATION	Lívia S. MARQUES, Christiane GRESSE VON WANGENHEIM, Jean C. R. HAUCK, Teaching Machine Learning in School: A Systematic Mapping of the State of the Art, Informatics in Education 19(2020), no. 2, 283-321, DOI https://doi.org/10.15388/infedu.2020.14
KEYWORDS	Computational thinking; Education.
ABSTRACT OR SHORT DESCRIPTION	The main contribution of this article is the mapping and synthesis of the characteristics of instructional units (IUs) for ML education from elementary to high school, regarding their content, context and the analysis of how they were developed and evaluated. the article highlights that it is possible and beneficial to introduce ML education in K-12 and this overview can help instructors to select and/or curriculum developers to develop instructional units and we hope that the discussion can further foster the inclusion of ML education in K-12.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The mapping reports that IUs mostly focusing on beginners at any educational stage from elementary to high school also indicates the recognition of an early exposure of students to ML concepts, not limited only to high school as typically indicated by general computing. Being an emergent topic, most of the IUs are proposed as extracurricular units ranging from 1-hour taster workshops to semester-long courses. Several IUs also provide customized frameworks and tools in order to teach ML at this educational stage using e.g., block-based programming environments curriculum guidelines. The IUs teach competencies varying from presenting what is ML, to specific ML techniques as well as the impacts of ML. However, we observed that several IUs present ML concepts only on an abstract level, black-boxing some of the underlying ML processes even as part of hands-on activities in order to reduce complexity.
CONTEXT AND TARGET GROUP	Professional training (teachers)
SUBJECTS	Science
TYPES OF ATTACHED MATERIALS	Details on instructional units for teaching Machine Learning in elementary to high school files.eric.ed.gov/fulltext/EJ1257498.pdf

TITLE OF THE PUBLICATION	I. Temitayo Sanusi and S. Sunday Oyelere, "Pedagogies of Machine Learning in K-12 Context," 2020 IEEE Frontiers in Education Conference (FIE), 2020, pp. 1-8, doi: 10.1109/FIE44824.2020.9274129. https://ieeexplore.ieee.org/document/9274129
KEYWORDS	Education; Machine learning; Artificial intelligence; Computer aided instruction;
ABSTRACT OR SHORT DESCRIPTION	This research presents the pedagogies of machine learning in K-12. This study examined how machine learning has been taught in the recent past and further explores the ways and suitable approaches for K-12 context. The study is divided into five parts. The first section introduces the topic of inquiry. The second section synthesizes applicable literature while section three explores the appropriate methodology for the study. Section four displays the result and discussion while the last section shows the conclusion with future study alertness.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The new learning pedagogies and technologies are introduced with the aim of enhancing student engagement, experience and learning outcome. . Literatures on pedagogies associated with machine learning were reviewed to understand the dynamics and suitability of these pedagogies to support machine learning teaching. The literature survey revealed several pedagogical strategies such as problem-based learning, project-based learning and collaborative learning used in higher education institutions. The revealed pedagogies suggest learners-centered approaches such as active learning, inquiry-based, participatory learning, design-oriented learning among others will be suitable for teaching machine learning in K-12 settings.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Science
TYPES OF ATTACHED MATERIALS	Taxonomy of Machine learning pedagogy for K-12 ieeexplore.ieee.org/document/9274129

TITLE OF THE PUBLICATION	Kahn, K., & Winters, N. Constructionism and AI: A history and possible futures. In Proceedings of the 2020 Constructionism Conference. https://ora.ox.ac.uk/objects/uuid:e28cfdeb-9c2b-428b-bab2-2de7b7c732bc
KEYWORDS	Artificial intelligence; constructionism; Deep neural networks; Machine Learning; Snap!; Logic programming; Logo
ABSTRACT OR SHORT DESCRIPTION	This paper presents an excursus of the development of AI education programmes from a Constructionist point of view, from the birth of Logo, implying natural language processing, robotics, artificial game players etc to support AI programming by children, to intelligent tutoring systems, Snap! with new blocks for speech synthesis, speech recognition and image recognition to enable learners to create and train deep neural networks. The article closes with speculations about possible futures for AI and constructionism exploring more closely whether learners' hands-on exposure to AI and machine learning concepts has any effect on their self-reflection and learning skills.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The paper focuses on the core constructionism idea that learning "happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity". Computational concepts are explored focusing on the learner's ideas about how they learn, represent things, solve problems, and create. AI-oriented constructionist projects are presented considering the strategies to help learners acquire deeper and more effective ways of learning and creating artefacts, allowing to correlate different disciplines, connecting for instance programming with composing music, and generating poetry.
CONTEXT AND TARGET GROUP	Formal education (Students, Educational Practitioners, Researchers)
SUBJECTS	AI
TYPES OF ATTACHED MATERIALS	Article https://ora.ox.ac.uk/objects/uuid:e28cfdeb-9c2b-428bbab2-2de7b7c732bc

TITLE OF THE PUBLICATION	Greenwald, E., Leitner, M., & Wang, N. (2021). Learning Artificial Intelligence: Insights into How Youth Encounter and Build Understanding of AI Concepts. Proceedings of the AAAI Conference on Artificial Intelligence, 35(17), 15526-15533. Retrieved from https://ojs.aaai.org/index.php/AAAI/article/view/17828
KEYWORDS	K-12; Artificial Intelligence.
ABSTRACT OR SHORT DESCRIPTION	The work aims to uncover how K-12, particularly high school students, approach AI concepts, what obstacles they face, and how to guide them through the obstacles. The work builds upon previous investigations into linking AI to K-12 math curriculum to identify AI concepts suitable for high school students, as well as work investigating the learning of computational thinking and seminal research into comprehension of mathematical representations and statistics.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The study uses cognitive interviews with middle school and high school students using five AI problems to gain an understanding of what type of AI concepts and difficulty is suitable for the high-school population, what are the challenges they face, and what pedagogical approach can be applied to guide students in AI problem-solving.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	AI
TYPES OF ATTACHED MATERIALS	Semi-structured interview protocol https://ojs.aaai.org/index.php/AAAI/article/view/17828

TITLE OF THE PUBLICATION	T. K. F. Chiu and C. S. Chai. “Sustainable Curriculum Planning for Artificial Intelligence Education: A Self-Determination Theory Perspective,” Sustainability, vol. 12, no. 14, pp. 5568, 2020. DOI: https://www.mdpi.com/2071-1050/12/14/5568
KEYWORDS	Artificial intelligence education; Curriculum planning; Curriculum design; Self-determination theory; K-12 education.
ABSTRACT OR SHORT DESCRIPTION	This case study aims to explore the views of teachers with and without AI teaching experience on key considerations for the preparation, implementation and continuous refinement of a formal AI curriculum for K-12 schools. Accordingly, the two research questions are from the teachers’ perspectives. RQ1: How do the three psychological needs—autonomy, competence and relatedness—in SDT relate to curriculum development? RQ2: How do curriculum planning approaches relate to curriculum development. Findings revealed that genuine curriculum creation should encompass all four forms of curriculum design approach that are coordinated by teachers’ self-determination to be orchestrators of student learning experiences. This study also proposed a curriculum development cycle for teachers and curriculum officers?
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The study drew on the self-determination theory (SDT) and four basic curriculum planning approaches—content, product, process and praxis—as theoretical frameworks to explain the research problems and findings. We conducted semi-structured interviews with 24 teachers—twelve with and twelve without experience in teaching AI—and used thematic analysis to analyze the interview data. The interviews explored: 1. How to prepare new teachers to design and teach AI curricula (see the three needs in SDT). 2. How to plan and develop the AI curriculum and its content (content and product approaches). 3. Logistical issues within a school environment (e.g., timetable and facility activities) (see relatedness in SDT). 4. Teaching strategies and learning design (process and praxis approaches). 5. How to refine the curriculum in an iterative manner (see the four approaches)
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	AI
TYPES OF ATTACHED MATERIALS	Curriculum thematic map https://www.mdpi.com/2071-1050/12/14/5568

