Design-Based Research on Education and Public Engagement through and with Primary School Teachers and Children to promote Artificial Intelligence and Data Literacy and Awareness

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ENRICA AMPLO

ID No.: 19212743

Date: 14/08/23

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List of Abbreviations

AI	Artificial Intelligence
AI4T	Artificial Intelligence for Teachers
DCU	Dublin City University
EPE	Education and Public Engagement
EU	European Union
GDPR	General Data Protection Regulation
ICT	Information and Communications Technology
K-12	School grades from primary to secondary school
ML	Machine Learning
MOOC	Massive Open Online Course
PDST	Professional Development Service for Teachers
PICO	Population, Intervention, Comparison, Outcome framework
PLS	Plain language statement
STEAM	Science Technology Engineering Art Mathematics
STEM	Science Technology Engineering Mathematics
TPCK	Technological Pedagogical Content Knowledge

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Abstract

Design-Based Research on Education and Public Engagement through and with primary school teachers and children to promote Artificial Intelligence and Data literacy and awareness

Enrica Amplo

Emerging technologies such as Artificial Intelligence (AI) are shaping our world at a very fast pace, and they are challenging us to rethink our lives as well as our education systems. Technologies powered by AI can be used to solve problems for good in various domains e.g., health or sustainability. However, AI algorithms that are coded to “learn” from data, can be biassed, wrong, or misused. This is the reason why developing skills and competencies to better understand AI and be aware of both its positive and negative impact is extremely relevant to every citizen. Still, only a few research studies examine how to teach AI in schools, and even fewer concentrate on teachers' learning.

This is a designed-based research study that investigated effective Education and Public Engagement on emerging technologies, specifically AI, through active teachers’ participation. In this study, teacher learning complexity was acknowledged through the Technological Pedagogical Content Knowledge framework (TPCK). Constructionist learning principles and Design-Based Learning (DBL) approach underpinned the interventions designed to engage both teachers and children to promote AI literacy and awareness. A learning programme focused on AI for primary school teachers was developed and iteratively tested and improved with preservice teachers, teachers, and teacher advisors. Lastly, a learning programme for children was co-designed together with teachers and piloted in school.

The findings and recommendations of this study could potentially constitute a guide to support research groups working with emerging technologies to address the need and responsibility of building a bridge between research and the general public. Ultimately, the practical outcome of this research is a scalable and replicable learning programme on AI integrated with curricular subjects designed for primary school teachers and children. Resources and materials created were collected and published in a bespoke printed and digital handbook for teachers and an open-access website.

Fig. 1 Video finalist at ‘Tell it Straight’ competition on my research project
https://youtu.be/fnQ_AGXzo94?t=4007

1. Introduction

The first chapter of my thesis aims to welcome the reader to the journey of my Ph.D. study. A study that developed at the intersection of Technology, Education, and Design. When I first embarked on this journey I had been working as an educational designer and teacher trainer for a number of years having completed my degree in Mechatronic Engineering and Design. Since 2015 my mission has been to understand and design solutions to engage with teachers and children around creative technology and digital learning to create opportunities for them to develop 21st-century skills while developing digital competencies.

This Ph.D. study was part of the 2018 Insight-Science Foundation Ireland Ph.D. recruitment scheme: "*Insight engagement in "Smart Partnerships" to develop STEM (Science Technology Engineering and Mathematics) competencies that transform lives to live and thrive in a complex connected global society*" with the aim to find a solution to the problem of bridging the gap between research on emerging technologies (i.e., Artificial Intelligence) and the public.

The methodology that underpinned my study is Design-Based Research (DBR) often also called Educational Design Research. This is an approach to research that aims to develop a proposal for solutions to complex educational issues (Mckenney and Reeves, 2013). The results of this research can be educational programmes, products, or policies (Mckenney and Reeves, 2013).

The educational problem in context is presented in this chapter with the proposed solution developed and the overarching research question investigated. The methodology that underpinned this research is then described, while the structure of this thesis is described in the latter part of this chapter.

1.1 Understanding the educational problem (why)

Artificial intelligence (AI) like other emerging technologies is reshaping our world forcing us to restructure both our personal lives and educational systems (OECD, 2021). The use of AI and data analytics as tools to enhance the teaching and learning process, to monitor and evaluate students' learning progress, is now receiving a lot of attention (Chassignol et al., 2018). On the other hand, the DigComp 2.2 EU framework on digital competencies for citizens, outlines the relevance of AI in terms of knowledge (i.e. recognising AI systems and their uses), skills (i.e. enabling a day-to-day interaction with the technology), and attitude (being aware of both negative and positive impact of AI) (Vuorikari, Kluzer and Punie, 2022). Also, a number of countries are working toward the introduction of AI literacy in digital learning policy and responsible and aware use of technologies for good (Ireland Department of Education, 2022). However, only a few studies examine how to teach AI in schools, and even fewer concentrate on teachers' learning of AI (Kahn and Winters, 2021).

Children should be ready to take on active roles in designing and governing AI-enabled technology (UNICEF, 2020). Therefore, we need to provide opportunities for them to develop skills and competencies to be the ethical innovators of the future and to explore how technology can be used to foster their creativity and critical thinking (NCCA, 2020). Even though AI learning programmes for young students, resources, and activities are available online only recent studies have attempted to share best practices and guidelines to design them (Zhou, Van Brummelen and Lin, 2020). Furthermore, there are just a few learning programmes for teachers relating to AI and even fewer that also engage teachers in the design process (Zhou, Van Brummelen and Lin, 2020). A few studies point to the need to focus more on pedagogy and frameworks (Kahn and Winters, 2021) and provide support for teaching AI (Marques, Wangenheim and Hauck, 2020).

Consequently, the primary objective of this study was to frame EPE focused on teacher learning in relation to emerging technologies (i.e., AI) proposing a collaborative and creative approach that acknowledges teacher learning complexity, the importance teacher role, and impact on children.

1.2 The solution (what)

The proposed solution to promoting effective EPE between research on emerging technologies, specifically AI, and the public, is collaborating with primary school teachers and children by:

A. Creating well designed opportunities for teachers to develop their understanding of AI, acknowledging their knowledge complexity and engaging them in learning programmes underpinned by constructionist learning principles and design.

B. Co-creating resources for children with teachers, to promote AI literacy and awareness, integrated with curricular subjects (as part of teachers' learning process) underpinned by constructionist learning principles and design

C. Reaching children through teachers' work in schools promoting an AI learning programme for children underpinned by constructionist learning principles and design

D. Collaborating with teacher advisors to promote peer-learning (scalable and replicable programme)

E. Developing support materials (handbook and website resources)

The solution was developed through a series of iterations which focused on different interventions with specific cohorts of participants i.e., preservice teachers (students of the faculty of Education who will be future primary school teachers), teachers, teacher advisors (i.e., teachers who train teachers as part of their job), and children.

1.3 Research question

The overarching research question of this study is: **[RQ 1] What are the characteristics of an EPE action focused on teachers, for creating effective learning opportunities both for primary school teachers and children to promote AI literacy and awareness?**

The overarching question of this research embraces three layers:

1. EPE focused on collaborating with teachers (Teachers as experts)
2. Framing teacher understanding of AI (Teachers as learners)
3. Teachers engaging with children to promote AI literacy and awareness (Impact on children)

Sub-research questions were narrowed to address the specific phases of this study focused on teacher and children learning programmes to promote AI literacy and awareness, as described in the Methodology in Chapter 3.

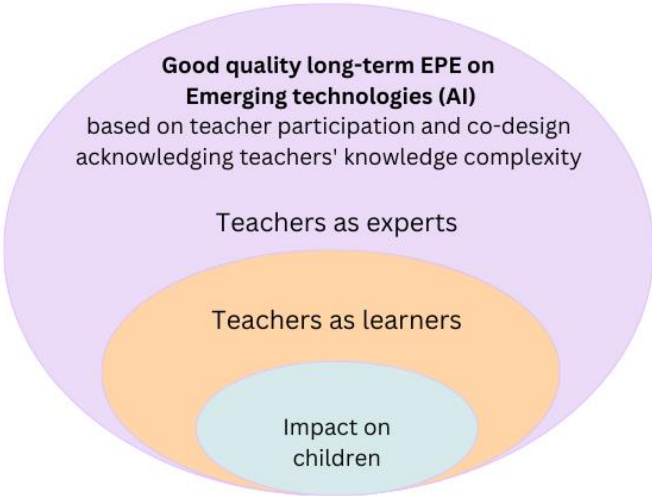


Fig. 2 Ph.D. study layers

1.4 Research methodology (how)

The research method that guided me throughout my Ph.D. study was design-based research (Plomp and Nieveen, 2013). The design cycle started with understanding and defining the problem to solve, ideating a solution, creating a prototype, and testing it through a number of iterations. The goal of this Ph.D. was to frame EPE with and for primary school teachers while having a real-world impact and practical outcomes. Design-based research resulted in a robust and flexible approach that supported the development of my research.

PHASE 1 of my research was dedicated to the literature review, developing researcher knowledge and establishing a network. In PHASE 2 I started to collaborate with preservice teachers, and later with teachers and teacher advisors. During each PHASE from 2 to 6, I collected qualitative data, in the main, that were analysed through thematic analysis and descriptive statistics after each phase. Results from each phase informed the next phase and the development of learning programmes and materials. An overview of this study is presented in Fig. 3.

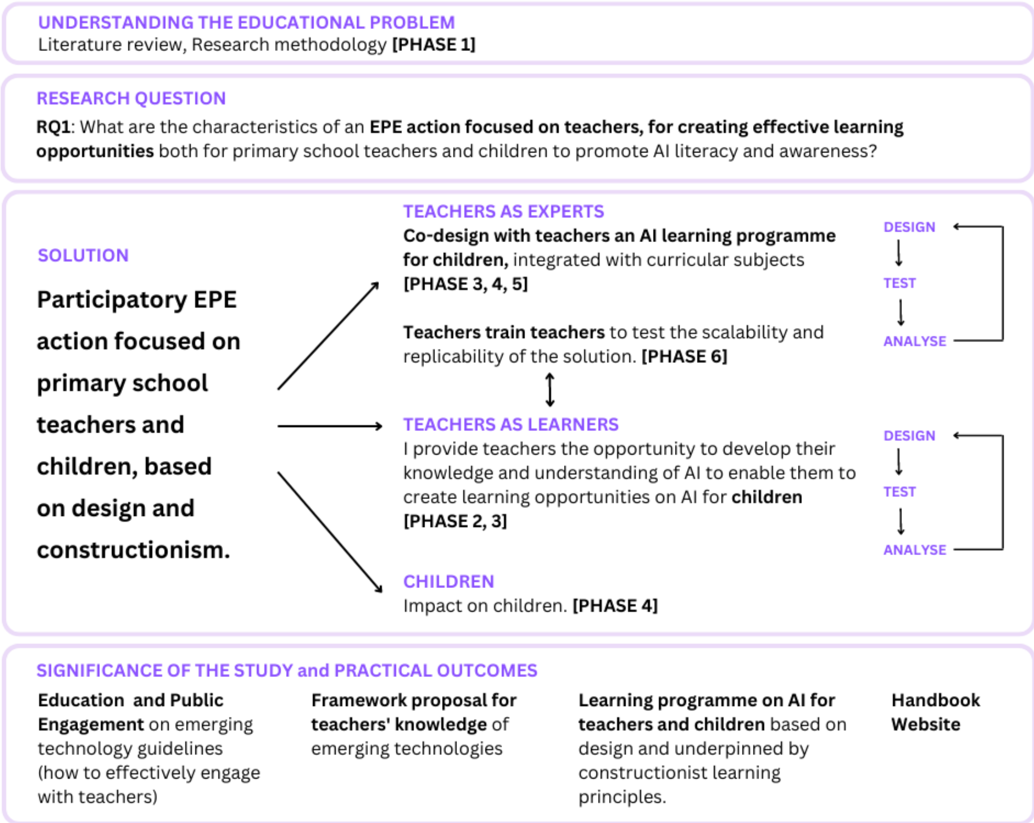


Fig. 3 Brief study overview

1.4.1 Teachers as learners

A teacher learning programme on AI was designed and developed through a series of three iterations, the first with two groups of preservice teachers (from Dublin City University (DCU) and Università Cattolica del Sacro Cuore of Milano) [PHASE 2], the second with a small group of primary school teachers and teachers' advisors in Ireland [PHASE 3] and the last with teacher advisors involving a new group of teachers [PHASE 6]. The content of the programme was informed by a review of the literature and based on AI big ideas for K-12 (Touretzky, Gardner-McCune, Martin, *et al.*, 2019), AI literacy competencies (Long and Magerko, 2020), and teacher role as citizens in the era of AI (Floridi *et al.*, 2018). The programme was framed with TPCK (Technological Pedagogical Content Knowledge) and underpinned by constructionist learning and design-based learning principles.

1.4.2 Teachers as experts

At the end of the learning programme for teachers a face-to-face co-design session was conducted on campus to ideate activities for children [PHASE 3]. In this session, teachers and teacher advisors brought to the table their expertise and competencies on pedagogy and didactics. Moreover, a refinement of the programme, both for teachers and children, was informed by a design session with teachers and teacher advisors [PHASE 5] that culminated with the review of supporting materials (handbook and website). Lastly, to investigate the scalability of the solution, teacher advisors who participated in the study were asked to conduct a pilot of a learning programme for a new group of teachers (teacher advisors, as experts, train their peers) [PHASE 6].

1.4.3 Children's learning programme

The children's learning programme co-created with teachers was piloted in school. This programme was underpinned by constructionist learning and design-based learning principles. The programme which was co-designed at the end of the learning programme for teachers [PHASE 3] was piloted in three schools [PHASE 4]. Findings from the pilot studies informed a co-design session with teachers and teacher advisors [PHASE 5] to refine both the learning programme for children and teachers. It was published in a handbook for teachers and open access on the website developed for this study (teachingAI.eu).

1.5 Thesis structure

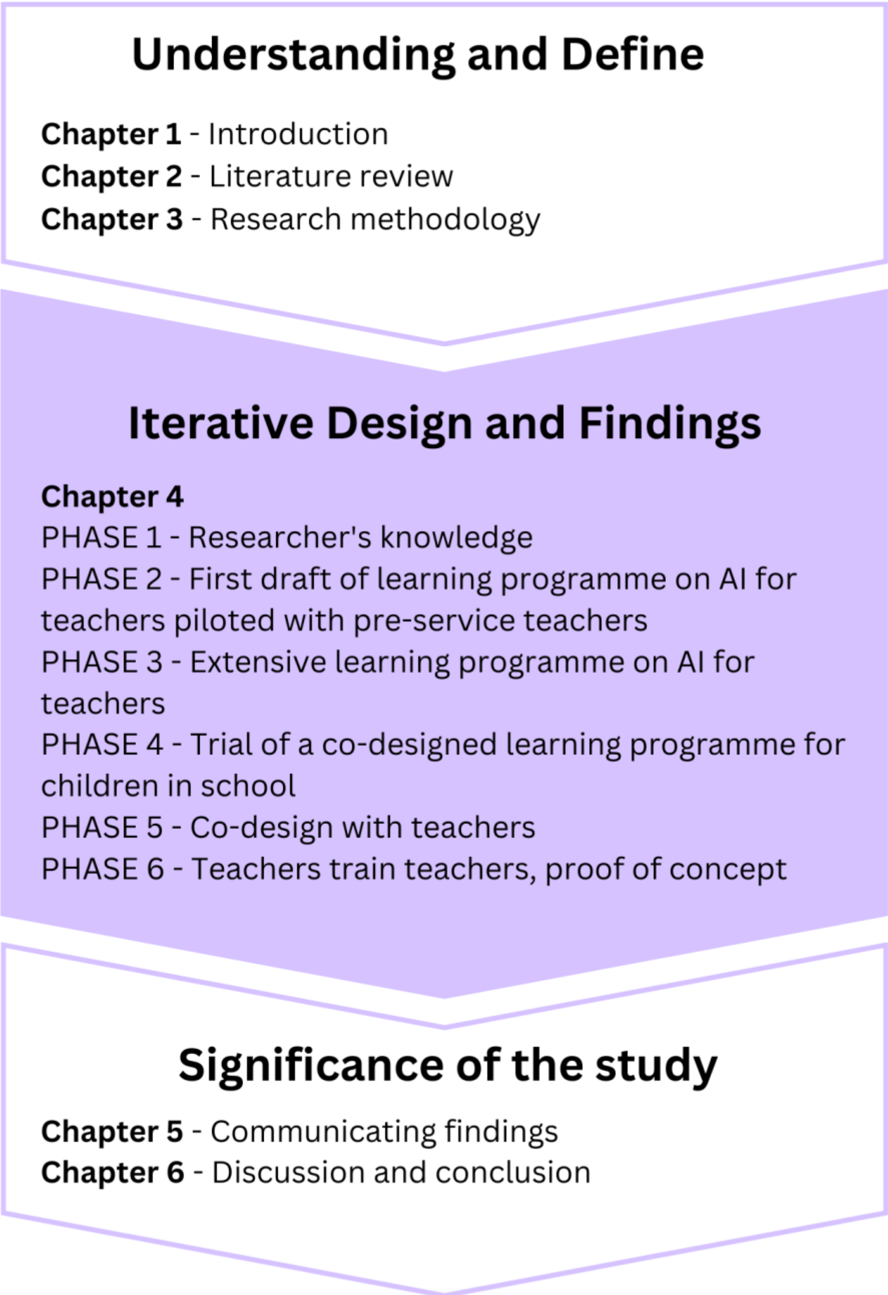


Fig. 4 Thesis structure

The structure of this thesis follows the phases of this design-based research study, which occurred in chronological order, as shown in Fig. 4. **Chapter 1** of this thesis introduces the reader to the research study. **Chapter 2** deepens the context by exploring the literature through an extensive narrative review focused on AI, Data, and Education and a scoping literature designed to examine the overarching research question of this study. **Chapter 3** presents the methodology that underpinned this research study. The data collection instruments, and the data analysis methods are presented in-depth. The researcher's philosophy and ethical considerations are also included in this chapter. **Chapter 4** is focused on the iterative design process of this study. I acknowledged the community of learner perspective and the development of my own knowledge, as a researcher, in phase 1. I then present each of the phases 2 to 6, with findings that informed the following phase. **Chapter 5** presents the practical outcomes of my study and the experience of communicating and sharing the findings of this work. Lastly, a final comprehensive discussion is detailed in **Chapter 6** where findings are critically evaluated against the backdrop of the relevant literature. Chapter 6 concludes this thesis by highlighting the contribution this study has made to the knowledge in this area and makes recommendations for policy, practice, and academia going forward.