TITLE OF THE PUBLICATION	C. D. L., Higuera (2019). A report about Education, Training Teachers and Learning Artificial Intelligence: Overview of key issues. https://www.k4all.org/wp-content/uploads/2019/11/Teaching_AI-report_09072019.pdf
KEYWORDS	Artificial intelligence; Computational thinking; Critical thinking.
ABSTRACT OR SHORT DESCRIPTION	This report studies the different interactions between AI and Education with an emphasis on the following question: If we accept that artificial intelligence is an important element in tomorrow's landscape, what are the skills and competences which should appear in the future curricula and how can we help to train the teachers so that they can play the required role? Based on the experience of teachers, researchers, academics and practitioners the report highlights pillars or core questions on which should focus the develop of a curriculum to introduce AI in education
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	This report revolves around a core question concerning the skills and competences which should appear in the future curricula and the way that educators should be trained in order to be able to meaningfully teach AI technologies. Therefore, five pillars are proposed as basis for building curricula for properly addressing AI's immanent challenges. These are: a. uncertainty and randomness, b. coding and computational thinking, c. data awareness, d. critical thinking and e. post AI humanism. Some of the targeted objectives of these pillars are: understanding and explaining basic probabilities concepts; considering problem solving through computational thinking; coding and writing simple programs; understanding algorithms; manipulating and visualizing information from large data sets; evaluating information and information sources; as well as analyzing how technology is modifying society and values. The main goal of the pillars is to sustain a larger framework of competences the teachers and learners will need to master in order to use and create AI systems.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Artificial Intelligence, Machine Learning
TYPES OF ATTACHED MATERIALS	Article https://www.k4all.org/wp-content/uploads/2019/11/Teaching_AIreport_09072019.pdf

Processes, guidelines to develop AI curriculum and activities, examples of how AI has been introduced in education

TITLE OF THE PUBLICATION	Alpay Sabuncuoglu. 2020. Designing One Year Curriculum to Teach Artificial Intelligence for Middle School. In Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education. 96–102 DOI: https://dl.acm.org/doi/10.1145/3341525.3387364
KEYWORDS	Artificial Intelligence Education; Curriculum Design.
ABSTRACT OR SHORT DESCRIPTION	This paper presents the design process of curriculum, and observations from the teacher (n=18) and student (n=60) workshops. Overall, the curriculum offers three contributions for middle school AI education: (1) The design of the curriculum aims to help students see the interdisciplinary connections, and better understand how science and innovation work in conjunction. (2) The curriculum provides the recent open-source resources and interactive web examples, through which teachers can integrate these activities into their classes. (3) The curriculum presents an inclusive approach by providing both online and unplugged activities (that do not require a computer or internet infrastructure) for each subject and offers suggestions to increase accessibility.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	Touretzky's "Five Big Ideas on AI Education" was adopted as the core principles of each module, staring with the related physical explanation to understand how computers perceive the world, how they see, how they hear, even how they might taste. Within the curriculum students learn how to structure the perceived data to use in different algorithms. Then, they view sample applications from the field to understand how developers use their data to build an AI algorithm. Finally, students examine ethical cases concerning AI, as well as applications that aim social-good which provides a discussion ground on the effects of developing new technology. The modules feature activities from open-resources such as Cognimates, ITiCSE '20, June 15–19, 2020, Trondheim, Norway Alpay Sabuncuoglu Machine Learning for Kids and MIT's Ethics Curriculum
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners)
SUBJECTS	Science, Mathematics, Electronics and Sustainability, UN's Sustainable Development Goals
TYPES OF ATTACHED MATERIALS	Didactic Units https://ai.twinscience.com/en/why-and-how.html

TITLE OF THE PUBLICATION	Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI?. Proceedings of the AAAI Conference on Artificial Intelligence, 33(01), 9795-9799. https://doi.org/10.1609/aaai.v33i01.33019795
KEYWORDS	Artificial Intelligence education; Curriculum design; Robotics; Visual programming.
ABSTRACT OR SHORT DESCRIPTION	This report provides advice to teachers, on artificial intelligence (AI) and the emerging technologies (virtual, augmented and mixed reality) in school education. It explores and explains often complex technical, social and ethical issues associated with the technologies in an accessible manner for the teaching profession. The K-12 guidelines define what students in each grade band should know about artificial intelligence, machine learning, and robotics, also creating an online resource directory where teachers can find AI-related videos, demos, software, and activity descriptions they can incorporate into their lesson plans.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The guidelines unpack AI's "Big Ideas" along five thematic strands, and organize them by four grade bands: K-2, 3-5. 6-8, and 9-12, formulating key ideas and concepts relevant and substantial for teaching AI. Additional Articles on this project: D. Touretzky, F. Martin, D. Seehorn, C. Breazeal, and T. Posner, "Special session: AI for K-12 guidelines initiative," In Proceedings of the 50th ACM technical symposium on computer science education, pp. 492-493, 2019. C., Gardner-McCune, D. Touretzky, F. Martin, and D. Seehorn, "AI for K-12: Making room for AI in K-12 CS curricula," In Proceedings of the 50th ACM Technical Symposium on Computer Science Education, pp. 1244-1244, 2019.
CONTEXT AND TARGET GROUP	Formal education (researchers, educational practitioners)
SUBJECTS	Science, social and ethical themes, robotics
TYPES OF ATTACHED MATERIALS	AI's "Big Ideas" along five thematic strands, and organised by four grade bands https://ojs.aaai.org//index.php/AAAI/article/view/5053

TITLE OF THE PUBLICATION	Gong, X., & Zhao, L., & Tang, R., & Guo, Y., & Liu, X., & He, J., & Wang, F., & Tang, Y., & Shi, W., & Niu, X., & Wang, X. (2019, June), AI Educational System for Primary and Secondary Schools Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. 10.18260/1-2--32050 https://www.asee.org/public/conferences/140/papers/27262/view
KEYWORDS	AI Education; Innovation capability; Constructivism.
ABSTRACT OR SHORT DESCRIPTION	This paper presents an AI education system and related AI curricula specifically designed for primary and secondary students at different cognitive levels. In this system, complicated AI algorithms are encapsulated and modularized with friendly and easy-to-use interfaces. AI curricula are developed based on constructivism, project-based learning and multidisciplinary integration. Typical teaching cases, such as speech recognition, text recognition, image recognition, intelligent transportation, smart home, intelligent robots, etc., which are used to enhance comprehension of AI concepts and applications, are also discussed.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	This paper describes the design and implementation of a modular AI education system. The goal was to design a modular, well-packaged, and expandable platform that is conducive to education of AI disciplines, allowing students to generate interests and deeper understanding on AI. Through configuration of software and hardware modules, teachers and students are provided with easy-to-learn and easy-to-use teaching and learning tools.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Mathematics
TYPES OF ATTACHED MATERIALS	Perspectives for Standlized, Modulized and Personalized AI Curricula Systems 10.18260/1-2--32050 https://www.asee.org/public/conferences/140/papers/27262/view