2. Literature review

2.1 Literature review design

This study is focused on investigating how to build a bridge between research and the public through teacher collaboration to develop and promote AI literacy and awareness. When I started my Ph.D. in 2019, there was a lack of literature concerning the field I was addressing, i.e., AI education. Moreover, lacking expertise in either domain, an extensive narrative literature review was essential to build my knowledge and understanding of theoretical concepts while assembling a bibliography of sources (Rowley and Slack, 2004). The network of experts I built during the first year of my study as well as the course and conferences I attended on AI in computer science were key in defining initial key ideas. The first presentation of my developing framework was illustrated in a poster (Fig. 7) I designed for the Insight Centre event in 2019.

As I continued to develop my understanding of my research focus it became apparent that there were two main areas that were underpinning my research question: EPE and AI as represented in Fig. 5.

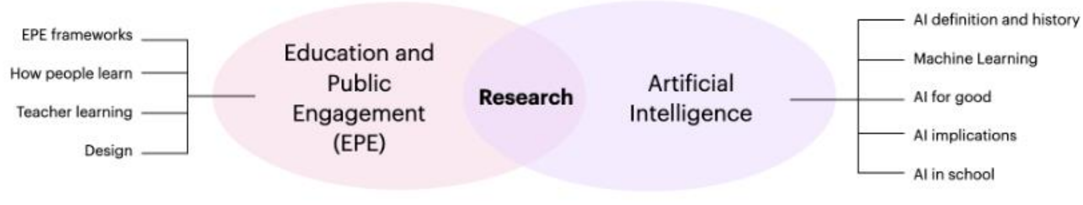


Fig. 5 Literature review framework

In particular, I realised it is paramount to study and understand educational best practices and approaches to design effective learning opportunities which resulted in my focus is on creative learning, constructionism, and design learning principles.

Then the review explores AI from its history to its more recent definition. The main focus is on AI as a subfield of computer science and data. AI and Data have been investigated to highlight their fundamentals, their impact, and their implication on our present lives and for the future. A holistic understanding of EPE related to AI required an interdisciplinary study of concepts e.g., computational thinking, statistics, pedagogy, and ethics.

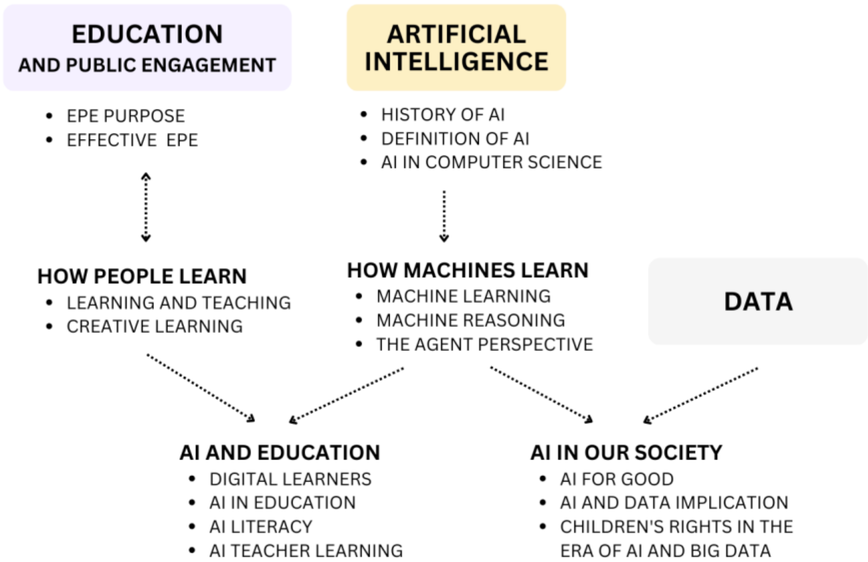


Fig. 6 Final literature review structure

During my research process, I employed a rigorous approach to evaluating information sources, prioritising peer-reviewed papers and books while sparingly referring to web pages that were authored by experts. To access information, I relied on databases i.e., the DCU library, Google Scholar, and scientific journals (e.g., Elsevier, Sage, Institute of Electrical and Electronics Engineers). Finally, I synthesised my findings and insights into a comprehensive literature review, providing a well-founded exploration of AI and Education. A mind map of the concepts covered in the literature review is illustrated in Fig. 6.

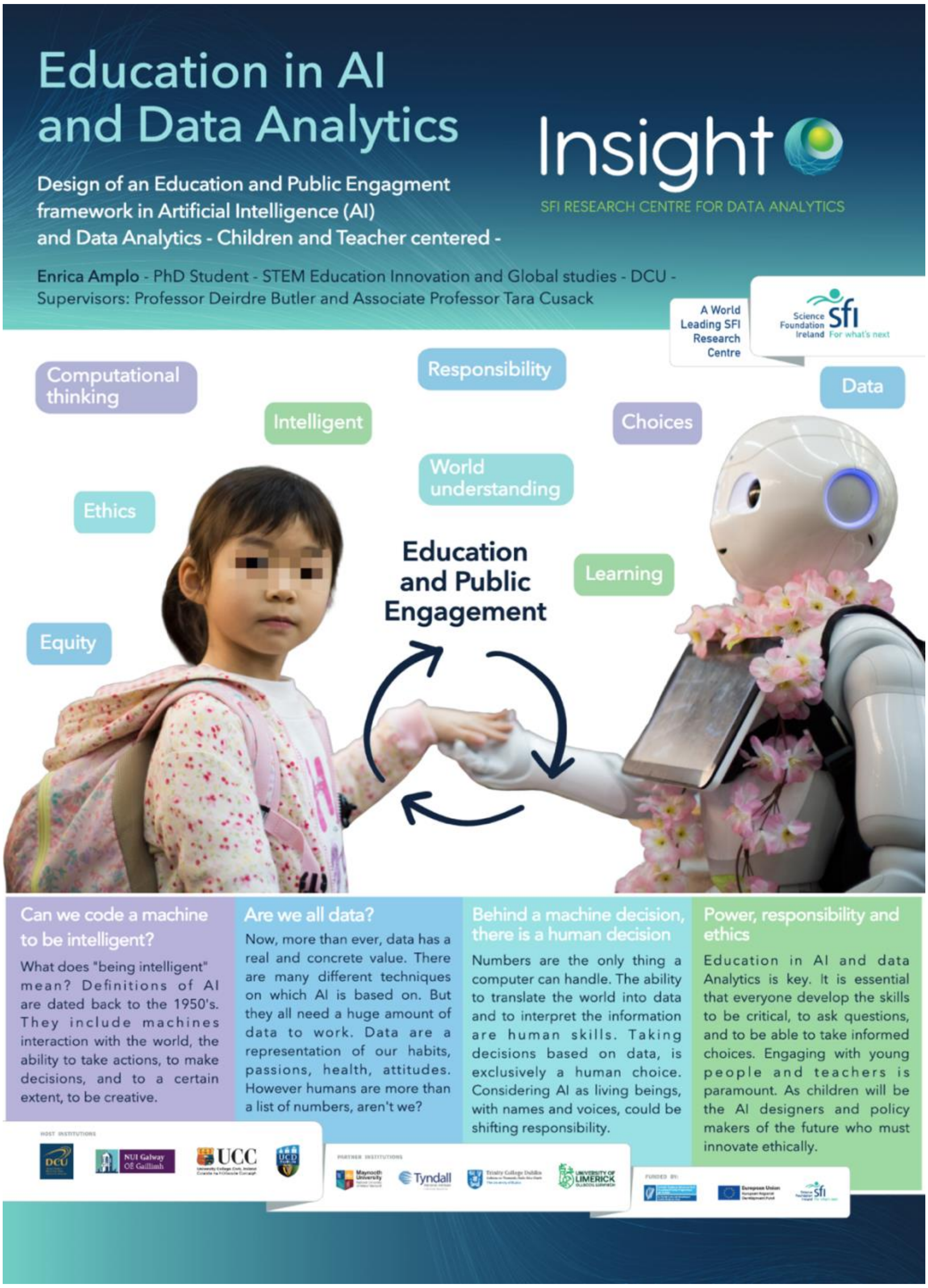


Fig. 7 Poster on EPE on AI research for Launch event of Insight Centre, 2019

Due to the emergent nature of this study topic, it felt appropriate in 2021, to also conduct a more updated scoping literature review. This review aided in identifying the relevant literature to which my research would contribute, contextualising my study within a narrower existing body of knowledge (Rowley and Slack, 2004). The scoping literature review was framed according to the overarching research question of my study. Its design is detailed in Section 2.9.1, database searches and screening are presented in Sections 2.9.2 and 2.9.3 while the results of the scoping literature review are in Section 2.9.4.

2.2 Artificial Intelligence

AI is a word with a multitude of meanings and perspectives. Therefore, it is not trivial topic to be investigated. There are several routes that can be followed to explore AI definition and its history.

"The first is the route of imagination, **what might be**. Next is the route of **philosophical inquiry**, which provides the bridge between imagination and what is. The third, of course, is **what is**: in this case, AI as it has been realised since the **development of the digital computer**." (McCorduck, 1991, p.4). This means, as illustrated in Fig. 8, that AI is a technology that has been studied and developed in computer science with numerous applications in different fields. The perception we have of AI is strongly influenced by our imagination and the narratives around it. Finally, it challenges us on moral and philosophical dilemmas (McCorduck, 1991).

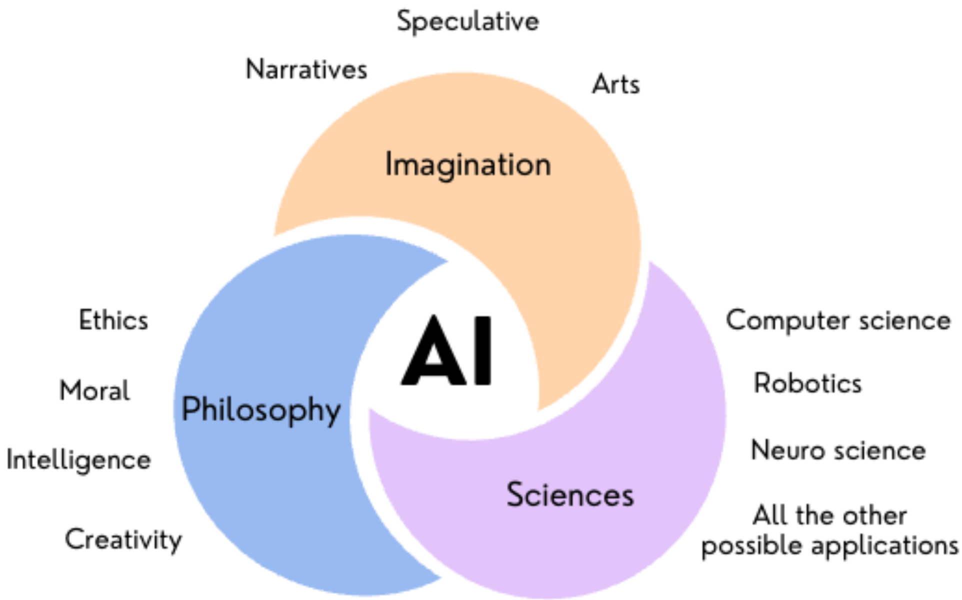


Fig. 8 AI conceptual framework

Going back in the literature it is easy to find many works on futuristic machines, *beings* able to assist humans, and robots with the desire of becoming human themselves (Schneider, 2016). AI stems from the human desire "to reproduce the quintessence of our humanity, our faculty for reason" (McCorduck, 1991). The collective imaginary is full of suggestions about super intelligent machines or anthropomorphic robots (humanoid) capable of everything and often more than a human can do. Examples can be found in English literature with Mary Shelly "Frankenstein" (1823) and in Italian literature with "Le avventure di Pinocchio" (Collodi, 1883). More recent examples include Isaac Asimov's stories written from 1940 to '80s, such as "I, robot" or "The Bicentennial Man" or "The wild robot" by Peter Brown (2016).

AI also features in a lot of movies from the western world depicted as embodied in robots. Robots are often servants and have human stereotypical characteristics such as big muscles if they are "men" (The Royal Society, 2018), or described with a sexual appeal if they are “female” (Cave, Dihal and Dillon, 2020). There are also narratives where AI is not embodied but distributed in society and in charge of its governance (The Royal Society, 2018). AI narratives are also evident in the Eastern world, and it is extremely interesting to see how culture creates narratives about AI differently. For example, in comics, anime, and manga from Japan, where AI was embodied in ロボット (‘robotto’) robots as companions rather than servants (The Royal Society, 2018).

AI narratives can be a powerful tool to communicate, engage and inspire people and new technologies. However, the same narratives can lead to false myths and misinformed preconceptions (The Royal Society, 2018). Aware of the risk, it is paramount that the general public is informed and that citizens are given the tools to think critically and ask questions about AI. On the other hand, imagination and fiction can create futuristic speculative scenarios. Such **speculative design** can encourage people to ask questions, to reflect on and interrogate key ideas and dilemmas, to start to ignite discussions (Dunne and Raby, 2013). For the scope of this research the route highlighted in the following chapters will be the one more related to the actual development of AI as an evolution of digital computing and robotics and its impact and implication for our society.

2.2.1 History and people of AI

The field of AI is so broad that every aspect of it such as self-driving cars, biomedical applications, DNA study, robotic agents, have their own timelines. However, there are key people and milestones in AI that laid the basis and foundations which defined its history. AI ideas are dated back to 1930-50, and only recently there has been an increased interest in AI worldwide, so much so that it is applied in several fields and is taught in universities. The *Boom* of the 2000's, compared to AI origins, is particularly related to the fact that researchers and companies now have huge amounts of data to work on, and powerful computers to compute all this huge amount of data (Russell and Norvig, 2010).

The following timeline (Fig. 9) is based on "The History of AI" and "The foundations of AI" from the book *"Artificial Intelligence a Modern Approach, Third Edition"* by Norvig and Russell, 2010 and "The history of AI" from the book *"Introduction to Artificial Intelligence"* by Ertel, 2017.

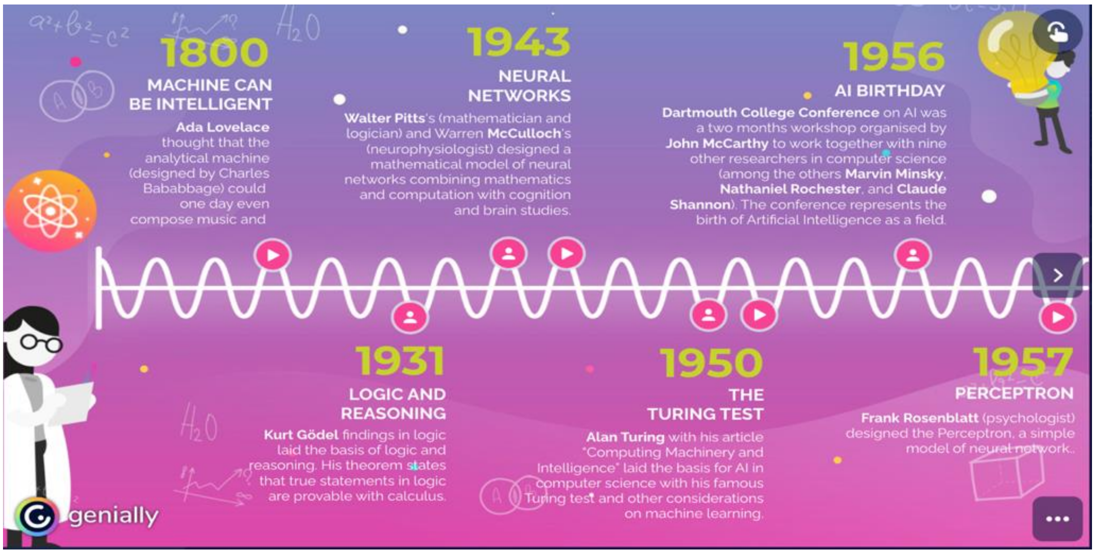


Fig. 9 Preview of the interactive AI timeline (https://teachingai.eu/ai/)

1815-1852 Ada Lovelace is known as the first programmer of history. In the 19th century she worked with Charles Babbage who designed the analytical machine (1837). Ada Lovelace believed the analytical machine could one day potentially be able to compose music.

1931 - Kurt Gödel (mathematician, logician, philosopher)
Kurt Gödel's findings in logic laid the basis of logic and reasoning. His theorem states that true statements in logic are provable with calculus.

1943 - Walter Pitts (mathematician and logician) and **Warren McCulloch** (neurophysiologist). Their work defined the start of neural networks. They in fact designed a mathematical model of neural networks combining mathematics and computation with cognition and brain studies.

1950 - Alan Turing mathematician and computer scientist. With his article "Computing Machinery and Intelligence" laid the basis for AI in computer science with his famous Turing test and other considerations on machine learning.

1956 - the birth of AI - Dartmouth College Conference on AI was a two-month workshop organised by John McCarthy (Princeton University) to work together with nine other researchers in computer science. Among others Marvin Minsky, Nathaniel Rochester, and Claude Shannon participated. The conference represents the birth of AI as a field. Subsequent studies in the years that followed were led by these researchers and their colleagues with students from MIT, Stanford, CMU and IBM.

1957 - Frank Rosenblatt (psychologist) designed the **Perceptron,** a simple model of neural network. Although this model could learn everything that can be represented.

In **1969 - Marvin Minsky and Seymour Papert** with their book "*Perceptrons*" highlighted the limit of the perceptron and its lack of representation in that, with a very simple neural network it is only possible to represent linear functions. In the same year **Bryson and Ho** invented the back-propagation algorithm which is now used in neural networks and supervised learning.

At the end of 1980's there were a number of years called **AI winter** where there was a lack of interest in AI because companies could not design what they promised.

1985 and 1988 Peter Cheeseman and **Judea Pearl** with their works respectively *"In Defense of Probability"* and *"Probabilistic Reasoning in Intelligent Systems"* respectively brought **Baysian probability** into AI. Bayesian networks approach allowed for learning from experience. In the same years Erik Horwitz (from Microsoft) and David Heckerman highlighted the concept of designing an expert agent based on laws rather than on imitating human thoughts.

1997 - Gary Kasparov the chess world champion lost against IBM computer Deep Blue designed to play **chess**.

2001 - The increasing availability of **data** once again generated a lot of interest in AI.

2009 - The first self-driving car by Google operated on the street in California.

2011 - IBM Watson and Siri voice assistant were on the market.

2015 - An open letter to ban the development and use of autonomous weapons was signed by many people, and among the signatories were, Stephen Hawking and Elon Musk.

The timeline describes an overview to date of AI, but history is still in the making. The field nowadays is dominated by researchers and developers both in universities and in a range of companies who have an interest in the field of logistics, robotics, translations, spam fighting, game playing, speech recognition vehicles and more (Norvig and Russell, 2010) (e.g., Yann André LeCun "father" of Convolutional neural networks among many others). Together with personalities involved in outreach and public engagement activities on different media on AI such as Cathy O'Neil (mathematician and blog author), Susan Schneider (researcher and philosopher), and Pamela McCorduck (author of books on the history of AI and technology).

Many are influential people in the field, who could with their contributions, change and shape the future directions of AI with a strong impact on our society. For this reason, it should be a moral imperative for researchers from universities as well as companies to enable society to develop its voice. It should be a priority to give society the tools and competencies to ask questions and take informed actions in the era of AI and big data. At the same time, it should be paramount to involve teachers and children to give them the possibility to be responsible and aware future makers.

2.2.2 Definition of AI

There is not just one definition of AI and it is still evolving. Defining what AI means has been challenging experts for decades, both from a computer science, and philosophical perspective. There is a main distinction that needs to be highlighted, and it is between general AI and narrow AI. **General AI** is a concept nearer to the science fiction and imaginary idea of AI. A machine (computer, robot, entity) that is intelligent, able to perform and make decisions and take actions in every possible scenario and aspect of the world (Searle, 1980). Experts also talk about **super** Intelligence and **singularity**. "Singularity" is a term from astrophysics usually used to describe "black holes". Referring to AI is the idea that super machine intelligence will exceed human intelligence in the near future (Kurzweil, 2003). Only time will tell if a super intelligent machine (general AI) could one day exist, and if this is the case, what the relationship between this super intelligence and human beings would be. As suggested by Russell, 2019, if machines surpass human intelligence, how do we make sure we will be able to control them forever? Up to now the standard way to work with AI is task-oriented, as better explained in the following paragraph. He suggested finding new design ways to lead to AI that will learn from humans, while respecting human decisions (Russell, 2019).

The type of AI commonly studied and developed nowadays is the kind of AI called **narrow**. Algorithms developed by researchers that can perform **a specific task**, for example, to recognise a cat in a picture or detect sentiments from a text. This task-oriented approach to define AI relies on a standard model which researchers use to make the machine act humanely (Norvig and Russell, 2010). In 1950 Alan Turing was the first who tried to design a test to prove the intelligence of a machine. Scientifically proving the intelligence of a machine, he defined **the "intelligence" of the machine** as the ability to perform **a task**. Consequently, if the machine can perform the task, then it means the machine is intelligent (Turing, 1950). Turing, instead of asking himself “Can machines think?”, that would require further investigation of the meaning of the worlds “machine” and “think”, he described a more specific and narrower test called “**the Imitation game**”. In the test there is a person in a room and in the other room two other participants, one human and a robot. The first person has to ask questions by typing them and has to work out which one of the two other participants is a person or a robot. Many programmers coded software capable of passing the Turing test. Among the most famous ones are three chatbots called Eliza, Parry, and Eugene (Norvig and Russell, 2010). However, most of them were based on the concept of “fooling” the human involved rather than on building a program that really understands and speaks as a human. When a program can act as if it is intelligent or as if it can think, it is called a **weak AI** hypothesis. While a **strong AI** hypothesis is when a program or a machine is “actually” able to think or understand and not just simulate it. Turing himself, in his article presented objections and consideration about his test, indicating that he was well aware of the complexity of intelligence. However, his intuitions laid the bases of computer science and AI (Norvig and Russell, 2010).

To mark the difference between weak and strong AI, another test was developed by Searle in 1980, called “*The chinese room argument*”. In this test Searle describes how it is possible both for a human and a software, to write in Chinese without knowing the language. It is possible simply by following instructions on what symbols to write. As a consequence, he argued that knowing the instructions does not actually mean knowing the language.

In Ada Lovelace's work (1815-1852) there were already considerations regarding the possibility of having powerful machines. She believed, in fact, that the Babbage machine could one day perform calculus, scientific reasoning, and even compose music (Boden, 2016). In 2001 a group of researchers created a new test called "The Ada Lovelace Test" with which they argue that a machine can be considered intelligent if it is able to generate an original object that the creator of the machine cannot expect (Bringsjord, Bello and Ferrucci, 2001). They defined a machine to be intelligent if it can be creative. However, again this is a matter of definition, as are we sure that novelty can be considered as creativity? Creativity is not only about new ideas (novelty), but these new ideas also have to be valuable (meaningful, useful) to be considered creative. AI can perform really well in generating new ideas, the tricky part for machines is to evaluate those ideas (Boden, 1998).

The claim that, "Every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to **simulate** it." (McCarthy, 2007) is inspiring the research. Not only in coding and computational thinking, but also in the understanding of human and animal intelligence (Boden, 2012). Consequently, there is a virtuous cycle in which definitions of AI challenge the research, and the research progress on how to make the machine "be intelligent" forces the definition of Artificial Intelligent to change. From machines that can emulate humans to machines that can be creative, to ***"systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals"*** (High-Level Independent Group on Artificial

Intelligence, 2019)**,** definitions of AI are numerous and still evolving. A more recent definition from Council of the European Union Council highlights the need to provide criteria to discern AI-powered systems from systems which are not. The definition was narrowed to:

> ***"artificial intelligence system' (AI system) means a system that is designed to operate with elements of autonomy and that, based on machine and/or human-provided data and inputs, infers how to achieve a given set of objectives using machine learning and/or logic- and knowledge based approaches, and produces system-generated outputs such as content (generative AI systems), predictions, recommendations or decisions, influencing the environments with which the AI system interacts"*** (European Union, 2022)**.**

It is still quite complicated dividing the imaginary/narrative/marketing approach from the real state of the art of AI, especially in terms of general definitions. This happens because the AI field is full of words like "intelligence", "learning", "creativity", "thinking" that are the so-called "suitcase words" i.e., words that have different meanings for different fields and different meanings for people with different backgrounds (Minsky, 2007). For instance, there are many assumptions in defining what "being intelligent" means. As an example, AI can be defined as the study of "How to make a machine use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves." (McCarthy *et al.*, 1955) or how to make computers do things at which, at the moment, people are better (Rich, 1983), but what about animal intelligence? (Hassabis *et al.*, 2017).

2.2.3 AI in computer science

AI as a science is interdisciplinary. It has been influenced by statistics, logic, mathematics but also operations research, image processing, linguistics, philosophy, neurobiology (Ertel, 2017). Since the late 1980’s AI research in computer science has been predominantly focused on solving real-world problem tasks, using the scientific method (Norvig and Russell, 2010). Using the scientific approach allows them to study replicable experiments, to share data and code, and to be able to use quantitative methods to analyse outcomes and hypotheses (Cohen, 1995).

There are several techniques, algorithms, and different approaches associated with the umbrella term of AI in computer science. But **all of them are based on algorithms (formulas) and data. These algorithms can predict outcomes with a degree of accuracy, based on data analysed and thanks to probability and statistics** (Burkov, 2018). Numerous are the areas of research in AI and its applications. Current AI research in computer science includes pure algorithm study to create new layers for neural networks, and new machine learning models (computational thinking, mathematics and statistics) even though research suggests that for many problems now the issue is more related to data than mathematical formulas. Therefore, AI research is primarily on understanding how to use models with different types of data (images, text, speech, numbers) to solve real world problems (in health, finance, marketing, law...) (Norvig and Russell, 2010).

Machine learning is a central subfield of AI in computer science. Machine learning is inspired by the human ability to learn, to behave and adapt in certain environments and contexts (Ertel, 2017). Around the 1970's experts started to explore concepts such as “knowledge” and “learning” for machines. One of the first famous attempts was the *Perceptron* developed by Frank Rosenblatt

(American psychologist, 1928-1971). It consisted of an IBM machine that emulated biological learning processes (Emlen, Howland and O'Brien, 1971). However, only around the 1990's machine learning became a stand-alone subject in computer science (Kubat, 2017).

There are currently many machine learning tools, libraries and frameworks available. Developers select the right tools and make modifications and adaptations for specific applications (Ertel, 2017). There are also services that perform specific tasks very well, such as customer service chatbots, object detection, face recognition with user friendly interfaces. Microsoft Azure and Amazon AWS are two examples with their off the shelf applications (face recognition, bot, or other services which explicitly states "no machine learning knowledge required"). These applications have been more and more commonly used and sold to customers who can directly use them for their work as a "**black box**". It means they can use them with a very minimum knowledge in terms of how they are created and how they work.

Beside Machine Learning, there is another field of AI in computer science called **Machine Reasoning**. While machine learning models are based on statistics and probability concepts that allow the model to make predictions on a very specific task, based on data analysis; machine reasoning algorithms generate outputs using information stored and logic techniques, like deduction and induction, to draw conclusions (Norvig and Russell, 2010). This approach is linked to the so-called *knowledge-based agents* or systems. It builds on the concept that human intelligence relies on knowledge but also on processes of reasoning and not only reflex mechanisms (Norvig and Russell, 2010).

2.3 How machines learn

2.3.1 Machine learning and neural networks

Machine Learning is currently used in many different fields such as computer vision and image recognition, text and speech analysis and several other applications. It is essential to highlight that it is not “actual learning” (Burkov, 2018). “Learning” is another *suitcase-word.* This word in fact is packed with many different meanings (Minsky, 2007). The name Machine Learning was invented by Arthur Samuel at IBM in 1959, for marketing purposes to attract both clients and employees (Burkov, 2018). As represented in Fig. 10, *“Machine learning can also be defined as the process of solving a practical problem by gathering a dataset, and algorithmically building a statistical model based on that dataset. That statistical model is assumed to be used somehow to solve the practical problem”* (Burkov, 2018, p.3).

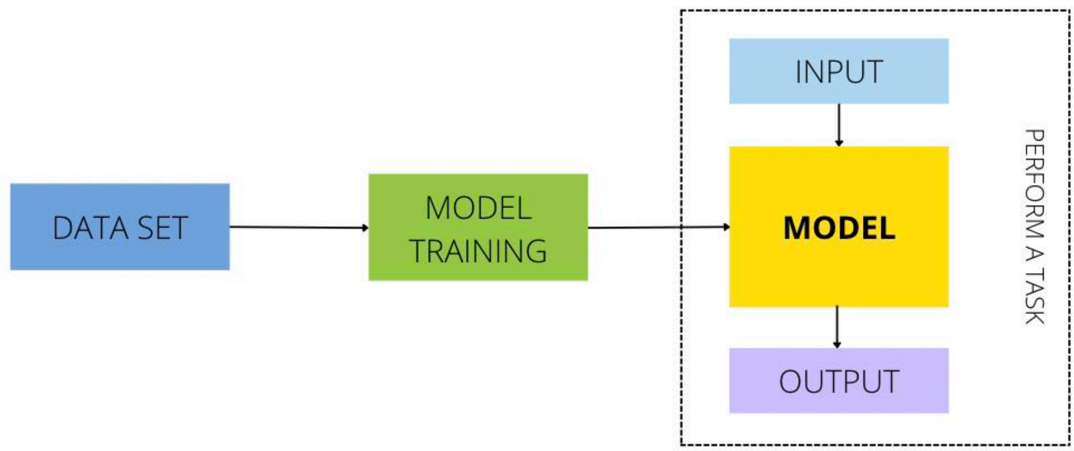


Fig. 10 Machine Learning workflow (Burkov, 2018)

Machine learning workflow starts with *data collection*. Gathering data can be done using sensors for example or collecting information from social media or health data from a wearable. There are also open data sets available that can be used by researchers and developers to train machine learning models, examples can be ESA dataset from satellite images or Covid19 data from Google. Once that data is available, they are prepared and manipulated in order to be handled by a model and to obtain a certain desired result, *data preparation*. Then there is the training of the model (*model development*), its *evaluation*, *post processing* and *deployment* to prepare the model in order to be used with new data by users (Suresh and Guttag, 2019).

Despite how AI for good applications are sometimes advertised, it is important to understand where the technology stands (Gartner, 2022). In a complex project such preventing fires, AI is just one of the actors and AI techniques are currently used to solve a narrow and specific task. So, it is not AI that prevents fires but a teamwork of several tasks, techniques, technologies, and skills i.e., software development, web design, robotics, data analytics, geography, geo-computation, fire teams. In a complex situation an AI technique such as machine learning can be used for a narrow specific task, in this example machine learning is used to analyse images of the ground (taken with a camera on a drone or robot) and makes predictions on an image representing dry or not bushes and campfires that can potentially be the starting point for a fire. Machine learning techniques can be also used to enable a drone to move autonomously in the environment, while for example sending an alarm to the fire station is coding and telecommunication, the software used by the fire is based on coding and can have AI functions such as a chatbot that can give fire teams advice (Yfantis and Harris, 2017).

There are several approaches to machine learning: supervised, unsupervised, reinforcement learning… Despite the differences, they all rely on training a statistical/probabilistic model through the use of data (TRAINING). Trained models can then perform a task, by providing answers (prediction) on data never seen before (INFERENCE) as depicted in the picture Fig. 10, (Norvig and Russell, 2010).

In **Supervised learning,** the model is trained using a labelled dataset. The trained model takes an input and give, as output, the label of the input with a certain degree of confidence (Burkov, 2018). A **dataset** consists of a group of examples (*instances*) with a characteristic in common (*attribute*) (Hand, 2007) e.g., 100 pictures of cats or a number of spam emails. **Labelled data** are data with a defined attribute. For example, this image has a "Cat", this email is a "spam image". On the other hand, in **unsupervised learning,** the dataset used is not labelled. Unsupervised learning is commonly used for clustering. Its task is to assign a label to examples by elaborating an unlabelled dataset (Burkov, 2018). **Reinforcement learning** is commonly used for tasks that require long term actions and strategy (sequential decisions) like playing chess. The machine perceives a feature vector from the environment per each state, and then acts. Different actions have different rewards and lead to the next state. The objective is to "learn" a policy, that is again a mathematical function similar to supervised learning. The action is optimal if it maximises the expected average reward. **Semi-supervised** learning is a learning approach where the input data set has both unlabelled and labelled data. Usually, the unlabelled are many more then the labelled ones (Burkov, 2018). It relies on the fact that with the information from the labelled data it is possible to improve the model trained with the unlabelled one (unsupervised) (Galeone, 2019). A simplified illustration of the three techniques of machine learning is shown in Fig. 11.