TITLE OF THE PUBLICATION	Vega, J.; Cañas, J.M. PyBoKids: An Innovative Python-Based Educational Framework Using Real and Simulated Arduino Robots. Electronics 2019, 8, 899. https://doi.org/10.3390/electronics8080899
KEYWORDS	Science teaching; Robotics framework; Python; Arduino; Education.
ABSTRACT OR SHORT DESCRIPTION	This paper presents the PyBoKids framework for teaching robotics in secondary school, where its aim is to improve pre-university robotics education. It is based on the Python programming language and robots using an Arduino microprocessor. It includes a software infrastructure and a collection of practical exercises directed at pre-university students. The software infrastructure provides support for real and simulated robots. Moreover, it describes a pilot teaching project based on this framework, which was used by more than 2000 real students over the last two years.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The teaching was carried out following a constructivist methodology,. The academic program was also inspired by the authors' previous experiences with the use of LEGO Mindstorms to teach robotics in secondary education through a constructivist methodology.The central pillars of the design are: robots with free hardware processors (Arduino), the Python programming language, and a collection of practice activities of progressive complexity.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Science
TYPES OF ATTACHED MATERIALS	Teaching framework (http://jderobot.org/PyBoKids) that includes a hardware platform (Section 3.1), a software infrastructure (Section 3.2), as well as an educational program (Section 3.3) for a full academic year, and a suggested specific pedagogical methodology (Section 4).

TITLE OF THE PUBLICATION	Guerreiro-Santalla S, Bellas F, Duro RJ. Artificial Intelligence in Pre-University Education: What and How to Teach. Proceedings. 2020; 54(1):48. https://doi.org/10.3390/proceedings2020054048
KEYWORDS	Artificial Intelligence education; STEM ; Smartphone-based education.
ABSTRACT OR SHORT DESCRIPTION	The paper is part of the European Erasmus+ project on educational innovation entitled “AI+: Developing an Artificial Intelligence Curriculum adapted to European High School”. In this paper, the progress achieved during the first year of the project are presented. Mainly, the definition of the methodological approach for this future subject is defined, and the AI topics to be dealt with at this age have been established: eight topics to be addressed in the curriculum are: (1) perception, (2) actuation, (3) representation, (4) reasoning, (5) learning, (6) collective intelligence, (7) motivation, and (8) Sustainability, Ethics, and Legal aspects of AI (SEL)
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	Each unit presents a challenge or project, following the PBL (Project Based Learning) and cooperative methodology, which students will have to solve, organized into groups, in a creative and practical way. This approach is based on totally proactive learning and through real-world problem solving (learning by doing), in accordance with the eminently practical approach of the curriculum. This curriculum will focus on the sensors that are currently most used in AI, such as cameras, microphones, and touch screens. Regarding actuation, it will be focused on a more general approach beyond typical motors, and multiple actuators that can be found in AI systems, such as speakers or LCD screens, will be presented to students
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	AI
TYPES OF ATTACHED MATERIALS	Article Guerreiro-Santalla S, Bellas F, Duro RJ. Artificial Intelligence in Pre-University Education: What and How to Teach. Proceedings. 2020; 54(1):48. https://doi.org/10.3390/proceedings2020054048

TITLE OF THE PUBLICATION	Randi Williams. 2021. How to Train Your Robot: Project-Based AI and Ethics Education for Middle School Classrooms. Proceedings of the 52nd ACM Technical Symposium on Computer Science Education. Association for Computing Machinery, New York, NY, USA, 1382. DOI:https://doi.org/10.1145/3408877.3439690
KEYWORDS	AI Education; K-12; Robotics; AI literacy, CS education; Machine Learning.
ABSTRACT OR SHORT DESCRIPTION	This paper presents a new curriculum designed by MIT researchers and collaborators to teach middle school students about artificial intelligence (AI). How to Train Your Robot curriculum aimed to bring awareness of the technology to the sector of the population which is growing about surrounded by AI. The open-source educational material was piloted and covers aspects of the technology such as how AI systems are designed, ways they can be used to influence the public, and their role within the future job market.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	How to Train Your Robot Companion is a curriculum for students in 5-8th grade to explore artificial intelligence and ethics. In this course, students participate in a range of hot-topic discussions and hands-on, creative activities to learn about how artificial intelligence is impacting society today. Students design robot companions to solve real-world problems and use machine learning to make them intelligent.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Science
TYPES OF ATTACHED MATERIALS	Details on How to Train Your Robot curriculum activities and programming platform DOI:https://doi.org/10.1145/3408877.3439690

TITLE OF THE PUBLICATION	T. K. F. Chiu, H. Meng, C. -S. Chai, I. King, S. Wong and Y. Yam, "Creation and Evaluation of a Pretertiary Artificial Intelligence (AI) Curriculum," in IEEE Transactions on Education, doi: 10.1109/TE.2021.3085878.
KEYWORDS	Artificial Intelligence; Education; curriculum design.
ABSTRACT OR SHORT DESCRIPTION	The paper presents the evaluation of the AI4Future AI curriculum framework at the secondary school level) co-created the first for Hong Kong and evaluated its efficacy. The pre post test multifactor evaluation about students' perceptions of AI learning confirmed that the curriculum is effective in promoting AI learning. The teachers also confirmed the co-creation process enhanced their capacity to implement AI education. Research Questions were: Would the curriculum significantly improve the student perceived competence, attitude, and motivation toward AI learning? How does the co-creation process benefit the implementation of the curriculum?
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	This study adopted a mix-method with quantitative data measures at pre- and post-questionnaires and qualitative data emphasizes teachers' perspectives on the curriculum co-creation process. Paired t-tests and ANCOVAs, and thematic analysis were used to analyze the data Apart from demographic data, the questionnaires included five variables to measure the students' perceived competence, attitude, and motivation toward AI. Perceived competence covers perceived AI knowledge (AIKG), AI readiness (AIRD). Perceived attitude refers to AI confidence (AICF), and the students' perception of the relevance of AI (AIRE). Motivation refers to the student's intrinsic motivation to learn AI (AIIM).
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	AI
TYPES OF ATTACHED MATERIALS	Overview on the curriculum and its implementation; evaluation variables 10.1109/TE.2021.3085878.

AI in education, techniques and applications

TITLE OF THE PUBLICATION	Subosa, P., Subosa, M., Rivas, A., Valverde, P. (2019) Artificial Intelligence Education:Challenges and Opportunities for Sustainable Development Education Sector. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000366994
KEYWORDS	Artificial Intelligence; Education. Education for sustainable development; Computational thinking
ABSTRACT OR SHORT DESCRIPTION	This document gathers examples of how AI has been introduced in education worldwide. The first section analyses how AI can be used to improve learning outcomes. It presents examples of how AI technology can help to improve educational equity and quality. The section is divided into two topics that address pedagogical and system-wide solutions: i) AI to promote personalisation and better learning outcomes, exploring how AI can favour access to education, collaborative environments and intelligent tutoring systems to support teachers.The second section explores the different means by which governments and educational institutions are rethinking and reworking educational programmes to prepare learners for the increasing presence of AI in all aspects of human activity, focusing on the importance of advancing in digital competency frameworks for teachers and students and presenting some initiatives are presented such as the “Global Framework to Measure Digital Literacy” and “ICT Competencies and Standards from the Pedagogical Dimension”.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The documents highlights 3 Frameworks: 1) Information and Communication Technologies Competency Framework for Teachers (ICT-CFT) developed by UNESCO which emphasises the role of digital technologies supporting six key knowledge: 1-Understanding ICT in education; 2-Curriculum & Assessment; 3-Pedagogy; 4-ICT; 5-Organisation & Administration; 6-Teacher Professional Learning. The framework sets three phases of knowledge acquisition empasizing that teachers must help their students be capable of collaborating, solving problems and being creative in the use of digital technologies: 1-technology literacy; 2-knowledge deepening; 3-knowledge creation. 2) “ICT Competencies and Standards from the Pedagogical Dimension”, developed by UNESCO (2016) conceived as a guiding base for any teacher and educational institution to evaluate their practices and educational strategies with use of ICT regarding the expected standards, and from this process of identification and recognition, continue with a process of training. 3) DigComp (Joint Research Centre, 2018) supporting the development of digital skills of individuals needed to use digital technologies in a critical, reliable, collaborative and creative way to participate in the digital society, namely Information and data literacy; Communication and collaboration; Digital content creation; Safety; and Problem solving.
CONTEXT AND TARGET GROUP	Formal education (researchers, policy makers, educational practitioners)
SUBJECTS	Digital literacy
TYPES OF ATTACHED MATERIALS	Digital literacy competency areas and competencies framework; References related to the introduction to artificial intelligence https://unesdoc.unesco.org/ark:/48223/pf0000366994