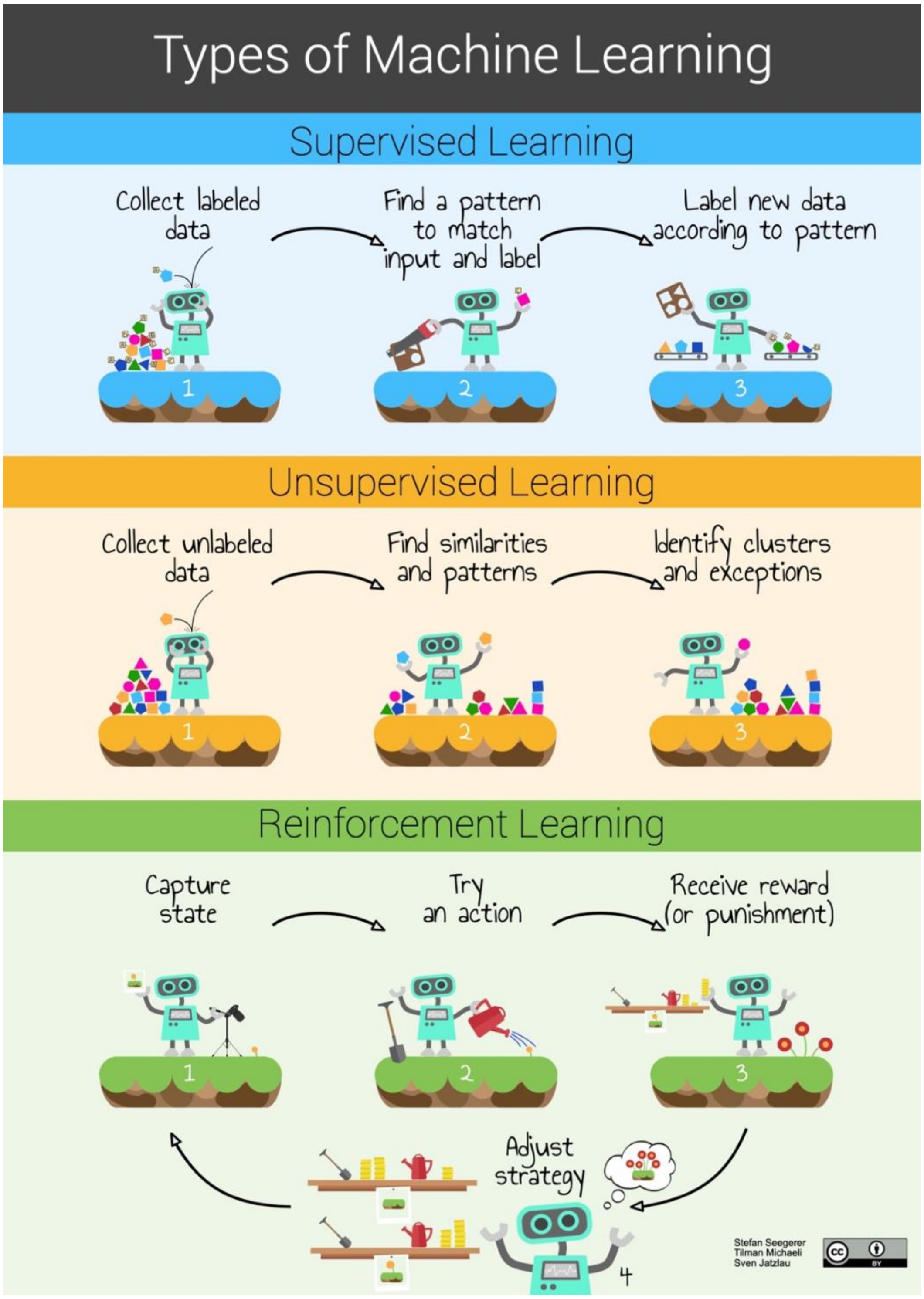


Fig. 11 Illustration of machine learning types (Seegerer, Michaeli and Romeike, 2020)

Most of the learning algorithms which Machine Learning is based on are called **shallow**. It means that they extract parameters from the dataset directly. The exceptions are **Neural Networks** organised in single and multiple layers (**deep learning**) (Burkov, 2018). Neural networks are related to the concept of human neurons getting multiple inputs and elaborating them to provide an output (Perceptron, as shown in Fig. 12).

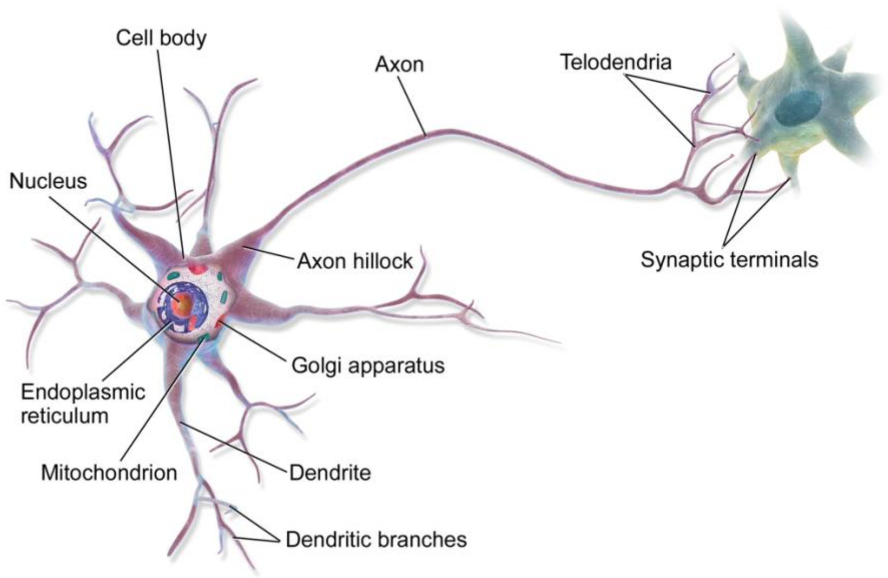


Fig. 12 Neuron anatomy by Bruce Blaus (via Wikipedia)

In the case of the artificial neural network the elaboration is done with a linear function, as illustrated in Fig. 13 (Aggarwal, 2018).

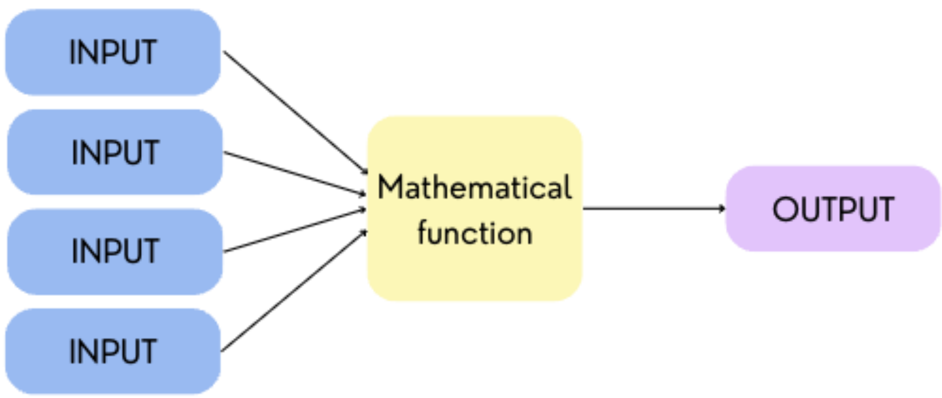


Fig. 13 Simplified perceptron scheme (Aggarwal, 2018)

Deep learning is a subfield of machine learning where researchers use multilayer **neural networks**. In multilayer neural networks there are different computational layers. There is an input layer and an output layer. The layers in between can vary per number and type. These layers in between are called *hidden layers*. Hidden layers are so called because the computation in those steps is too abstract to be visualised (Aggarwal, 2018). There are many different types of neural networks such as convolutional, recurrent, and feed-forward (Burkov, 2018).

2.3.2 Supervised learning

This section will introduce the basics of machine learning using an in-depth description of **supervised learning technique**. **Supervised learning** is a machine learning technique which relies on learning from examples, where the examples are labelled data (Norvig and Russell, 2010). The task of a model, trained using supervised learning, can vary. If the attribute of the labelled data is categorical, “Cat”, “People”, “Cars”, then the task of the model is to **classify**. While, when the attributes are numerical, “price of a property”, “humidity in forecast”, the task of the model is called **regression** (Hand, 2007). Supervised learning workflow is composed of three main steps, gathering **data**, **training and validating** the model, and **testing** the model (Galeone, 2019). The **dataset** is probably the most critical part of the entire workflow of Machine Learning and its *quality* has a deep impact on the final model performances (Galeone, 2019). The entire data set gathered is divided into three samples. One is called the **Training set**, and it is used to train the model, a second one is called the **Validation set** and it is used to measure the performances of the trained model and also to improve it. The **Test set** is the third batch, and it is used to perform the final evaluation of the trained model (Galeone, 2019). Once the data is available (pictures in these examples) the next task is to understand how to translate it into something that is manageable for a computer (Burkov, 2018). For example, as shown in Fig. 14 a picture of a cat for a computer is a matrix of numbers. Each pixel of the image is in fact described by a number or an array of numbers (they can represent colour, temperature, depth etc.). In the case of this image (Fig. 14), the image is represented as a matrix of 248 X 400 pixels, where each pixel has 3 numbers to describe its colour (RGB, Red, Green, Blue standard) (Stanford University, 2020).

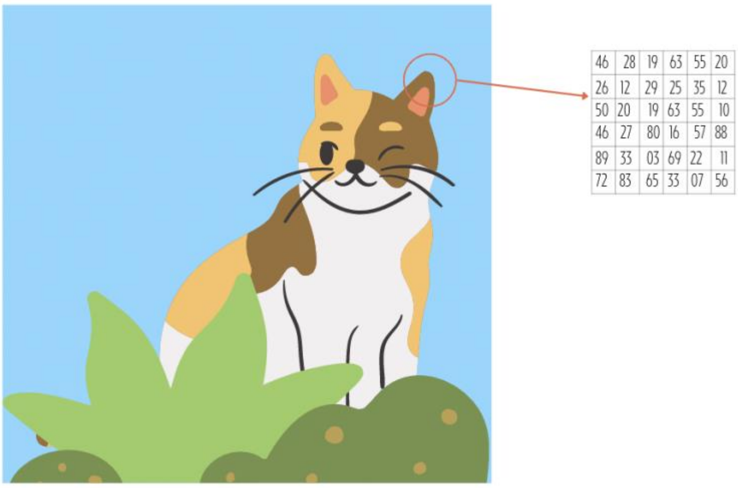


Fig. 14 How computers "see" images, numbers are just an example, they usually indicate the colour and the position of each pixel, from the online resources by CS231n course (Stanford University, 2020)

All the data available needs to be labelled (since this example uses supervised learning) according to **classes**. Once data are labelled the next phase is **training and validation**. During the training, the algorithm uses the data to create a model with specific characteristics that aim to solve the specific task considered. Using mathematical annotation, an example from the dataset $\mathbf{e}_i$ is entirely described by a feature vector of **N** attributes, $e_i = (x_0, x_1, \ldots, x_{n-1})$, (Galeone, 2019). The number of features taken into account can have an impact on the model's performances. Sometimes, taking into account only one feature is not enough. Imagine having a model that classifies cats and dogs, having one feature as for example "the average of red colour in the image" could be not enough to accomplish the task, while adding a second feature and a third one, as for example "average blue" and "average green" could improve the performance of the model, and better enable it to classify dogs and cats, (Stanford University, 2020).

Each model is described by a different function. These models are defined as **parametric models**. For example, the function called "linear regression" is represented by the equation y=mx+b. It is a linear function that describes the relationship between two variables x and y. In supervised learning both x (data from the dataset) and its y (class, label) are known. Training of the model consists of the finding of the **parameters**, in this particular function m and b, so that giving x (data of the dataset) as input to the model, the model can give as output the correct y (label, class) (Galeone, 2019).

In machine learning, there are several learning algorithms that can find and adjust the parameters to create the model able to perform a task. To do that when the dataset is ready, the **learning algorithm** takes all the feature vectors. It theoretically places all the vectors in a multidimensional space of N dimensions (*hyper-plane*) and draws a hyper-line. This hyper-line sets the boundaries between the classes *(decision boundary)*. The distance between the two classes is called *margin*. The margin is an indicator of the generalisation of the model

(Burkov, 2018). That means how well the model will be able to classify a completely new example (not from the dataset used at the beginning).

To find the largest margin the algorithm solves an optimisation problem. The solution of this problem is the model and the whole process is called training. The decision boundary can have different shapes and it determines the **accuracy** of the model (Burkov, 2018). The accuracy is the ratio of the number of correct predictions made, to the number of all predictions made. For instance, 100% is the best accuracy possible (usually indicated in decimals 0.99, 0.95) (Galeone, 2019). The higher the accuracy, the better the model can perform the task (Burkov, 2018).

The process described in which the learning algorithm computes data to adjust the parameters of the model to perform the desired task, is an iterative process. It uses both the training dataset and the validation dataset. The validation dataset is key in the hyperparameter tuning (Galeone, 2019). Each iteration of the training process is called **epoch** and the accuracy can vary during different epochs (Burkov, 2018).

In models with many parameters, sometimes too many iterations can lead to undesired results. This phenomenon is called **overfitting**, it means the model is good only in predicting the label of the data used for the training. The opposite phenomenon is called **underfitting**, while the optimum scenario is in between the two and it happens when the model can be considered **robust** (Galeone, 2019). The final evaluation of the model performance is then run with the test data sample at the very end of the whole workflow (Galeone, 2019). There is also another parameter with which it is possible to define the performance of the model. Besides the accuracy there is also the **loss function**. While the accuracy, as formally described previously, represents “the ability to perform the task” (“how many predictions are right”), the loss indicates “how well the task is performed” (what was the confidence for each right prediction) (Igual and Seguì, 2019). The function indicates the difference between the predictions and the truth. In the best case possible the loss would be zero, otherwise it is greater than zero (Galeone, 2019).

Every algorithm and formula used in machine learning should be coded in order to be computed. Statistical algorithms have been currently coded in Python a program language, most used among machine learning engineers (Burkov, 2018). Machine learning is used and studied by different people at different levels. Usually, only researchers of machine learning look at models at the level of formulas and try to improve the models and create and study new ones. Usually, engineers and researchers who use machine learning as a tool, do not go into this depth but they use already coded algorithms. To make it clearer with an analogy, think about architects and mathematics. Every architect **uses** formulas to calculate parameters they need for their work, but only mathematicians strive to improve the formulas or to find new and better ones.

To summarise the machine learning/deep learning process as a workflow, at a higher level a hands-on example was run using the Teachable Machine tool by Google.

The main steps in machine learning are:

1) Data collection
2) Data labelling
3) Training
4) Test on the working trained model

In this example we would like to train a model to be able to classify **markers**. That means the capability of making predictions on an image, telling if the image represents a marker or not. If the model is correct, it will then be able to classify as a marker, not just exactly the ones used to train it, but also slightly different new ones e.g., never computed from the model before. To train the model of this example, it has used a variety of markers, but not a particular type of markers called “sharpies”. It is expected that at the end of the training, the model will be able to classify a “sharpie” as a marker as well.

The dataset is composed of a set of images of markers (same marker in different positions, different types of markers, and other stationary (pencil, pen...), see some examples in Fig. 15. But also, data of a different class, *not_marker,* with pencils and pens, as shown in Fig. 16.

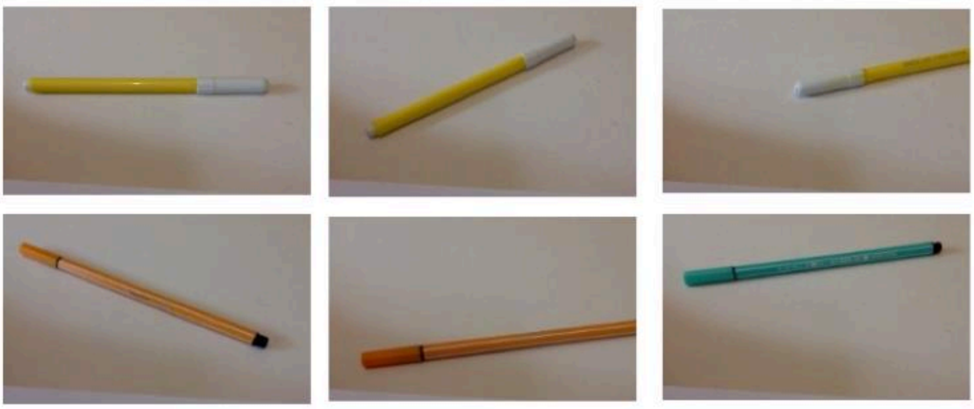


Fig. 15 Example of data from class “Markers”

Fig. 16 Example of data from class “Not_Markers”

Once the dataset is ready, the model can be trained, workflow represented in Fig. 17, where the dataset is highlighted in pink. Once the training process is completed with a satisfactory performance, the model is ready. It is possible to test the working model with data never used before. The model with a certain degree of confidence will then give a prediction on the new data. Model confidence is called accuracy. The better the accuracy, the closer to 1 or 100%, the better the model will be at its task. It is important to highlight that a model can be 100% "sure" of the wrong answer. Model performances can be only partially controlled managing some parameters of the training process (i.e., epochs) or improving the dataset.

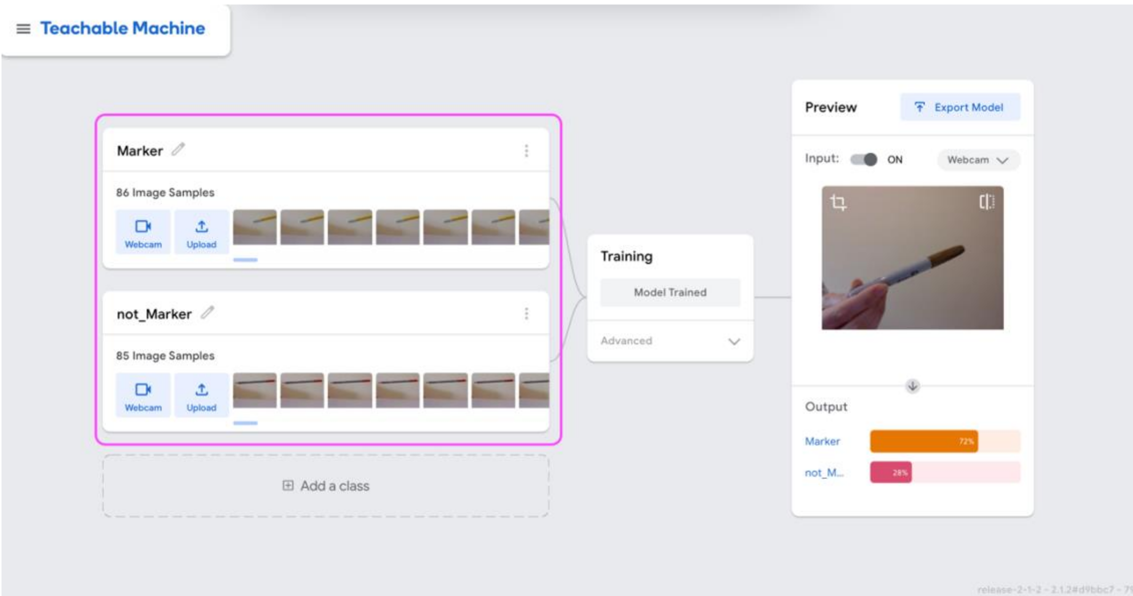


Fig. 17 Teachable Machine example of training a model to classify markers. The model is tested with a maker never seen before by the model. The model output in relation to the input given (gold marker in front of the camera) is "Marker" with a confidence of 72%.

As seen throughout these examples, machine learning is task oriented. Models are trained in order to perform very specific tasks such as recognising cat images or **markers in a picture**. But researchers claim that human intelligence is not only related to knowledge but also to our ability to reason and perform tasks to solve problems (Russell and Norvig, 2010). Following this assumption there is another field of AI in computer science called **machine reasoning**.

2.3.3 Machine reasoning

A definition for machine reasoning by Bottou, 2014 is “algebraically manipulating previously acquired knowledge in order to answer a new question”. Machine reasoning is another field of research in AI and Computer science, and while machine learning is, up to now, task-oriented, machine reasoning tries to build “all-purpose” algorithms (Bottou, 2014). In machine learning and deep learning, the trained model can give as an output a number or a category (classification or regression). Machine reasoning algorithms, instead, can find relationships rather than attributes. Machine learning is based on statistical models while machine reasoning is mainly based on logics (Russell and Norvig, 2010).

One application of machine reasoning is to make results from machine learning and neural networks clearer (Keane and Kenny, 2019). This is possible because machine reasoning uses symbolic models, based on facts, knowledge and logic (Marin, Marios and Saurabh, 2019). These models are very difficult to build but thanks to their declarative form they can be used in different contexts and by their nature, are more understandable by humans (Marin, Marios, and Saurabh, 2019). Therefore, the current direction of research in this area is towards a combination of both machine reasoning and machine learning working together completing each other (Bottou, 2014). The importance of finding methods to make AI more understandable is known as Explainable AI, XAI, trustworthy AI (Keane and Kenny, 2019).

Some interesting logic key ideas are used in Machine reasoning (Bottou, 2014) to emulate the human "thinking process". Logic can in fact be defined as "the study of thinking" and it is based on concepts, judgments, and inferences (Pfänder, 2009). Concepts are "the elements of thought" (Pfänder, 2009, pp.18-19). Judgments are a kind of thought that make assertions. Inferences are interconnections among judgments or other thoughts and is the process with which it is possible to derive a judgement from others (Pfänder, 2009). The philosopher Aristotle (384–322 B.C.E.) could be called the father of logical inference. In logic it is possible to define **deductive** reasoning and **inductive** reasoning. Deductive reasoning tries to find rules from a more general and vast observation, while inductive reasoning starts from a particular observation and tries to generalise (Dyanni, 2016). Inductive reasoning is about inferences and probability and the result from a trained model in machine learning is called both *inference* and *prediction* because it is based on the concept of inductive statistics (Heumann and Schomaker Shalabh, 2016). Machine reasoning goes beyond statistical models used in machine learning, working on more complex systems called *reasoning systems* (Bottou, 2014). "Just like statistical models, reasoning systems vary in expressive power, in predictive abilities, and in computational requirements" (Bottou, 2014). Examples of reasoning systems are first-order logic reasoning, causal reasoning, spatial reasoning, knowledge graph, and many others. Approaching AI from the concept that **humans do not act in the world with only mechanical reflexes but also use reasoning in order to act** is driving research on the development of the so-called **knowledge-based**

agents. The agent perspective in AI in computer science and robotics is better described in section 2.2.4.

An example of a logic model is the decision tree (Touretzky *et al.*, 2019). Decision trees can be used to classify "objects" using their characteristics rather than analysing numbers that define them. For example, machine learning is used to predict house prices based on data collected from previous years' house prices or can classify a picture of a cat translating pixels into numbers. While machine reasoning could tell you if an animal is a mammal. See Fig. 18, if an algorithm "knows" what the most common characteristics of mammals are and if your animal has similar ones, it will be classified as a mammal.

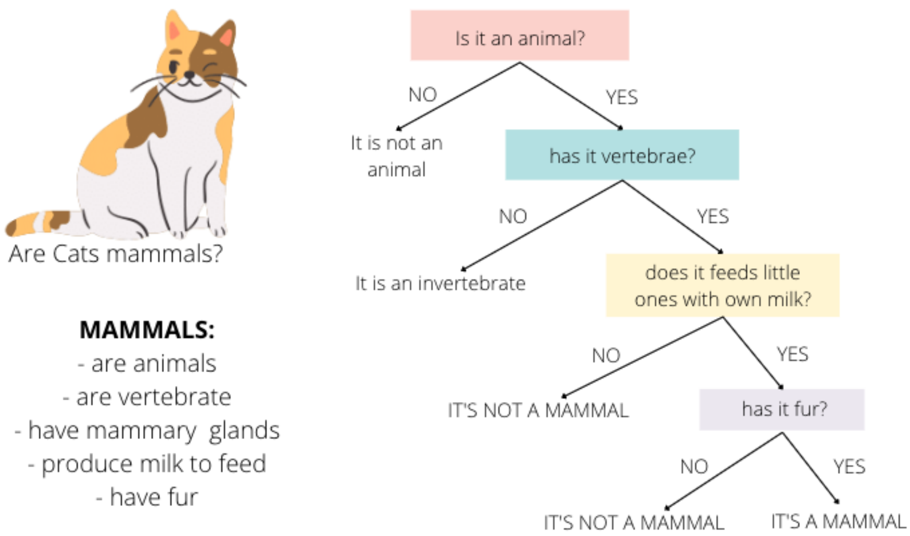


Fig. 18 Example of decision tree

2.3.4 The agent perspective

Systems that can perform tasks providing an output when given inputs, are called “Agents” (Ertel, 2017). Agents can be both software (computer programs) and hardware (robots). The agents are programs that respond to the user's inputs with outputs, like for example chatbots. While robots and other hardware are developed also to take input from the environment thanks to sensors, they can perform actions in the same environment thanks to actuators. Inside robots there is a computer or processor that can compute several programs one of which can be a software agent (Ertel, 2017).

The word “agent” comes from latin “*Agere*” that means “to act”. In AI, computer science, and robotics, the Agents are systems that can autonomously perceive information from the environment and act to achieve a goal (Norvig and Russell, 2010). When Agents can achieve the best outcome or the best expected outcome, they are called **rational agents** (Norvig and Russell, 2010). There are many intelligent agents developed by research groups and companies. The more sophisticated systems are known as **knowledge-based systems**. These systems can manage information and knowledge, reason, and process language (Ertel, 2007). Some developed robots are humanoid, humans-like robots and some others are like pets. Under the umbrella name of **social robots** there are all the robots that interact with humans including children (Bartneck and Forlizzi, 2004).

Many researchers are investigating the interaction between intelligent agents and children. They are trying, for example, to understand the impact of robot pets on the lives of preschool children (Kahn *et al.*, 2006) or how children perceive humanoid robots (Kahn *et al.*, 2012) or smart toys, and what is the influence of the devices on them (Williams *et al.*, 2018).

2.4 Data science

As described in the previous chapters, the relationship between AI and data is very close. Data science education differs from AI education however there are many commonalities between the two both from content and competencies point of view (Danyluk and Buck, 2019). Data science is the subject that studies formulas and strategies to translate the real world into numbers, studies how to analyse those data to find patterns and information, and uses software and technologies such as AI, to do so. Data literacy, on the other hand, can be seen as more related to ethics, safety, and privacy (using data in the best way possible for a better world) (Baston et al, 2020). Data science is a subject that can introduce to children the importance of conducting research. From planning how to gather data, to collecting data, analysing data using charts, and then deducting information. To introduce data science to children we can use the Data Detective Cycle as a framework (Leavy et al., 2012), see Fig. 19.

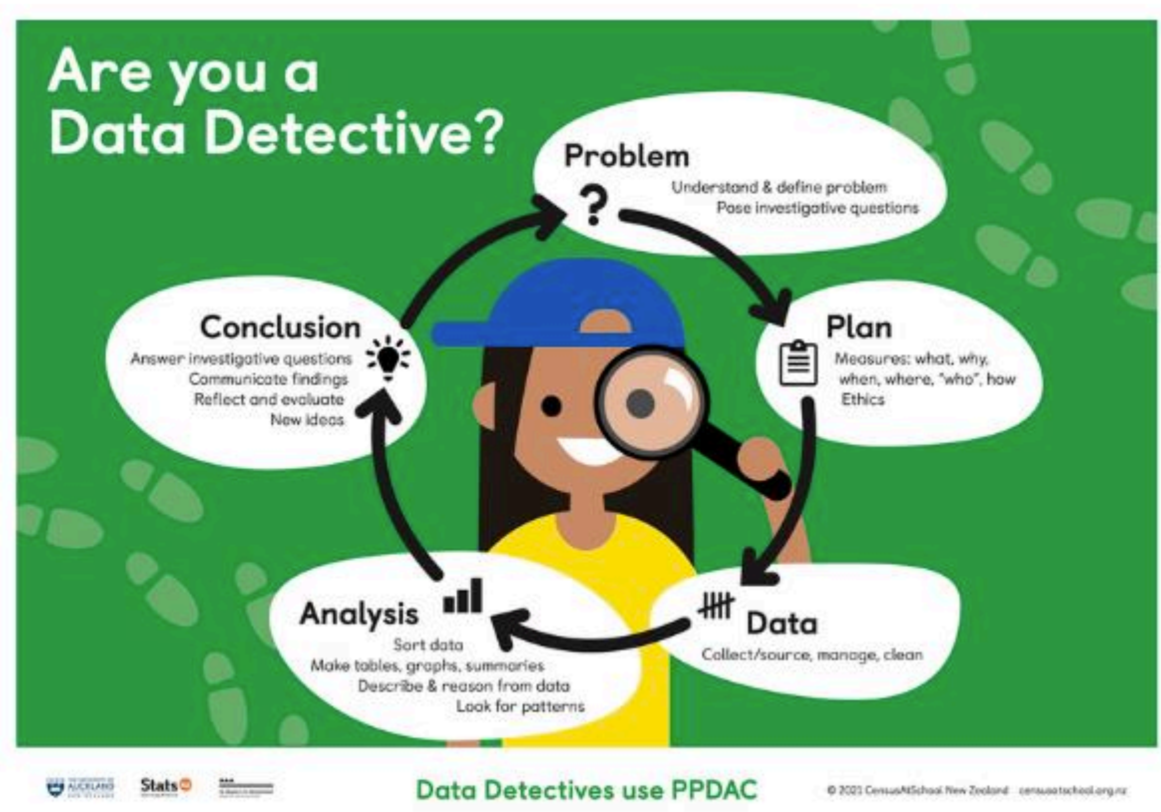


Fig. 19 Data detective cycle (Leavy et al., 2012)

2.5 AI in our society

AI is an emerging technology as in the past the engine was (Floridi et al., 2018). It is pervasive and can influence our lives. As with any other emerging technology, it follows ups and downs in terms of developments, meeting expectations, and reaching the general public. Gartner's hype cycle is useful to understand the reality of the emerging technologies from the commercial promises (Gartner, 2022). For example, general AI was/is the trigger of innovation and interest but is very far from becoming reality right now. While developments of techniques such as machine learning, and deep learning, can be adopted mainstream (Gartner, 2022).

AI is not new; the first works are dated back to the late 50's. So, what has changed since then? What has changed is the availability of massive amounts of data and the computing power able to manage them (Russell and Norvig, 2010). Data are collected every day from sensors, thanks to the dissemination of devices connected to the internet (IoT, internet of things), a massive use of social media and web sites. The majority of today's data available has been collected in the past four-five years, Fig. 20.

Despite the impression that AI as the internet and the digital world is something ephemeral and often associated with the cloud. AI is a real and concrete industry based on a complex infrastructure that makes it possible. AI can be mapped in terms of data, planet resources and human labour. And it has an impact on our society and on our environment (Crawford and Joler, 2018). Data centres, where data are stored and computed, consume approximately 2% of worldwide electricity and estimated 8% in 2030 (Andrae and Edler, 2015).

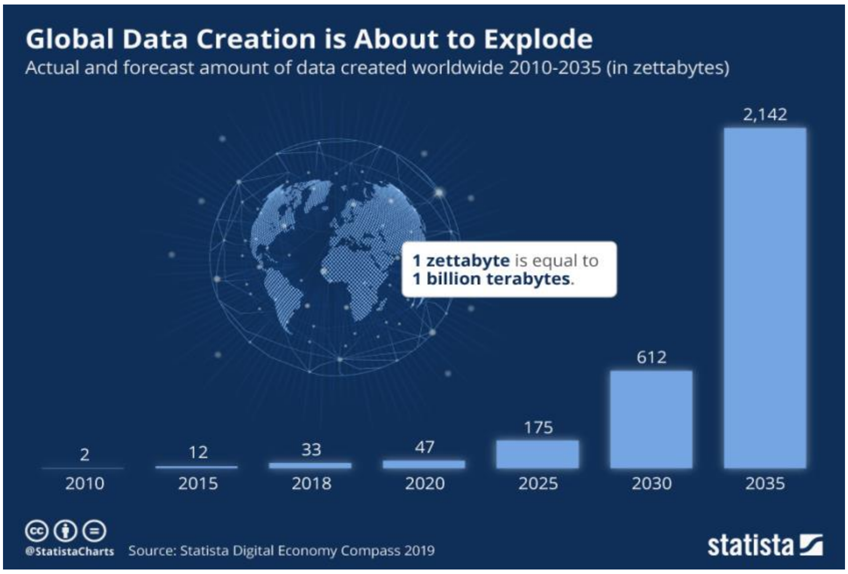


Fig. 20 Data creation over time

2.5.1 AI for good

With AI we can solve real-world problems and we have the responsibility to make sure this technology is beneficial for humans (Floridi *et al.*, 2018). Applications of AI for good relate to the environment, our health, inclusion, arts, education and much more. Ideally, AI can be used to help in the achievement of all UN Sustainable Development Goals of our age. A demonstration is the work of The International Research Centre in Artificial Intelligence (IRCAI), under the auspices of UNESCO, for example, developed and deployed in 2021, the IRCAI Global Top 100 international call for applications which mobilise current AI technologies to achieve the 17 United Nations Sustainable Development Goals (IRCAI, 2021).

2.5.2 AI and Data implication

What is AI role in our society? Companies, universities, research centres are working on developing tools and services based on AI to solve real world problems and to meet market and business requirements. AI tools and services have an impact on all our lives and everyone should be informed about it. Policymakers are working and should work in order to provide guidelines for companies and universities to ensure their products and services are ethical, guarantee equality and respect citizens' rights (Floridi et al., 2018). On the other side companies, universities and research centres have the moral imperative to engage with the general public informing them of the impact that this technology can have on decision making in our daily lives (Floridi et al., 2018). Not only because research is possible thanks to public funding but also because much of the data used to develop AI technologies comes from the citizens, consciously or unconsciously. Investing in EPE is crucial to give everyone the opportunity to develop their own understanding and to have the tools to ask questions and make informed decisions (Floridi et al., 2018). AI holistic perspective is presented in Fig. 21 which represent all the actors involved.

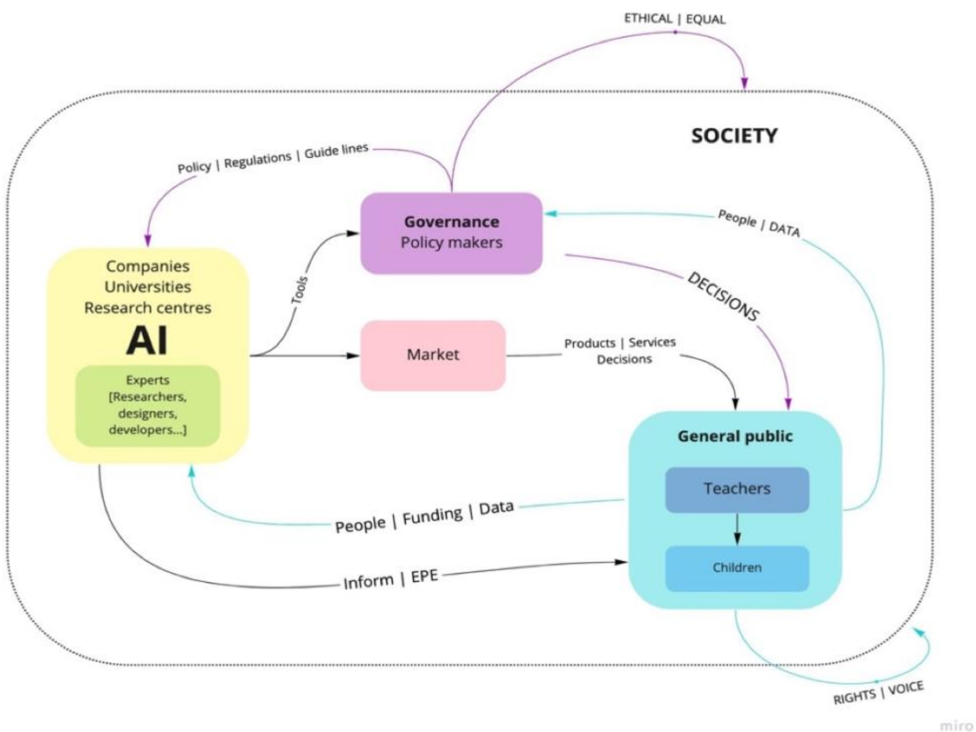


Fig. 21 AI impact: a holistic perspective. Actors involved and their roles. (Floridi et al., 2018)

How can AI be ethical? The impact of AI on our society is not questioned anymore, what is questioned though, is what this impact will be. There is a risk that AI will be overused and misused but there is also the risk that good intentions and fear could lead to underused and lack of funding to guarantee better regulations (Floridi et al., 2018). AI should be *beneficial* for the all humanity, for the planet, and should considered a common good. Citizens should have the *autonomy* to make informed decisions for themselves. Therefore, AI should be understandable (*explicability*) to avoid the “black box” excuse used to shift responsibility from people to the technology. Aware of the blackbox risks, and the fact that AI is very difficult to explain to a general audience, it has been developing another field of AI in computer science, called XAI or Explainable AI towards a more trustworthy AI. Up to now what machine learning does, is giving predictions. *Explainable AI* approach suggests ways to make those outputs clearer by providing similar cases as reference or arguments to explain a specific output (Keane and Kenny, 2019). Lastly, to guarantee *justice,* AI should be equal and ethical. It should respect rights and privacy and should avoid any type of discriminations due to its use (Fjeld *et al.*, 2020).