TITLE OF THE PUBLICATION	Holmes, Wayne; Bialik, Maya and Fadel, Charles (2019). Artificial Intelligence In Education: Promises and Implications for Teaching and Learning. Boston, MA: Center for Curriculum Redesign. https://curriculumredesign.org/our-work/artificial-intelligence-in-education/
KEYWORDS	Adaptive learning; Metacognition; AI; Education.
ABSTRACT OR SHORT DESCRIPTION	The publication immerses the reader in a discussion on what to teach students in the era of AI and examines how AI is already demanding much needed updates to the school curriculum, including modernizing its content, focusing on core concepts, and embedding interdisciplinary themes and competencies with the end goal of making learning more enjoyable and useful in students' lives. The second part of the book dives into the history of AI in education, its techniques and applications –including the way AI can help teachers be more effective, and finishes on a reflection about the social aspects of AI. This book is a must-read for educators and policy-makers who want to prepare schools to face the uncertainties of the future and keep them relevant.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The pedagogy model represents knowledge about effective approaches to teaching and learning that have been elicited from teaching experts and from research in the learning sciences
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Mathematics, Science, Technology,
TYPES OF ATTACHED MATERIALS	Video: https://www.youtube.com/watch?v=n7dgWnPIENU&feature=em-upload_owner&utm_content=bufferc762e&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Case studies AI in education

TITLE OF THE PUBLICATION	Chalmers, C., Williams, M., Keane, T., Boden, M. (2018, 21-23 November). Humanoid robots: programming at school. pp. 60-64 Paper presented at the Integrated Education for the Real World', the 5th International STEM in Education Conference, Brisbane, Australia.https://stem-in-ed2018.com.au/wp-content/uploads/2019/01/5th-International-STEM-in-Education-Post-Conference-Proceedings-2018.pdf
KEYWORDS	Technology; Robotics; Humanoid; Computational thinking; Coding
ABSTRACT OR SHORT DESCRIPTION	This paper reports on a study that is part of a three-year research project investigating how NAO humanoid robots were used in early childhood, primary, and secondary school settings and what teachers and students learnt by working with these robots. This qualitative study focuses on three case studies, from the three schools settings, to explore how the NAO humanoid robots were incorporated in the classroom, how teachers and students engaged with the robot, and what computational thinking skills students working with the humanoid robot developed. A multiple case study design allowed for an exploration of the use of the humanoid robot in the different school settings as well as a comparison between settings. Multiple forms of data were collected from ten teachers, across the three schools, in order to gain their views and to enable the teachers to discuss their experiences and perceptions on using the humanoid robot in their classrooms. The findings indicate that humanoid robots can be useful across a range of schools settings, have a positive impact on students engagement, and can not only help develop students' computational thinking, but can also help develop other 21st century skills.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	A multiple case study design allowed for an exploration of the use of the humanoid robot in the different school settings as well as a comparison between settings. The project examined how humanoid robots were used in early childhood, primary, and secondary classrooms and what teachers and students learnt by working with these robots. Questionnaires and semi structured interviews have been used in order to evaluate the results of the project. Students were able to achieve success with programming the robots by using computational thinking skills including Problem decomposition, Algorithmic thinking, Problem solving, Testing, and Debugging. Teachers in this study noted that student learning extended well beyond the expected skill level for their age in computational thinking and coding.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Computational thinking, 21st century skills
TYPES OF ATTACHED MATERIALS	Article https://stem-in-ed2018.com.au/wp-content/uploads/2019/01/5th-International-STEM-in-Education-Post-Conference-Proceedings-2018.pdf

TITLE OF THE PUBLICATION	Sakulkueakulsuk, Bawornsak & Witoon, Siyada & Ngamkajornwiwat, Potiwat & Pataranutapom, Pornpen & Surareungchai, Werasak & Pataranutaporn, Pat & Subsoontorn, Pakpoom. (2018). Kids making AI: Integrating Machine Learning, Gamification, and Social Context in STEM Education. DOI: 10.1109/TALE.2018.8615249
KEYWORDS	AI; Machine Learning; STEM; Agriculture.
ABSTRACT OR SHORT DESCRIPTION	The paper presents an approach in STEM education at the intersection of machine learning, gamification, and social context. In particular it presents an agricultural based AI challenge designed to foster students to learn the process of creating machine learning models in the form of a game with the emphasis on the Four P's of Creative Learning (Projects, Passion, Play, and Peers). Goal was is to come up with an innovative education model that encourages the students to connect the emerging technological solutions such as AI with the pressing real-world problems in the playful environment. It is found that machine learning can be used as a tool to successfully conduct interdisciplinary education at the middle school level.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The papers explores the clggages and outcomes of the educational programme for middle school students (grade 7 to 9) combining knowledge, observations, and teamwork efforts to achieve the goal of using the machine learning model for a use case in agriculture. The paper included details on the evaluation framework developed to assess the learning outcomes of the participants, as the results of the pre and post-workshop surveys conducted, highlighting that machine learning can be used as a tool to successfully conduct interdisciplinary education at the middle school level.
CONTEXT AND TARGET GROUP	Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Mathematics, Science, Technology, Agriculture
TYPES OF ATTACHED MATERIALS	Article https://ieeexplore.ieee.org/document/8615249

Tools reviews and mapping

TITLE OF THE PUBLICATION	Kahn, K. M., Megasari, R., Piantari, E., Junaeti, E. (2018). AI Programming by Children Using Snap! Block Programming in a Developing Country. In Proceedings of the 13th European Conference on Technology Enhanced Learning, Leeds, UK, 2018 https://ecraft2learn.github.io/ai/publications/EC-TEL_2018_source-files_48%20kk%20edits%20changes%20accepted.pdf
KEYWORDS	AI programming; Block programming; Snap!; Education; Computer Science; Visual tools.
ABSTRACT OR SHORT DESCRIPTION	Following the trend of visual languages for introducing algorithms and programming in K-12, the paper presents a ten-year systematic mapping of emerging visual tools that support the teaching of Machine Learning at this educational stage and analyzes the tools concerning their educational characteristics, support for the development of ML models as well as their deployment and how the tools have been developed and evaluated. As a result, the paper highlights 16 tools targeting students mostly as part of short duration extracurricular activities. Tools mainly support the interactive development of ML models for image recognition tasks using supervised learning covering basic steps of the ML process. Being integrated into popular block-based programming languages (primarily Scratch and App Inventor), they also support the deployment of the created ML models as part of games or mobile applications. As the results of this mapping also provide a first indication that the adoption of visual tools for teaching ML in K-12 can be beneficial and provide a valuable contribution especially for novices and considering the current importance of the popularization of AI/ML, it also provides a basis for further research in this area to support the teaching of this innovative knowledge area in K-12.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The mapping presented can help instructional designers and educators to choose the most appropriate tool for their educational goals and contexts. It points out several implications for future research in this area, including - Development of tools for the introduction of Machine Learning at earlier educational stages. -Large-scale applications and studies of learning progress in K-12 regarding ML concepts and practices - Enhancement of tools for the support of a greater variety of ML tasks to facilitate the interdisciplinary integration of teaching ML into existing K-12 curricula. • Extending the provision of adequate technical infrastructure and educational material. • Provision of support for different levels of learners. • Provision of tool support for different learning modes. • Analysis of learning performance to improve the underlying learning strategies. • Adoption of rigorous scientific methodologies for the development of tools and their functionality.
CONTEXT AND TARGET GROUP	Vocational and Formal education (students, teachers, educational practitioners, researchers)
SUBJECTS	Computing AI, Machine Learning
TYPES OF ATTACHED MATERIALS	Information regarding the evaluation of the tools https://ecraft2learn.github.io/ai/#programming-guides

TITLE OF THE PUBLICATION	Kahn K., Winters N. (2017) Child-Friendly Programming Interfaces to AI Cloud Services. In: Lavoué É., Drachsler H., Verbert K., Broisin J., Pérez-Sanagustín M. (eds) Data Driven Approaches in Digital Education. EC-TEL 2017. Lecture Notes in Computer Science, vol 10474. Springer, Cham. https://doi.org/10.1007/978-3-319-66610-5_64
KEYWORDS	Visual programming; Block languages; AI.
ABSTRACT OR SHORT DESCRIPTION	The paper provides a review of services are available for speech synthesis, speech recognition, image and video recognition, text analysis, and machine learning, that students could use in a wide variety of programming projects including voice commands to robots, chatbots, audio games, and vision-based robotics. The paper highlights the strengths of such programming projects to learn about perception, language, psychology, and the latest empowering technologies, and discusses the obstacle to using these services in schools in relation to their technical complexity beyond the ability of most school students. The challenge addressed in this paper is how to provide interfaces that are much easier to use and yet still support most of the functionality of these AI services. It describes the addition of new programming blocks to the Snap! visual programming language that provide easy-to-use interfaces to these services. It presents developed blocks for speech input and output and image recognition. It includes Learning materials developed and trialed with a small number of children.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The eCraft2Learn project developed a set of extensions to the Snap! programming language to enable children (and non-expert programmers) to build AI programs. The blocks are available as projects with examples of using the blocks as well as libraries to download and then import into Snap! or Snap4Arduino.A guide consisting of six chapters describes the new blocks, possible projects, sample programs, background information, and the larger context about AI and machine learning
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Computing, AI, Language
TYPES OF ATTACHED MATERIALS	Programme and demos https://ecraft2learn.github.io/ai/AI-Teacher-Guide/chapter-1.html https://docs.google.com/document/d/1jnibYTmeu_Y06rhLNLI-zel4Im0O68TqH9Z0U023RXs/edit https://ecraft2learn.github.io/ai/AI-Teacher-Guide/chapter-2.html https://ecraft2learn.github.io/ai/AI-Teacher-Guide/chapter-3.html

TITLE OF THE PUBLICATION	R. Williams, H. W. Park, and C. Breazeal. “A is for Artificial Intelligence: The Impact of Artificial Intelligence Activities on Young Children’s Perceptions of Robots,” in Proc SIGCHI, Glasgow, Scotland, pp. 1-11, 2019 https://dl.acm.org/doi/10.1145/3290605.3300677
KEYWORDS	AI education; Child-robot interac-tion; Social robots; Computational thinking; K-12 education; Computing methodologies
ABSTRACT OR SHORT DESCRIPTION	The paper presents a novel developed early childhood artificial intelligence (AI) platform, PopBots, where preschool children train and interact with social robots to learn three AI concepts: knowledge based systems, supervised machine learning, and generative AI. The paper presents the findings of the evaluation focusing on how much children learned by using AI assessments developed for each activity, how did developmental factors, like perspective taking skills, impacted what children could learn about AI, as well as how did children’s perceptions of “thinking machines” changed after they engaged in educational AI activities.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The approach of PopBots Platform primary design focuses on the Theory of Mind Assessment considerations to help children draw connections between the activities and their own experiences, to appeal to children with varied backgrounds and interests, and to empower children to reflect on and discuss AI. Findings highlights that early AI education can empower children to understand the AI devices that are increasingly in their lives.
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Robotics
TYPES OF ATTACHED MATERIALS	Assessment procedures and data https://dl.acm.org/doi/10.1145/3290605.3300677

TITLE OF THE PUBLICATION	Gresse von Wangenheim, C., Hauck, J.C.R., Pacheco, F.S. et al. Visual tools for teaching machine learning in K-12: A ten-year systematic mapping. Educ Inf Technol (2021). https://doi.org/10.1007/s10639-021-10570-8
KEYWORDS	K-12; Computing; Machine Learning; AI.
ABSTRACT OR SHORT DESCRIPTION	Following the trend of visual languages for introducing algorithms and programming in K-12, the paper presents a ten-year systematic mapping of emerging visual tools that support the teaching of Machine Learning at this educational stage and analyzes the tools concerning their educational characteristics, support for the development of ML models as well as their deployment and how the tools have been developed and evaluated. As a result, 16 tools are highlighted targeting students mostly as part of short duration extracurricular activities. Tools mainly supporting the interactive development of ML models for image recognition tasks using supervised learning covering basic steps of the ML process. Being integrated into popular block-based programming languages (primarily Scratch and App Inventor), they also support the deployment of the created ML models as part of games or mobile applications.
DESCRIPTION OF THE MAIN ELEMENTS AND DYNAMICS OF THE PEDAGOGICAL APPROACH	The objective of this study is to answer the research question: What visual tools exist for teaching ML in K-12 through the development of custom ML models. The goal of this work is to characterize and compare these tools, to provide an overview to guide their systematic selection as well as to identify potential gaps and opportunities for future research. It analyzes the following questions: AQ1. What visual tools for teaching ML exist? AQ2. What are their educational characteristics? AQ3. What are their characteristics concerning the ML platform? AQ4. What are their characteristics concerning the deployment platform? AQ5. How have the tools been developed and evaluated?
CONTEXT AND TARGET GROUP	Formal education (teachers, educational practitioners, researchers)
SUBJECTS	Machine Learning
TYPES OF ATTACHED MATERIALS	List of tools https://doi.org/10.1007/s10639-021-10570-8

3. AI in education: a brief overview

As the recent scientific literature witnesses, in the last decade we have observed a growing interest **for a meaningful pedagogy of AI**. Based on the review of best practices we can delineate a broad **taxonomy** with relation to six main aspects involved in the introduction of AI at school:

- AI didactic approach
- AI teaching/learning formats
- AI pedagogical style
- AI learning content
- AI learning objectives
- AI tools

With relation to the first aspect, we can distinguish **three fundamental approaches**: **didactics of AI** (i.e. Ai as a field of study, that is, the teaching/learning of technical aspects of AI such as machine learning algorithms, embedded systems, etc.); **AI in didactics** (i.e. subject-specific lessons which integrates AI as tools to empower and extend knowledge in a discipline, for example a science course illustrating the usefulness and functioning of AI for seabed detection); **AI for didactics** (i.e. AI based devices and softwares to support teaching and learning, including personalized adaptive learning, for example automatic translation or e-learning platforms aiming at reinforcing specific knowledge).