Ethics of intelligent, smart, or autonomous agents is challenging the research (Bonnefon, Shariff and Rahwan, 2016). An example is the moral dilemma related to autonomous vehicles. In the case of an accident (something that is unpredictable), how should self-driving cars be coded to react? While we as humans have so-called “instinct” machines do not. Research highlights that it is important to tackle these dilemmas before such emerging technologies reach a global market, because even if these situations are unlikely, they might occur

(Bonnefon, Shariff, and Rahwan, 2016). MIT researchers developed a platform in which users can express their choice on moral dilemmas related to a self-driving car, by choosing from two different scenarios. While the importance of gathering such information and tackling these dilemmas is not doubted, these simulations are based on the paradigm of the “one-right answer”. Whereas moral problems are intrinsically not solvable due to their dilemmatic nature and should ignite debate and reflections (Sommaggio and Marchiori, 2020). From the end of the 20th century engineers and researchers have been questioning if it is possible to develop robots and software capable of moral decision making (Moral machines). Currently engineers and researchers working on the design of emerging technologies must face such ethical aspects (Wallach and Allen, 2011).

Moral dilemmas are not the only ethical implication of AI technologies. AI technologies in fact exist thanks to data availability, and Machine learning algorithms use dataset to train models that then make predictions on data never seen before. In other words, decisions on new data are taken based on data used to create these technologies. Data can be numbers, text, images and represent our habits. Internet websites, social media, streaming platforms, e-commerce, IoT, wearables, can store, manage, and extract huge amounts of data i.e. our click, reading time, object bought, but also running time from our sport wearable, smart watch, mobile phone (Crawford and Schultz, 2014). Data scientists ask questions to the dataset to extract information. Data science uses computer science, machine learning and statistics to handle huge datasets. Application of data analysis range from psychology, cognitive sciences, business, genomics etc. (Skiena, 2017). Fig. 22 presents an in-depth representation of machine learning techniques that can find patterns from big datasets, linking a specific demographic to specific habits and interests while making predictions that can influence decision-making (Kosinski, Stillwell and Graepel, 2013). This kind of privacy is called “predictive privacy” and it is not addressed by traditional privacy protection legislations (Crawford and Schultz, 2014). Examples of the consequences of this kind of data analysis are the Filter Bubble, the Echo chamber, micro-targeting, among many others (JRC, 2020).

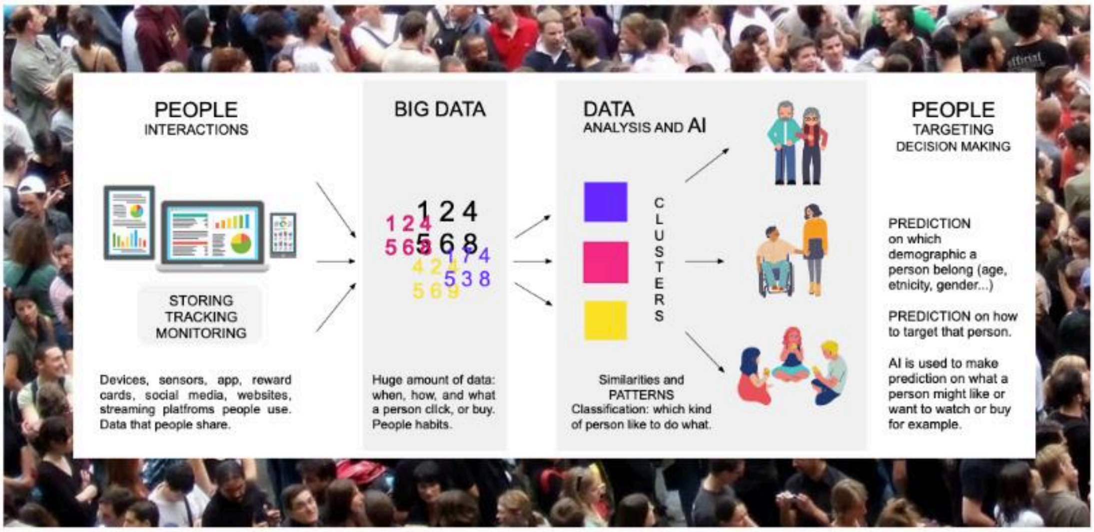


Fig. 22 From people to people, how data and AI can influence our lives based on, Suresh and Guttag, 2019

Despite the quantitative nature of data, numbers are not necessarily neutral and how AI relies on data has ethical implications. Datasets and how datasets are managed (algorithms) can, in fact, include errors and mistakes, both conscious and unconscious known as **Bias** (The Royal Society, 2015).

Humans are biassed and these biases can impact in many ways and stages in the machine learning process. Moreover, the machine learning process, as it is designed, intrinsically includes biases. **Historical** biases are due to the fact that machine learning models always use dataset from the past to make predictions on present new data. This can lead to inequality and unfair results. Therefore, if a dataset is biassed, predictions from the AI model are (Suresh and Guttag, 2019). **Representation** bias occurs when the data used do not equally include examples of all the parts of a whole, therefore it fails in generalisation. While historical and representation biases are related to data set collected and used, **Measurement** biases can occur when scientists decide what features of a data include in the model and how to label it. **Aggregation** biases are strictly related to model development when a single model cannot suit a heterogeneous population. **Evaluation** biases can occur when benchmarks are wrongly chosen to assess a model. Finally, **Deployment** biases occur when humans interpret model predictions and outputs in a wrong way (Suresh and Guttag, 2019).

Biases can have real world implications and a direct impact on people's lives. Research shows how bias can lead to discrimination and unfair decision making in many different contexts i.e., law, research engines, business. Researchers are studying methods to mitigate biases suggesting, to state upfront and in a more transparent way what biases are addressed or what assumptions are made (Suresh and Guttag, 2019). Systems based on data analytics and AI are or can be used in multiple contexts i.e., crime prevention, credit access, job recruitment etc. where bias can have a severe impact on people's lives. Minorities are often underrepresented, and machine learning models could be trained with biassed datasets. A lack of heterogeneity in AIcould increase bias, discrimination, and stereotypes. AI experts suggest critically evaluating technology implementation particularly in relation to the use of facial recognition (based on AI algorithms) in the context of crime prevention (BBC, 2020). AI models are well known to fail for minorities nevertheless they have been used to detect suspects in the US and to find a score of likelihood "a person is to reoffend" (Hao, 2019). Data and AI can be used by private businesses to generate income and to target users for political and societal reasons and interests as was publicly seen in the scandal of Facebook and Cambridge Analytica (Chan, 2019).

Since 2018, European citizens have had the privilege of having a law known as GDPR (The General Data Protection Regulation of the European Union) that defines our rights on personal data and automatic systems decisions. In particular it states that we are the owners of our personal data (**personal data** are all the data that can be linked to our name and surname) and we can decide to accept or not decisions, on ourselves, that are entirely automatically made (Loble, Creenaune and Hayes, 2017). However, big information ecosystems (research engines, social media...) use, store, and sell big data that are not personal, from which they extract information and make predictions using AI and data analysis outside privacy protection (Crawford and Schultz, 2014). Data has a real and concrete value, and together with AI has a considerable impact on our lives, for these reasons everyone should be informed. Being aware of the complexity of the big data and AI era is paramount to start to ask questions and to take informed actions.

2.5.3 Children's rights in the era of AI and big data

"Being children" in the era of AI and big data means having adults who share pregnancy pictures with friends and family before birth, using apps and wearable devices to monitor health and wellbeing habits, engaging with chatbots and voice assistants and smart toys, being tracked and monitored in terms of school performances and sharing contents on social media when teenagers. Children's "dataveillance" (collecting information using forms of data) starts immediately and can have positive effects but also risks (Lupton and Williamson, 2017).

The United Nations Convention on the Rights of Child (UNCRC) set in 1989 non-negotiable standards to protect children (persons under the age of 18). Milestones of the UNCRC are three: Provision, Protection, Participation. Rethinking these principles in the era of AI and big data means ensuring ethical AI, privacy, and safety rights for children. AI should be understandable, safe, equal, and inclusive (UNICEF, 2020).

"**Protection = { do no harm }**
Children need to be protected from any harmful and discriminatory impacts of AI systems and interact with them in a safe way. AI systems should also be leveraged to actively protect children from harm and exploitation.

Provision = { do good }
The opportunities that AI systems bring to children of all ages and backgrounds – such as to support their education, health care and right to play – need to be fully leveraged when, and this is critical, it is appropriate to use AI systems.

Participation = { include all children }
Ensuring participation means that children are given agency and opportunity to shape AI systems and make educated decisions on their use of AI and the impact that AI can have on their lives. All children should be empowered by AI and play a leading role in designing a responsible digital future for all." (UNICEF, 2020)

Children interact with many different devices from voice assistants to smart toys all of which are connected to the internet and use AI to give children feedback. Research suggests that children 4-10 years of age consider smart toys trustworthy (Druga *et al.*, 2017) and researchers are trying to understand to what degree smart toys can influence children's decisions and actions (Williams *et al.*, 2018). Children should have the right to have control over their data in any software or product with which they interact. That means that products for children should (Designing for Children's Rights, 2021) let users choose what data to share, not take more than the data needed, not sell children's data to other parties and lastly, respect and not misuse data.

There is also a fourth milestone of UNCRC, that is Prevention. It is paramount to create opportunities for children and youth together with parents, to understand AI, its power, and its impact on lives. Engaging with school should ensure everyone has an opportunity and can make AI EPE inclusive and equal.

2.6 AI and education

2.6.1 AI in education

AI as a technology already has a strong impact on our daily lives. Its use is spreading throughout many different fields and education is one of those. Researchers from academia and business are studying and developing software to support and enhance teaching and learning. Software based on AI can track, process, and analyse data from student performances to monitor their learning progress to customise students' learning path. Software can provide real-time feedback for teachers and help them monitor students' engagement and learning progress. There are applications that can track facial expressions or eye movements (OECD, 2021). Software and social robots based on AI can help students with special needs or abilities (Simut *et al.*, 2015). Social robots can be either tutors (Rosanda and Starcic, 2020) or peers (Park *et al.*, 2017). GPT models that can produce "human-like" text have raised many concerns and doubts about teacher's role in the future, what will their impact be in class, and if these tools should or not be used in schools. Experts are suggesting teachers to familiarising with the tools and helping students to be more aware and responsible, instead of banning it. Teachers are already advising peers around the use of ChatGPT in order to make teaching easier (i.e. writing reports, and exercises) or how students could use it as support their learning (e.g. starting with writing) (Lovegrove, 2023).

Studying the literature related to AI and school, there is a strong interest in using AI and data analytics as tools to improve the teaching experience, and to track and assess students' learning performances (Chassignol, Khoroshavin and Bilyatdinova, 2018). On the other hand, there are only a few very recent studies that try to discuss the introduction of teaching AI in school and very few on teachers learning on AI (Kahn and Winters, 2021). A number of key questions have emerged: Should AI be introduced in schools as part of computer science programmes? Should AI be a key knowledge for every student? What does "being digital learners" mean in the era of AI and big data? What is AI literacy?

2.6.2 Digital learners

The idea of working on student competencies in relation to information and communications technology (ICT) in school is not new. Seymour Papert in 1980 already highlighted the importance of computational thinking and computer technology in the class promoting the idea that it should be the child to programme the computer and not the opposite, i.e., *"the computer is being used to program the child"* (Papert, 1980). During the years technology literacy in school has changed names from "fluency in information technology" to "computational thinking", from "ICT" to "coding and media literacy" (Valtonen *et al.*, 2019). The education system still struggles to understand how to integrate technological knowledge, use, and awareness, into a standard curriculum with the other subjects (Twining *et al.*, 2020). It is well known that there is dystopia between the digital natives' generation and teachers and the need for alignment between policy and practice in order to create a better environment for students to learn in the digital era (Butler *et al.*, 2018), and to focus on digital learners rather than digital natives (Bullen and Morgan, 2011). So, what does "being digital learner" mean? Being digital learners does not only mean using technology and understanding technology, it is more than that. Being digital learners means being learners in an era where technology is used and affects everyone's lives. Being digital learners means having the opportunity to learn how technology works and how to use technology to enhance creativity and critical thinking, to encourage collaborative real-world problem solving and to empower ethical, critical, and aware choices and actions (NCCA, 2020).

Now more than ever it is paramount to engage children in good quality learning opportunities that allow them to discover emerging technologies, to understand how they work, what the implications are for our lives and how we can use them for good.

2.6.3 AI literacy

Research suggests that since experts' knowledge is built around core concepts and big ideas, the curriculum should be organised in the same way (Bransford, Brown and Cocking, 2000). AI big ideas are framed for K-12 students around five main concepts as illustrated in Fig. 23 (Touretzky *et al.*, 2019).

Perception, Representation and reasoning, Learning, Natural interaction, and Societal impact. In other words, how a robot (also called “agent”) uses sensors to take information from the environment, how AI systems analyse data, find patterns and make predictions, how this software relates to humans, and what the impact is on our lives.

Definitions of AI literacy as well as data literacy are still evolving. **Data science** is the subject that studies formulas and strategies to translate the real world into numbers, studies how to analyse those data to find patterns and information, and uses software and technologies such as AI, to do this. **Data literacy**, on the other hand, can be seen as more related to ethics, safety, and privacy (using data in the best way possible for a better world) (Baston et al, 2020). What is AI literacy? Researchers refer to **AI literacy** as a set of competencies (see Table 1) that we as learners need to be able to navigate and that enable us to question a world (work, school, health...) more and more affected by emerging technologies (Long and Magerko, 2020).

Once big ideas and competencies are framed, the following question arises: **What is the best way to introduce those concepts into school practice?** Researchers are studying how to engage teachers and children (in K-12, from primary to secondary school) with programmes on AI. Some studies use AI programmes and robots with a constructionist approach.

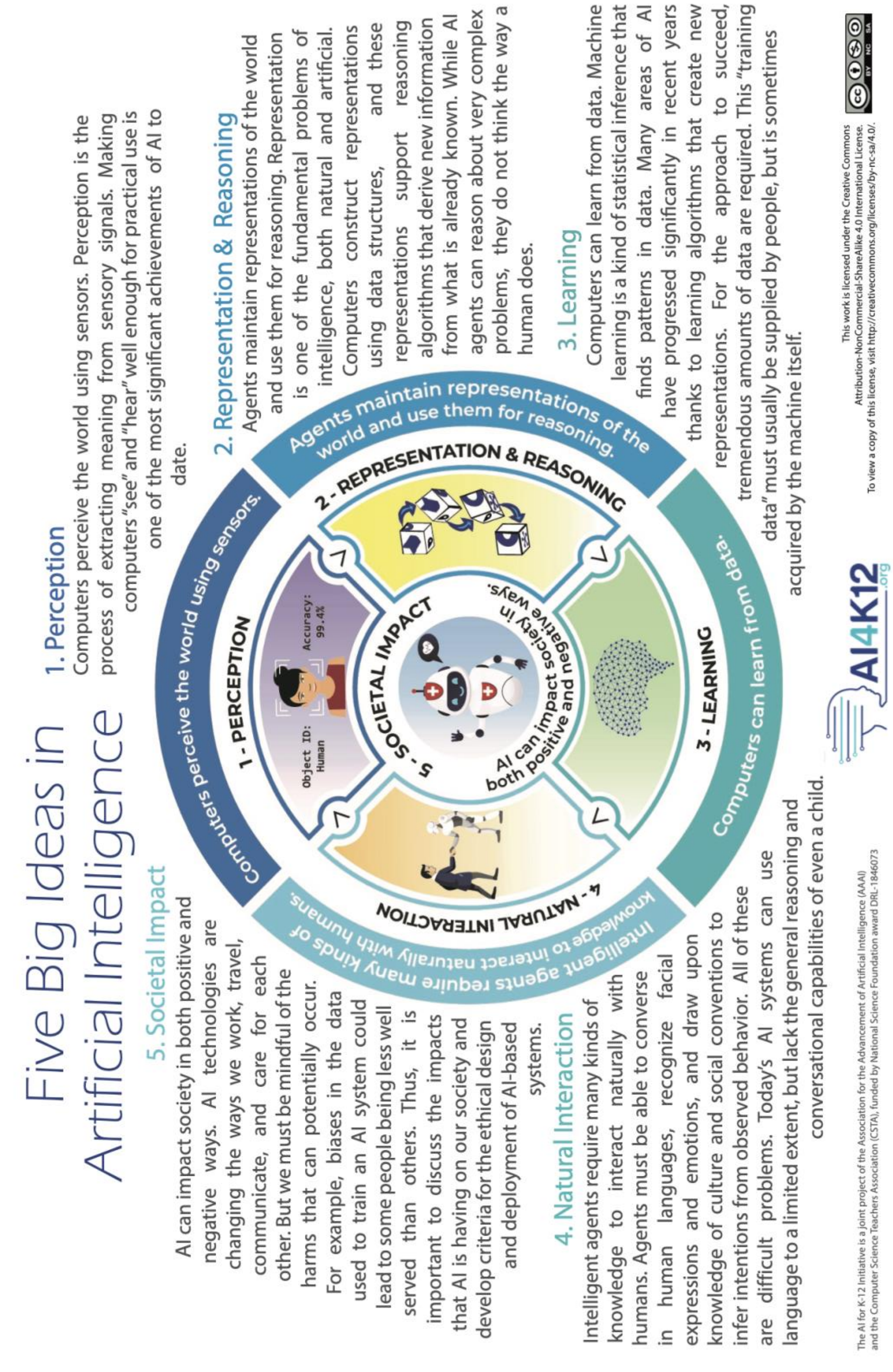


Fig. 23 AI4K12 graphics (*AI4K12*, 2020)

1	Recognising AI	Distinguish between technological artefacts that use and do not use AI.
2	Understanding Intelligence	Critically analyse and discuss features that make an entity “intelligent”, including discussing differences between human, animal, and machine intelligence.
3	Interdisciplinarity	Recognise that there are many ways to think about and develop “intelligent” machines. Identify a variety of technologies that use AI, including technology spanning cognitive systems, robotics, and ML.
4	General vs. Narrow	Distinguish between general and narrow AI.
5	AI’s Strengths & Weaknesses	Identify problem types that AI excels at and problems that are more challenging for AI. Use this information to determine when it is appropriate to use AI and when to leverage human skills.
6	Imagine Future AI	Imagine possible future applications of AI and consider the effects of such applications on the world.
7	Representations	Understand what a knowledge representation is and describe some examples of knowledge representations.
8	Decision-Making	Recognise and describe examples of how computers reason and make decisions.
9	ML Steps	Understand the steps involved in machine learning and the practices and challenges that each step entails.
10	Human Role in AI	Recognise that humans play an important role in programming, choosing models, and fine-tuning AI systems.
11	Data Literacy	Understand basic data literacy concepts
12	Learning from Data	Recognise that computers often learn from data (including one’s own data).
13	Critically Interpreting Data	Understand that data cannot be taken at face-value and requires interpretation. Describe how the training examples provided in an initial dataset can affect the results of an algorithm.
14	Action & Reaction	Understand that some AI systems have the ability to physically act on the world. This action can be directed by higher-level reasoning (e.g., walking along a planned path) or it can be reactive (e.g., jumping backwards to avoid a sensed obstacle).
15	Sensors	Understand what sensors are, recognise that computers perceive the world using sensors, and identify sensors on a variety of devices. Recognise that different sensors support different types of representation and reasoning about the world.
16	Ethics	Identify and describe different perspectives on the key ethical issues surrounding AI (i.e. privacy, employment, misinformation, the singularity, ethical decision making, diversity, bias, transparency, accountability).
17	Programmability	Understand that agents are programmable.

Table 1 Table AI literacy competencies (Long and Magerko, 2020)

If we reflect on it, AI was there since the beginning of constructionism, together with Papert's work on introducing computational, critical and creative thinking in school using Logo and computers. Papert, in fact, was well known at that time for his work on AI and to bring the computer science world into school in the best way possible, encouraging an active and creative role for children engaging with machines (Kahn and Winters, 2021). The constructionist approach shows promising results in engaging children in AI key ideas and competencies, e.g., very young children who teach a machine learning model to recognise feelings while learning about emotions themselves (Vartiainen, Tedre and Valtonen, 2020) or primary and middle school children projects on AI ethics and creativity using social robots and bespoke software (Ali *et al.*, 2019) or unplugged activities that allow students to engage with AI key ideas without the need of screens (Lindner, Seegerer and Romeike, 2019) (list of projects and resources in Appendix B). In relation to the future of AI and constructionism in school there are questions that still need to be investigated for example how to engage and frame teacher learning, how software and robots could be inclusive and accessible and how AI technology will impact students learning and metacognition (Kahn and Winters, 2021).

2.7 How people learn

2.7.1 Learning and teaching

How do people learn? What we know is that we are not a blank canvas and we build knowledge on knowledge (Bransford, Brown, and Cocking, 2019). We learn from others and with others, we learn about things we care about. We can experience being active learners when we use our hands and our hearts. Being an empowered learner means feeling that our ideas are valued and can have an impact on real problems, on our community (Bransford, Brown, and Cocking, 2019). Two definitions are paramount to start a conversation on Education: what does "*learning*" and "*teaching*" mean? ***Learning*** is something that comes from within, it develops thanks to personal experiences (Piaget, as quoted by Pound, 2018) and from interactions with others and the environment (Vygotsky and Dewey*,* as quoted by Pound, 2018). Effective learning experiences include play (*Learning through play)* (Pound, 2018), building and creating (*Constructionism)* (Papert, 1980), and solving real-world problems (*Design based learning and Design thinking*) (Mehalik, Doppelt and Schunn, 2008). Every person has multiple intelligences and learns in different ways (*Gardner,* as quoted by Pound, 2018). Moreover, learning is related to emotions. Negative feelings such as fear, or frustration can negatively affect the learning process. Key influences are a positive and supportive environment, as well as a context promoting emotional awareness (*High/scope* and *Emotional intelligence*) (Pound, 2018 and Papert, 1980).

In Italian, we have three different words for education: "Educazione", "Istruzione", and "Formazione". For example, the ministry of education is called "Ministro dell'Istruzione" while university courses on non-formal education and social working are named "Scienze dell'educazione" on the other hand university faculty for future primary school teachers is "Scienze della formazione". "Educazione" means also "good manners", "being polite". "Formazione" is used to say both "teaching" and "learning", for example, teacher development programmes are called “formazione insegnanti”. The etymology of the word “Istruzione” comes from the latin word “instruction”. Once, education was related to delivering and providing information, content and instructions. This concept of education was introduced in the industrial revolution age. At that time companies needed employees trained to follow rules and instructions all day long with fixed and repetitive tasks and schools were one of the few places where information could be found (Robinson and Aronica, 2015). But the school role changed over the centuries as well as the teacher's role. Educators and teachers are now more like partners and guides (Malaguzzi, quoted by Pound, 2018). ***Teaching*** is about designing and creating opportunities for learners to develop their own understanding. Its purpose is more educating rather than training and more inspiring hands-on and heads-in rather than lecturing and reciting (Bransford, Brown, and Cocking, 2019).

Often when people think about education, they think about school, however there is much more. Firstly, “Education” and “Learning” are part of life from when we since we are born and continues to be a lifelong endeavour. Secondly, children are at school for only part of each day (Fig. 24) so the role of school in learning should expand to family and communities. Family and community can also positively influence the school learning environment (Dewey, as quoted by Pound, 2018). People are community learners who continuously learn with and from others (Vygotsky, as quoted by Pound, 2018).

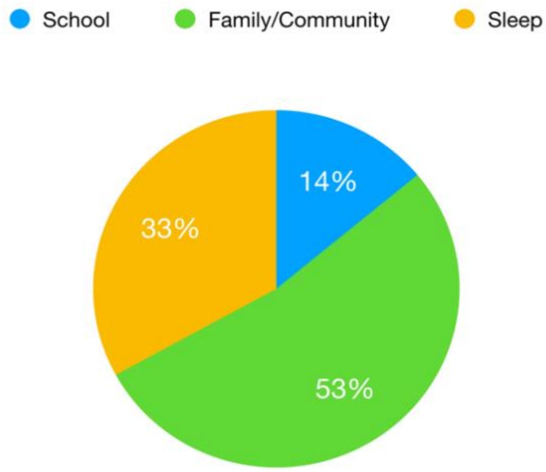


Fig. 24 Students' daytime (Bransford, Brown, and Cocking, 2019)

It is key to know how people learn before designing any educational environment. People have preconceptions and ideas already that could not be taken for granted. A simple example to better understand preconception is illustrated in the children's book by Leo Lionni "Fish is a fish". In the book there is a frog that asks a fish to imagine a bird. So, the fish does imagine the bird, but its idea of "bird" looks like a fish with wings because the fish already has its own ideas of the world and of what it knows and its familiar with.

The same perspective is applicable to any new knowledge. It is key to understand preconceptions and previous ideas that learners have. It is possible to gather information and to investigate learners' ideas using mind-maps or drawings, as mapping and drawings are means to show ideas, concepts, connections and can be used in class as well (Kara, 2012). To understand how people learn, researchers also studied experts' knowledge, and discovered that experts' knowledge is organised around meaningful ideas and key concepts ("conceptual understanding"). Therefore, promoting deep understanding versus factual disconnect knowledge is paramount. Experts are also able to identify meaningful patterns of information and to make connections. They can fluently retrieve knowledge and use their knowledge in different contexts (Bransford, Brown, and Cocking, 2019).

An important aspect of learning is also reflection and self-assessment. Learners are active agents with strategies to remember and solve problems, to plan and set learning goals. “Understanding our own level of understanding” is part of being active learners and has been studied together with approaches and practice under the name of “metacognition”. (Bransford, Brown, and Cocking, 2019).

2.7.2 Creative learning

Effective learning is far from what we as students probably lived or remember from our own school or university experience. It is more like what we experienced in kindergarten. It is not about waiting for information to fill our brains, it is about finding opportunities to develop our own competencies and knowledge (Resnick, 2017). A quality learning environment should be designed for learners and should be “learner-centered”. It should consider learners’ knowledge, skills, and competencies (Bransford, Brown, and Cocking, 2019). Anyone participating in a learning setting brings their own unique set of experiences which have developed their understanding, knowledge, attitudes and skills. New knowledge is built on preconceptions and prior ideas (Bransford, Brown, and Cocking, 2019). Children have their own knowledge and robust logic (Ackermann, 2001). They can develop new knowledge more effectively through experiences than receiving information (Ackermann, 2001). Moreover, children do not learn what they listen as it is told, however they interpret the information received (Ackermann, 2001).

Learners should be engaged inclusively, regardless of the competencies they already have or not. An inclusive learning environment should give individuals all the tools needed to grasp key ideas and principles. Approaches such as *scaffolding* can be used to enable individuals to engage with learning activities actively and positively. Scaffolding is about keeping the interest of participants, motivating them, and guiding them towards the goal, while keeping frustration under control (Bransford, Brown, and Cocking, 2019). Keeping a balance between challenging and achievable activities while giving freedom of expression. ***"Low floor, high ceiling and wide walls"*** approach can encourage participants to develop their own skills and actively and creatively engage with the learning subject (Resnick, 2017). Even though experiences are crucial in the learning process, there are important differences between projects that encourage hands-on doing, and those that encourage **doing with understanding**, as highlighted by Greeno (1991, as quoted by Bransford et al. 2019).

Learning can "*especially felicitously*" happen when children are actively engaged in constructing, stated Seymour Papert, 1991, as quoted by (Butler, 2007). Constructing means imagine, create, share, reflect, and then reimagine and create again and again, as in a creative spiral (Resnick, 2017). This is exactly how children are used to learn in kindergarten. It is the process itself that is more important and valuable than the final result or creation. Moreover, if at the end of such design activity the final outcomes are different it is an added value. It means children could engage in the activity and bringing their own ideas in, customising it and making modifications and choosing different paths (Resnick, 2017). Constructing and creating can happen with physical objects such as building blocks for example, or unstructured materials, but it can also happen with software and digital building blocks.

Logo, designed in 1967 by Wally Feurzeig, Seymour Papert, and Cynthia Solomon was a coding environment developed to introduce computational thinking to students with a hands-on approach. Each line of code was a block to build an algorithm and achieve an objective. Similarly, children use Scratch (MIT) today, a visual platform where it is possible to create animations, interactive video game and quizzes, coding with colour coded building blocks. Constructionism promotes the development of computational thinking skills. A further challenge could be towards "*computational action*", providing learning opportunities where students can solve real world problems with computational thinking skills and digital literacy (Tissenbaum, Sheldon and Abelson, 2019).

Children can learn through creativity and **creativity** is an expression of learning and understanding. In Bloom Taxonomy researchers added creativity at the top of the learning pyramid in 2001 (Fig. 25) (Krathwohl, 2002). Creativity is not necessarily related to art. Creativity is not only for artists, and it is not only related to talent, something that only inspired people can have. It is more related to knowledge and understanding (Munari, 1997).

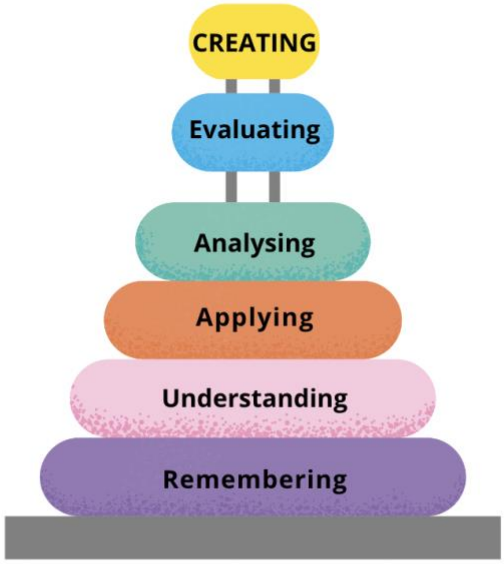


Fig. 25 Based on the revised Bloom's Taxonomy (Krathwohl, 2002) from educationaltechnology.net

Design thinking argues that anyone can be creative (Camacho, 2016). Design thinking is usually used in start-ups and research and development departments. It draws its origin from the problem-solving and design domain as we can read in Bruno Munari's work developed in the 90's. He defined the role of design as a strategy anyone can adopt to address problems and find solutions that can improve their quality of life. He was a pioneer of hands-on activities in museums for children and creative learning. Design thinking advocates the importance of centering the process on people needs to find problems and tackling them. The design thinking cycle (Fig. 26) starts with a first step focusing on people's understanding called, "Empathise". Through the understanding of the needs of a specific target audience, it is possible to define a problem to tackle. Then products or services are ideated and design to solve that problem in order to help that specific target audience.

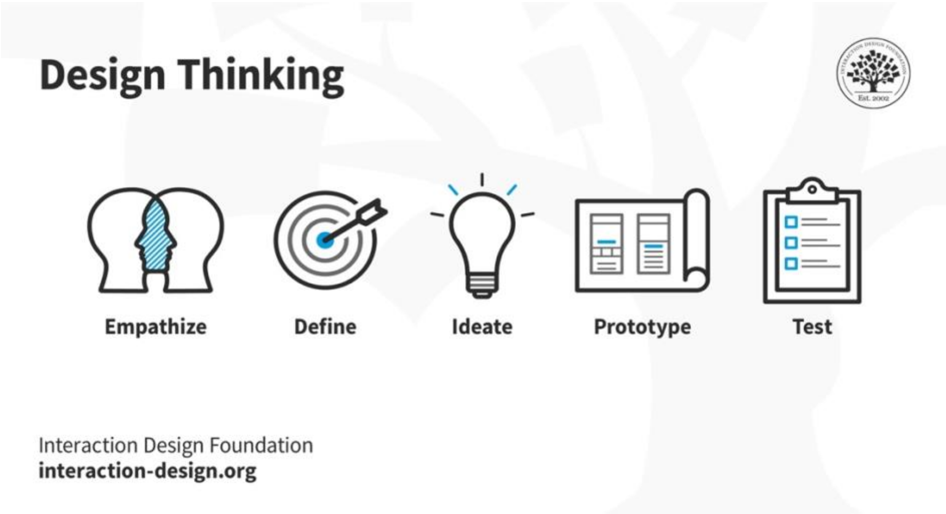


Fig. 26 Design thinking steps (*Design thinking*, 2023)

The Design thinking process is often presented as a linear sequence of steps.

However, it is an iterative process as illustrated in Fig. 27.

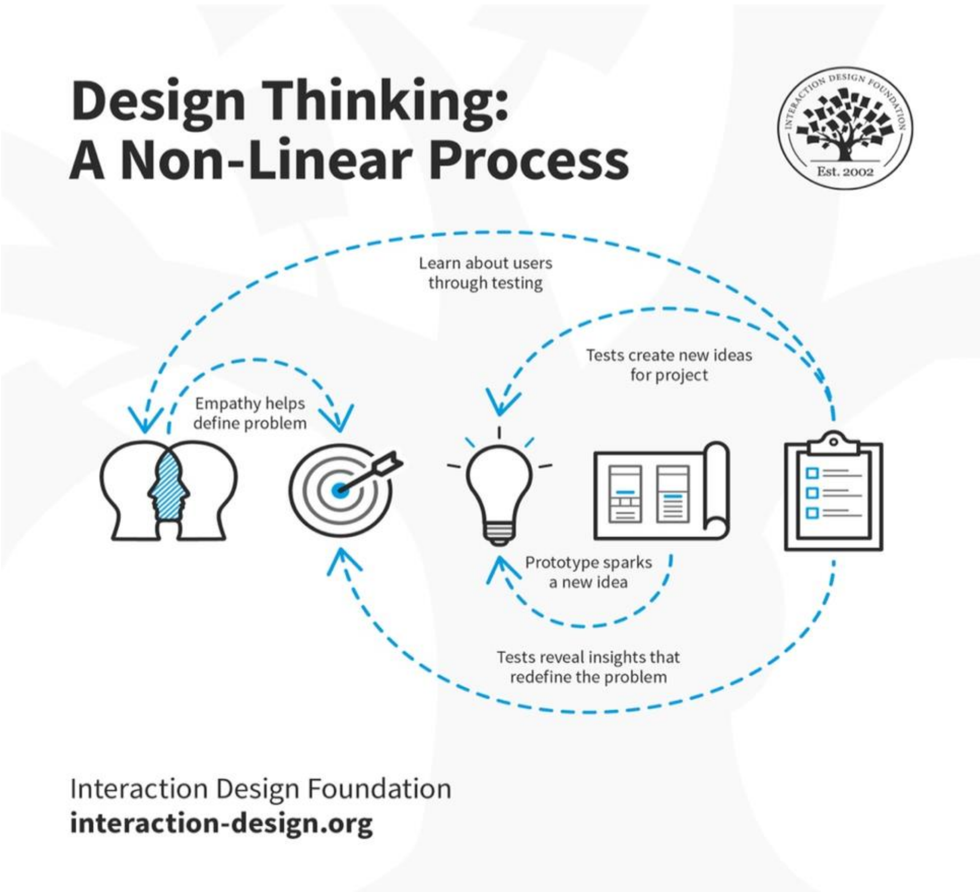


Fig. 27 Iterative Design thinking process (*Design thinking*, 2023)

The Design thinking process can be applied in many different fields and for many different purposes. Design thinking is not only for adults. It is possible to use design thinking to engage with children in school also. It encourages children to use all the skills and competencies that they can, to work in groups to find creative solutions to problems that can be real-world problems and problems related to student communities.