Concerning the second aspect, we can identify **several recurrent formats**, such as: **structured series of courses** covering both hardware and software characteristics of AI (Sabuncuoglu, 2020; Gong 2020); short workshops aimed at providing introductive contents along with hints to further develop knowledge and competences in AI (Estevez et al., 2020) **Design Based Research (DBR) interventions** to explore new methods and contents (McArthur et al., 2005); or, **project-based lessons** with in-deep and purposeful hands-on activities for specific implementation of AI (e.g. Ali et al. 2019).

About **pedagogical style**, AI activities can vary in terms of **amount scaffolding, involvement of teachers** in the design of the unit lesson and of AI tools, **role of students, high or low ceilingness** (i.e. in what extent activities can be developed in an open-ended way) (Li, 2020).

As for **learning content**, AI can be **subject-related** (i.e. connected with a specific school discipline) or **subject-independent**. Here the choice also depends on the **learning context** (whether the activities are led in a curricular or extracurricular context), but not uniquely. Lessons about AI often include an introduction about the **history of AI** (from Turing test to machine learning and deep-learning algorithms) and **basic knowledge on machine learning** (**supervised vs. unsupervised learning**) (ACTUA, 2020). AI is generally presented as a technology capable to sense, process, learn, decide, act. A pedagogical mainstream for K-12 AI education is the so-called "**Five big ideas**" content[1] which focus on : 1) **perception** (e.g. speech, sound and object recognition, scene understanding, etc.); 2) **representation and reasoning** (i.e. representation of the existing cognitive object such as city maps for the optimization of a path, or representation of a game board to elaborate a successful strategy, or representation of web page content to return specific pages in response to a query); 3) **learning from data** (i.e., train an AI device for

1 https://ai4k12.org/

specific computer vision tasks, or for translation, or to detect the shape and traits of faces etc.); 4) **interaction** (i.e., ontologies and domain knowledge required for AI entities to obtain a natural and smart interaction with humans, for examples robotic assistants or conversational agents); 5) **societal impact of AI** (i.e. positive or negative effects of AI use, for example: facilitate a caregiving community by matching people needs and caregiver availability vs. employ biased data to orient an AI device training to advantage someone and disfavour somebody else, etc.). Courses on AI also provide an overview of **AI applications** (autonomous systems, goal-driven systems, patterns and anomalies, recognition, predictive analytics and decisions, conversation and human interaction, hyper-personalization (Walsh, 2019). Finally, a relevant part of learning content is often dedicated to responsible or **ethical AI** (transparency and accountability, data biases, interpretability/explainability, responsible use of data, safety, reasonable use of resources to process data, etc.)

Concerning **learning objectives**, we can find several categorisations in the literature. A first distinction concerns **epistemic components** (knowledge, competences and skills related to specific domain, included technical AI domain) and **non-epistemic components** (soft-skills such as critical thinking, creative problem solving, meta-cognition, collaboration, etc.) of learning objectives (Tuomi, 2020). The AIforK12 network distinguishes between **Learning Objectives** (LO) – what students should be able to do - and **Enduring Understanding** (EU) – what students should know. For example, when studying how AI processes information, a relevant LO is "analyse one or more online image datasets and describe the information the datasets provide and how this can be used to extract domain knowledge for a computer vision system", while the corresponding EU is: "Domain knowledge in AI systems is often derived from statistics collect from millions of sentences or images".[2] In few words, LO describe competencies and skills while EU describe fundamental concepts for a correct understanding of the AI functioning.

Another important learning objective is **ethics**: students should also be aware of limitations and potential of AI in order to be capable of evaluating positive or harmful applications of AI and to project future scenarios (Tuomi 2020). Awareness can be divided in understanding of IA impacts on society (i.e., knowing the effect of non-neutral use of AI technologies), and understanding of the sustainability risks connected to AI functioning (i.e. data-driven learning as source of global warming). Other sources propose, as a comprehensive learning objective, the acquisition of an expertise in AI, which includes AI readiness, AI confidence, AI experience and Life skills (e.g. Intel, 2019)

With regards to **tools**, this castudents train AI for specific tasks (e.g. Google's teachable machine[3], Machine Learning for Kids[4] etc.), n be **virtual learning environments** where or **simulation softwares** (e.g. Playground TensorFlow[5]), but also **embedded tools** used to combine AI techniques and physical/electronic components to ideate new IoT devices (i.e. AI "infused" into tangible objects). Several tools can be freely accessible on the web, but students and teachers can also engage in the design and
testing of original tools, as is the case for the Edu4AI project.

2 https://ai4k12.org/wp-content/uploads/2021/01/AI4K12-Big-Idea-1-Progression-Chart-Working-Draft-of-Big-Idea-1-v.5.28.2020.pdf

3 https://teachablemachine.withgoogle.com

4 https://machinelearningforkids.co.uk/

5 https://playground.tensorflow.org

Table 1 Taxonomy of AI educational practices

Didactic approach	Didactics of AI	AI in didactics	AI for didactics	
Teaching/ learning formats	Courses (sequential lessons)	Short workshop	Design Based Research (DBR) interventions	Project-based lessons
Pedagogical style	Amount of scaffolding	Strong/weak involvement of teacher	Role of students	High/low ceilingness
Learning content	Subject-related/ subject-dependent content	What Ai can do: Perception, representation and reasoning, learning, interaction, social impact	Applications of AI: autonomous system, goal-driven system, recognition, patterns and anomalies, predictive analytics and decision, human interaction, personalization	Responsible AI/Ethical AI (transparency and accountability, explainability, responsible use of data, safety, reasonable use of resources to process data, etc.)
Learning objectives	Epistemic components: knowledge, competences and hard skills with concern to AI and to the subject area	Non epistemic components: critical thinking, creative problem-solving, meta-cognition, self-reflection, communication, collaboration (soft skills)	Awareness of IA sustainability and IA impacts	Expertise: AI readiness, Ai confidence, experience and Life-skills
Tools	Virtual learning environments	Simulation software	Embedded tools	Tools available on the web vs. tools created by teachers and students

This overview of AI in education is useful to support teachers in preparing the ground for a theoretically-informed design of innovative AI curricula. It helps teachers in situate their practice, and make choices on how they wish to develop AI projects by combining different aspects of AI education.

4. A pedagogical framework to bring AI in the classroom

In the following sections we will examine more in detail the three challenges that AI pedagogy faces in this century, and further discuss the present document approach with relation to such challenges, as well as our list of general recommendations to build a meaningful AI educational framework. The first challenge - AI for all - is inspired by the UNESCO 2019 report "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development" and is in line with Sustainable Development Goal 4, which strives for qualitative and equitable education for all. The second challenge - educational priorities of the XXI century – refers to the 2030 ONU Agenda for Sustainable development[6] and consists in educating students about how AI can be useful for environmental conservation, healthy lives, inclusive and resilient society, sustainable development, through experiential activities in daily contexts. The third challenge – building AI curricula through iterative and collaborative design – reaffirms the role of teachers in AI education: co-design of AI curricula is fundamental to foster teachers' motivation, commitment, and willingness to develop new contents. Furthermore, the literature points out that when adopting AI-based systems, students' improvement does not depend on AI technology but on how teachers can use technology in pedagogically meaningful ways (du Boulay, 2019). Co-design can be based on different expertise and proposals from, for example, technology developers, teachers and students.

AI for all: recommendations for ensuring equal opportunities

Although generally considered by students as an attractive and to-be-explored subject, AI is often perceived as destined for future Computer Scientists only. Students' representations of AI often include uneasily achievable levels of engineering skills, male-oriented job opportunities, complex and expensive machinery, research-based and abstract learning content (Marques et al., 2020; Sanusi and Oyelere, 2020). As a matter of fact, there are several factors that can prevent the undertaking of Ai studies and careers:

- **ICT** hardware and software **unavailability**, deficit of **Internet reliability**, **data costs**, and weakness in **students´ basic ICT skills** (Nye, 2015);
- **gender stereotypes**, i.e. the idea that AI is a male-oriented field as it requires characteristics that are seen as in-built in men (for example: interest for numbers, better understanding of logic, high affinity with machinery and abstraction etc.) (Wang et al., 2015);
- **difficulty in building a "computer identity"**, i.e. belief in one's performance/ competence, interest and recognition in computing, as a significant predictor of students' information technology career choice (Mahadeo et al. 2020);
- **lack of a "science capital"**, which gathers "the economic, social and cultural capital that specifically relates to science and that has the "potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science" – for example: parents with science degrees and/or who work in science jobs (Archer, et al. 2014, p. 5). According to the literature (Dewitt and Archer, 2015) the distribution of such science capital is strongly classed and racialised

6 https://sdgs.un.org/2030agenda

- **pre-conceived ideas** about the fact that AI jobs would not take in account those important **values** that allow to make useful contributions to society (Alshahrani et al., 2020).

In order to overcome these obstacles, we suggest that an AI framework which aims at ensuring equal opportunities for all learners should take care of several crucial elements:

Students' **previous knowledge, learning styles** and **differentiation needs**	take advantage of all the knowledge gained in the last decade on AI pedagogy in order to help teachers in setting **levels of progression for learning objectives** with relation to **different baselines** (pre-requisites in Computer science, such as coding skills, etc.); privilege **accessible tools** to experiment AI (i.e. fee-free software, inter-schools shared resources, etc.);
Personal relevance of AI learning experience	cultivate **a sense of "AI being for me**" by: leveraging learners' interest; engaging them through a focus on their identity, values and background; helping them in formulating projections about their future job and role in the society;
Students-friendly lesson dynamic	use **gamification techniques** that can facilitate a non-constrained exploration of the AI field, to enable students' familiarization with AI and neutralize possible preconceptions and biases;
Future perspective	encourage **career-relevant lessons**, in which students can discover the significant existing variety of AI professional profiles, including AI women networks[7] and ethically relevant jobs such as service-oriented AI;
Formative assessment	develop an **evaluation system** which motivates continuous learning by fostering autonomous training and aspirations towards improvements of AI know-how.

Key areas, topics and pedagogical objectives to develop AI learning contents

In order to define which are the key areas, topics and pedagogical objectives that should be considered as the main grounding elements to design AI educational projects, it is important to understand what AI is and what it is not. The web abounds with AI definitions, all of which describe

7 For example: https://www.womeninai.co/

AI as one of the greatest breakthroughs of contemporary society. A relevant amount of sources defines AI as a technology reflecting human willingness to make computers intelligent by data-driven machine Learning and knowledge-based AI (i.e. based on an explicit representation of domain knowledge that a machine reason about). However, Tuomi (2020) reminds that "AI is not a thing. It is a domain of research with many sub-disciplines, each with their own histories, domains of expertise, and developmental dynamics. And Zimmerman (2019) highlights that "Technology is just one component of preparing learnings for a world with AI. We need to grapple with philosophical questions and logical arguments that arise around AI".

The perspective adopted by the present document is that if, one side, it is true that AI concerns coding, patterning, data interpretation, sorting, comparing, classifying, identifying, etc., on the other side students cannot be oriented to the study of such AI mechanisms uniquely, otherwise they would fail to understand why the combination of machine-driven tasks and human-driven activities can result in useful, interesting and exosystemic progress.

In this sense, our recommendations are to:

- Identify **key areas** with relation to XXI century educational priorities: this can be done by: i) an attentive analysis (e.g. reading and discussing in class) the 2030 ONU Agenda for Sustainable Development Goals (Image 1) and the selection of specific goals to be treated through AI-based lessons ii) a pedagogical adaptation of the 2030 Agenda content to specific contexts of education, in order to trigger questions that can captivate students' attention and encourage them to inquire
- Define **topics** as a subset of identified key-area, with reference to subjects that can be personally relevant for students (for ex. homework and peer-to-peer evaluation)
- List broad **pedagogical objectives** in terms of epistemic (i.e. domain-knowledge related) and non-epistemic (i.e. transversal) components for the individual students and for learning community (i.e. class and school)
- Specify **alignment with national or educational standards** (e.g. curricular standards for specific disciplines, DigComp standards for digital know-how, etc.)
- Include **ethical AI-related issues** (e.g. algorithm transparency, data privacy, etc.)

For example:

- if the selected area of the 2030 Agenda is "resilient society", this latter can be adapted and narrowed down (e.g. "resilient school");
- an inquiry can then be started through a triggering question, such as: is there any AI solution that we can design to help keeping a sense of "classroom" when carrying out distance learning? (such as a solution for peer-to-peer homework)
- while the students develop the AI solution, an ethical constraint can be considered concerning students' data privacy

Image 1. The 17 goals contained in the 2030 Agenda for Sustainable Development. The agenda, which has been adopted by all United Nations Member States in 2015, aims at reducing inequalities, favouring education for all, ensuring a healthy planet and encouraging sustainable growth. Each goal includes a list of specific targets, for a total number of 169 targets.

Building AI curricula: a context-oriented, iterative and collaborative process

A "curriculum" can be defined as a system of didactic units describing consistent sets of learning experiences which are planned and guided by teachers, and learned by students. Curriculums include a description of what, why, how and when students should learn. The way curriculum is perceived and organized influences the process of teaching and learning (Chiu et al., forthcoming).

An exam of the existing literature reveals three main typologies of AI curriculum: human-oriented, context-oriented and engineering-oriented (Table 2).

Table 2 Typologies of AI school curricula for K12 Education

Type	Description	Examples

Human-oriented	This type of curriculum uses human socio-cognitive processes (e.g. reasoning, decision, acting, learning, etc.) as a metaphor to describe AI processes and to organize learning units accordingly.	AIforK12 curriculum (2020)[8]; Actua's artificial intelligence curriculum (2019)[9]
Engineering-oriented	This type of curriculum uses engineering processes (e.g. definition of what an AI project cycle is) as structuring elements of the curriculum.	Intel Artificial Intelligence curriculum (2019)[10]
Context-oriented	This type of curriculum uses contexts of AI application to define macro-units (es. smart cities, smart home, smart school, etc.) and sub-units (e.g. transports, caregiving, educational scaffolding, etc.)	Zimmerman (2019)

Within this document, we suggest to adopt a context-oriented curriculum for the following reasons:

- Context-oriented curriculum helps to build an "**AI landscape"**, that is, to progressively map AI-related learning contents and objectives in a way that fosters subject exploration, case-studies analysis, and identification (e.g. students can reflect about how they inhabit such landscape, how they act in it and how they can contribute to develop it in a sustainable way).
- Context-oriented curriculum is useful to create **links between AI and educational priorities** for XXI century, and to raise awareness about the **role of school in the society**, by creating **connections between classrooms and the world out there** (**citizens**, **families**, **local communities**, **local institutions** etc.).
- Context-oriented curriculum helps in creating **micro-worlds**, e.g. students-tailored learning scenarios. The first historical definition of microworld, that we adapt here replacing "mathematics" by "AI" is: a "place", where certain kinds of IA thinking could hatch and grow with particular ease. The microworld is an incubator... The design of the microworld makes it a "growing place" for a specific species of powerful ideas or intellectual structures." (Papert, 1980, p. 125). A second definition provide by M. Resnick defined microworlds as "simplified worlds, specially designed to highlight (and make accessible) particular concepts and particular ways of thinking" (1997, p. 50).
- Context-oriented curriculum can facilitate **experiential learning** through **hands-on interdisciplinary activities** with relation to **real fields of application**

Hence, once defined the type of curricula, we suggest opting for an iterative and collaborative design process (Psillos & Petros Kariotoglou, 2016). Iterative design is based on an ideate-test-evaluate-improve cycle which is built through collaboration between teams of teachers. (Table 3)

8 http://teachingaifork12.org/

9 https://www.actua.ca/wp-content/uploads/2020/01/Actua-AI_Handbook.pdf

10 http://cbseacademic.nic.in/web_material/Curriculum20/AI_Curriculum_Handbook.pdf

Table 3 Iterative and collaborative IA curriculum design

Step 1	Create or join an interdisciplinary **teachers' teams** to work jointly on the design of an AI curriculum
Step 2	Define a **curriculum overview**, e.g. an **abstract** which includes a summary of the curriculum and brief information on: prevalent AI didactics approach, subject area, themes, involved disciplines, purpose, learning objectives. Include a **list of learning units titles.**
Step 3	**Discuss** the curriculum overview **with AI experts, tutors from AI networks, parents and students,** and make eventual adjustments to your initial idea.
Step 4	Write a draft of the **learning units overview** including, for each unit: title, summary, duration, pre-requisites, learning objectives, type of tools
Step 5	Prepare **AI teaching cards** and **students cards.**
Step 6	**Test learning units** and ask for teachers, students and AI expert feedback through surveys and focus groups; improve the units if necessary.

Iterative design is very helpful to ideate meaningful learning experiences, because it renforce curricula development through participatory innovation (which can also includes specialists from outside the school), real world activities and continuous feedback for improvement.

5. Instructional design material for AI pedagogy

In this section we provide a set of instructional materials to scaffold AI didactics: curriculum template, learning unit canvas, teachers' and students' worksheet model . Before, some useful suggestions to introduce AI in class:

- provide a **scenario from real life**
- define **clear learning objectives** (knowledge, skills, attitudes)
- check **prerequisites** for students (technical knowledge and skills required)
- provide OERs (i.e. videos, how to guides, definitions, etc) to support students in carrying out the projects
- ensure **familiarisation** of students **with tools** required (software, hardware)
- write **worksheets** for students that will help them follow a sound pedagogical methodology (project-based learning approach)
- prepare **technical solutions** for the project (to help teachers themselves feel self-confident)

AI Curriculum canvas

Canvas 1: Curriculum Overview

Curriculum overview
Summary:
AI didactics approach: *is this a Didactics of AI/AI in didactics /AI for didactics curriculum?*
Key area: *which are the sustainable goals, amongst the 17 of the 2030 Agenda, that you would like to treat in this curriculum?*
Topics: *with relation to the selected sustainable goals, which are the themes that can be relevant for your class and for your colleagues?*
Context: *how these topics can be grouped into specific contexts?* (e.g. AI for school, AI for home, AI for smart cities). *Can such contexts be treated by different classes of your school in order to build an "AI landscape" project?*
Involved disciplines:
Purpose: *which kind of pedagogical vision you want to foster?*
Age target:
Learning objectives: *which epistemic and non-epistemic objectives student should reach once having accomplished this curriculum?*

Titles of learning units: *1.* *2.* *3.* *4.* *5.*

AI Learning unit canvas

Canvas 2: Learning Unit Overview

Learning unit overview
Title:
Summary: *detail the topic of the learning unit and the AI application in this domain*
Key-words:
Target grades:
Estimated duration:
Pre-requisites (*e.g. previous Computer Science knowledge, programming skills, domain knowledge:*)
Specific learning outcomes: **Outcomes related to Sustainable Development Goals:** **School subjects learning outcomes:** **AI learning outcomes in terms of knowledge, hard skills and soft skills, ethic awareness:**
Preparation
Type of tools: *learning environment, simulation software, embedded tool, etc.*
Materials
Supporting resources (e.g. videos, articles, etc.)
List of activities
Activity 1: Activity 2: Activity 3:

AI teaching cards canvas

Canvas 3: Teaching cards

Engage: *how can you raise the attention of your students and ignite a debate? Which problem/challenge the class will face?*
Explore: *which materials, projects, resources can you provide to your students in order to encourage them exploring the topic?*
Elaborate: *in which way students can systematize the explored information to prepare an AI artifact that can solve the defined problem/challenge?*
Prototype: *which hardware and software related activities are requested to realize the AI artefact?*
Test: *describe how you will implement the prototype with the class*: t*esting procedure, technical solutions etc.*
Evaluate: *is the learning unit effective in terms of approach, class dynamics, content, collaboration with experts/colleagues, AI artefact performance and learning outcomes? What can you improve?*

Tips for teachers

For the **engage phase**, captivate students' attention using the following techniques:

- show a video or a short documentary on the selected sustainable-related topic
- start a debate giving place to questions, opposite points of view, identifying a specific problem and discussing how AI can be a solution
- present AI job profiles related to the selected area
- propose the class to prepare an interview to an AI expert in order to better frame the problem
- propose an intra-school project in order to have two classes work together from different schools/regions/countries and explore cultural differences in AI

For the **explore phase**:

- check if somebody else have proposed solutions for the identified problem
- provide useful sources about history of AI, especially about those AI inventions that relate to the to-be-solved problem
- start from data, not form abstract concepts: data fuel AI; hence, ask students to search for set of data taking care of privacy and possible biases
- let students play with selected specific algorithms which are prototypical illustration of the most salient AI applications

For the **elaborate phase**:

- help students reframe the problem and the solution according to the information they have examined
- support students in identifying useful formats to systematize data and information

For the **prototype and test phase**:

- - in order to make learning visible, it can be useful to use embedded tools like microprocessor cards, etc.
- - you can choose to create from scratch or to use already existing hands-on activities to be remixed[11]
- - have students focus on hands-on activities and to verbalize what they do, e.g.,
- explain how sentence parsers handle ambiguity, use the Google Knowledge Graph[12], etc.

For the **evaluation phase:**

- encourage students to perceive evaluation as a "reality check", an occasion to consider concrete outcomes, instead of personal opinions, and to use failure as a lever for improvement

AI students card canvas

Canvas 3: Student cards

Engage: *why is the problem/challenge/project relevant for me/for my class/for my school? What do we expect to learn?*
Explore: *which information, data and resources are relevant for this project?*
Elaborate: *which are the more useful and interesting information gathered during the Explore phase? How can I organize the gathered information? How does the gathered information help me in better defining the problem?*
Prototype: *which steps are required to carry our project?*
Test: *how am I going to test the prototype in order to assess its proper functioning?*
Evaluate: *does our project respond to the 2030 Agenda challenges? Are we satisfied with our AI artifact? What can I improve?*

11 https://code.org/oceans

12 https://www.google.com/search/about/

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Online resources

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