An example of a design thinking cycle for school is the “launch cycle” (Spencer and Juliani, 2016). A design cycle can be used to engage children and teachers in a design activity on any topic where they wish to deepen knowledge and understanding (see Fig. 28). There is a first step in which learners should **study and understand** the topic, a second phase in which they **define** a “problem” to solve or an objective, then they start generating **ideas** in terms of solutions. After the ideation phase they can work on a specific solution and bring it from the form of an idea to a **concept** and then create a **prototype**. The prototype is key to test the idea and share it with others. Prototyping allows students to understand through making and afterwards to gain feedback to improve their work. Therefore, students can consider the “improvement” as their new objective and problem to solve. The Design thinking process is an iterative process that can potentially never stop. The final “**sharing** step” is key not only to learn how to communicate ideas with others but also to learn how to ask questions and give constructive feedback (Spencer and Juliani, 2016).

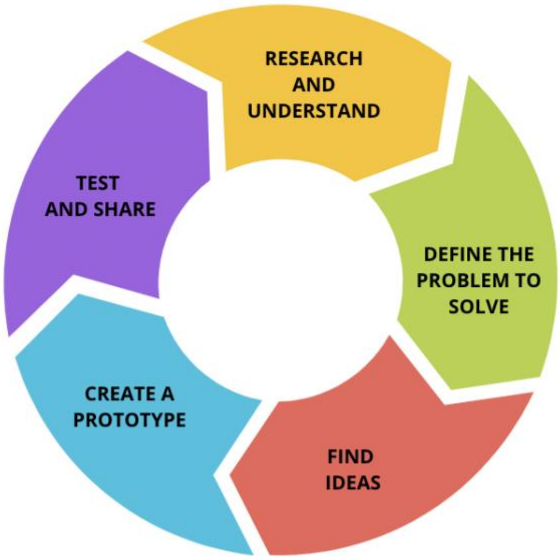


Fig. 28 Example of design cycle inspired by the Launch cycle (Spencer and Juliani, 2016).

Designing, ideating, and creating can help to reflect and develop learners' knowledge. This is good strategy for creating effective learning opportunities for children to working and reflecting on specific real-world problems, problems with which the learner can connect (Bransford, Brown, and Cocking, 2019). Furthermore, it is also possible to encourage reflection and critical thinking while working on speculative scenarios that work as a playground for students' minds. Ethical dilemmas that seem related to the future can engage people to ask themselves questions and stimulate debate (Dunne and Raby, 2013). *The Extraordinaires Design Studio* is a game developed by Northern Ireland designer Rory O'Connor, to engage children in imaginary designing challenges e.g., design a device for vampires who are scared of light or design wearable communication device for superheroes.

Design based learning allows to create learning opportunities that are interdisciplinary and use technology as a tool to achieve an objective together (Bransford, Brown, and Cocking, 2019). Technology can be used to find information (web), it can be used to create a prototype (3D printing, electronics, coding) and to document and share ideas (camera, smartphone, video editing, building a website). Moreover, engaging in creative learning opportunities allows learners to develop many different competencies that are key for their lives in the 21st century (European Union, 2019).

NCCA (National council for curriculum and assessment) of Ireland highlighted what the key competencies for today's learners are (Fig. 29). Additionally, there is also “being a digital learner” and “being creative” together with “communicating” and being “active citizens”. Therefore, it is paramount to create learning opportunities for students to engage with real and actual problems collaboratively critically and creatively, while learning about emerging technologies.

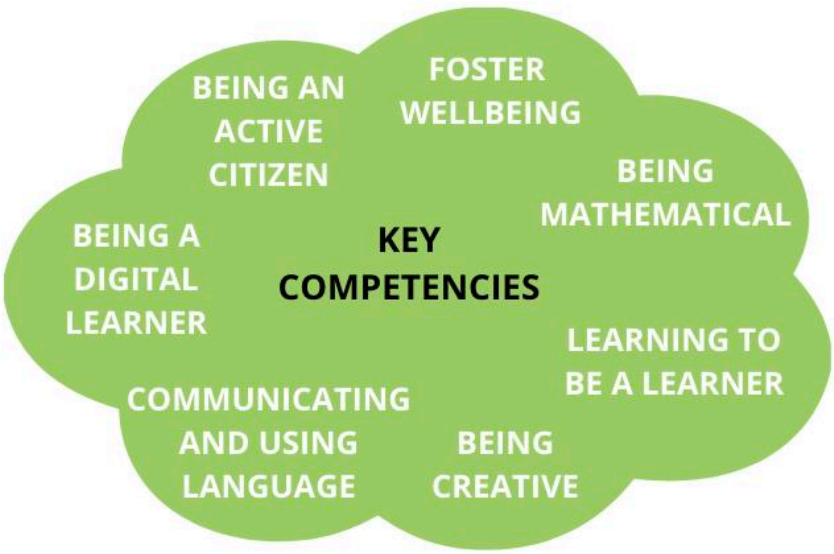


Fig. 29 Based on NCCA Ireland teaching council 2021

2.7.3 Constructionism and AI

Constructionism stated that learning can be particularly beneficial if it happens through building and creating artefacts or models that can be shared.

Those models or “objects to think with” (Papert, 1980) can be physical or digital. In constructionism learners are therefore seen as active creators of their knowledge (Papert, 1980). Echoing Papert’s ideas of ‘powerful representations’, the learning environment for preservice teachers should be centred not primarily on the software or tools used but rather on the big ideas the activities based on the use of these tools should convey (Butler and Leahy, 2021). Furthermore, learning situations and activities should be designed and developed for the specific learners and presented in relation to meaningful context i.e. possible real-world problems students can resonate with (Butler, 2007). The importance of a constructionist pedagogy in AI is evidenced by research (Kahn and Winters, 2021). Engaging teachers to work collaboratively to design lesson plans that integrate AI into non-computing subjects, could potentially represent an effective approach as recent studies have highlighted how it is possible to use datasets related to different subjects such as English literacy or social studies (Brummelen and Lin, 2020). Other research indicates that hands-on teacher professional learning programmes on AI positively engaged participants and empowered teachers to introduce AI to children in the class (Vazhayil et al., 2019).

2.7.4 Teacher learning

Teachers’ role is to design and create learning opportunities for students while inspiring them. They should engage with them in hands-on and heads-in activities that promote understanding and deep learning. Teachers are always interested in gaining feedback and insights from students. They understand that each student has different ideas and learns in different ways. Teachers know that feelings and emotions are part of the learning process and students need to understand the purpose and to feel their ideas can have an impact on their life (Bransford, Brown, and Cocking, 2019). Teachers know that students bring their own passions, skills and knowledge in the classroom.

Moreover, teachers have a multiplier effect because they can influence students' lives throughout their careers. Unfortunately, the opportunities for teachers in university to engage with the latest approaches and best practices suggested by the research are limited. Most of the preservice teachers' courses are still lecture based (Bransford, Brown, and Cocking, 2019). *"Preservice programs that prepare new teachers will play an especially important role during the next few decades",* as highlighted by Darling-Hammond, 1997, as quoted by Bransford et al., 2019). Teachers' learning is paramount to allow teachers to develop the skills needed to be able to design learning environments that are consistent with new approaches and guidelines from the research (Bransford, Brown, and Cocking, 2019). Learning development programmes should be designed to achieve long term effects. They should promote teachers' participation and sharing among teachers learning communities (Bransford, Brown, and Cocking, 2019). When designing learning opportunities for teachers, they need to be considered learners. Everything that is known and studied on children's learning is valid for teachers too, and is equally effective in engaging teachers in similar activities to those that they will use in the future with their students (Bransford, Brown, and Cocking, 2019).

Teaching learning is complex, as represented in Fig. 30. Teachers have their own ideas, beliefs and skills related to subject knowledge. They need time and opportunities to develop their own understanding of a specific new topic from a content point of view. They also need to develop their own understanding in terms of the better way to engage children in that specific content (pedagogy) and to do so they need to understand how children or students learn (Fennema and Frank, 1992, as quoted by Asli Özgün-Koca and Ilhan Şen, 2006).

When the specific new knowledge is related to technology there is the need for a framework to effectively create learning opportunities for teachers, as for any other topic. “It is clear that teachers need to be at the centre of such endeavours and frameworks are needed...to support their engagement with technology-based interventions” (Kahn and Winters, 2021). The TPCK framework tries to consider all aspects of teachers' learning from a complete and holistic perspective. Good teaching requires content, pedagogy, and technology knowledge, Fig. 31. The interconnection between the three is complex and not black and white (Koehler and Mishra, 2006).

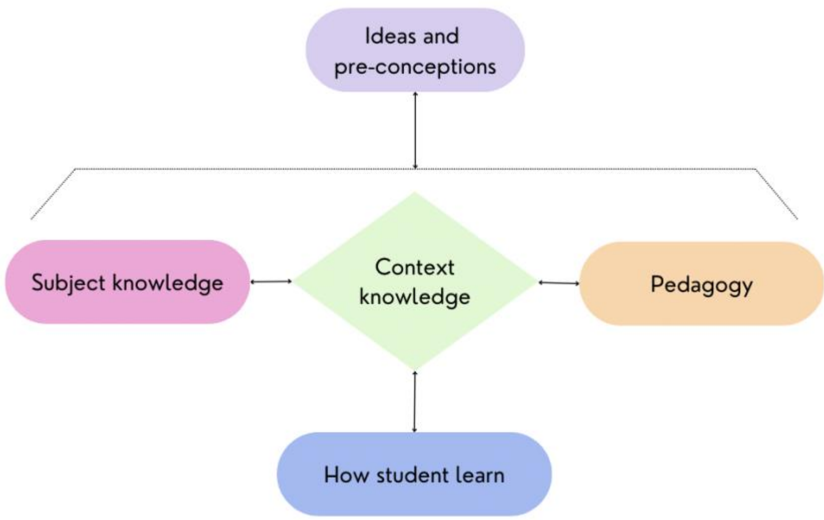


Fig. 30 Based on “Teachers' knowledge developing in the context”
(Fennema and Frank, 1992, as quoted by Asli Özgün-Koca and Ilhan Şen, 2006)

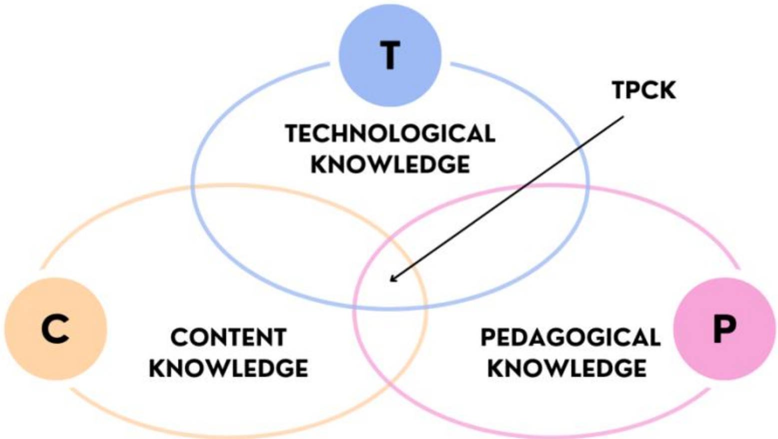


Fig. 31 TPCK framework (Koehler and Mishra, 2006)

As highlighted by Schulman, 1986, teachers' knowledge of new topic is not related just to the content rather on how this content can be elaborate in order to be taught. This knowledge is different from experts' one. Being experts in fact does not necessarily mean knowing how to teach (Bransford, Brown, and Cocking, 2019). The ultimate goal of a learning programme is not to tell teachers what to do specifically, rather to give them the opportunity to develop skills and confidence to reflect about their knowledge and design effective learning opportunities for children (Schulman, 1986, as quoted by Koehler and Mishra, 2006).

Teachers are asked to design curricula and assessment, and curriculum guidelines can change during their career. In transactions to new curriculum teachers should be engaged and considered as experts and professionals. Teachers should be given a voice and space to use their competences as a bridge between policies and the classroom (Twining et al., 2020). Research claims constructionism and co-design are promising approaches for professional development (Mishra and Koehler, 2005). An opportunity to increase teachers' design capacity, agency and confidence (Kelter *et al.*, 2021).

2.7.5 AI teacher learning

Teachers are expected to keep growing as digital creative leaders throughout their careers in order to be ready to prepare students to develop the skills and competencies they need as citizens in the 21st century (Vuorikari, Kluzer and Punie, 2022). Recent examples of learning programmes for teachers on AI can be drawn from both academic (Vazhayil *et al.*, 2019) and non-academic sources (European Schoolnet, 2021). On one side, teachers are the learners with their own prior knowledge ideas, and beliefs on the subject (Asli Özgün-Koca and Ilhan Şen, 2006). On the other hand, they need equal support and guidance in exploring the pedagogy of teaching AI (Tedre *et al.*, 2021). Therefore, research claims approaches, methods, and frameworks to guide educators when it comes to teaching AI to young students (Kahn and Winters, 2021).

Furthermore, the research describes how hands-on teacher professional learning programmes on AI could positively engage teachers, empowering them to introduce AI literacy in school (Vazhayil et al., 2019). More recent research states that designing AI curricula with teachers which can then be integrated into K-12 subjects, is considered to be more effective when compared to just delivering pre-made resources designed by others i.e. researchers or experts (Brummelen and Lin, 2020). Therefore, teachers should be involved in co-creating learning opportunities for students (Dolan, 2008) to promote a form of more inclusive and impactful STEM engagement (Severance *et al.*, 2016).

The literature has highlighted how Design-Based Learning could successfully lead learners to develop their knowledge of AI thanks to its iterative, creative, and collaborative process (Tedre *et al.*, 2021). Creativity is an expression of learning and understanding, as represented in Bloom's Taxonomy where researchers added creativity at the top of the learning pyramid in 2001 (Krathwohl, 2002). For that reason, designing with teachers should also represent a method that enables them to develop their own skills and competencies in AI.

An important consideration for teacher educators in particular is how do we empower teachers and preservice teachers to create learning opportunities for children to develop AI literacy? (Kahn and Winters, 2021). Research shows the importance of teacher learning and how effective EPE programmes should consider them as professionals (Twining *et al.*, 2020). Teachers should be involved as co-creators of learning opportunities for other teachers and for students (Dolan, 2008). As digital creative leaders, they are asked to continue to develop their competencies during their careers in order to be prepared to help students in developing AI and data literacy (Vuorikari, Kluzer and Punie, 2022).

2.8 Education and Public Engagement (EPE)

2.8.1 EPE purpose

STEM EPE represent the willingness to outreach and actively involve everyone in science, technology, and mathematics education. STEM education has an impact on present and future society. It has a positive impact on citizens' well-being and employability. It creates opportunities for citizens to feel empowered, cooperative, and active (Expert group on science education, 2015). ICTs (information and computer technology) as well as any emergent technologies challenge us as a society to rethink ourselves, our relationship with others and with reality. It is paramount to redesign interactions, work, and learning in the digital era (Floridi, 2018 and Expert group on science education, 2015). People need the skills to develop their own understanding of the 21st century world. Experts, universities, and companies have a moral obligation to inform the public about their works and discoveries that have and will potentially in time have an impact on the whole of society (Dolan, 2008). Smart partnerships among research, companies and schools can create a flourishing environment for children and teachers to learn and understand, to be actively engaged in emergent theories and technologies (Leahy *et al.*, 2016).

2.8.2 Effective EPE

Effective education means designing environments where learners can build their own knowledge and skill. Therefore, an effective EPE programme should consider how people learn in order to engage them actively and meaningfully. There should be a shift from the deficit *model* of science communication that tends to see the public as an information receiver, towards a more participatory model where the public has a voice (Trench, 2008). To ensure long-term impact, all the stakeholders should be involved in collaboration, co-design, and dialogue, as shown in Fig. 32. An effective EPE action needs to consider the importance of building strategic connections and smart partnerships in the whole community (Leahy et al., 2016). Participatory EPE actions can create connections with real community problems to solve that can support children's and teachers' learning. Learners can feel their ideas are valued and that these ideas can have a real and concrete impact on the world they are living in, while developing knowledge and critical thinking (Bransford, Brown, and Cocking, 2019).

Research shows the importance of teacher learning and how effective EPE programmes should consider them as professionals (Twining et al., 2020). Teachers should be involved as co-creator of learning opportunities for other teachers and for students (Dolan, 2008) creating a synergy as shown in Fig. 33.

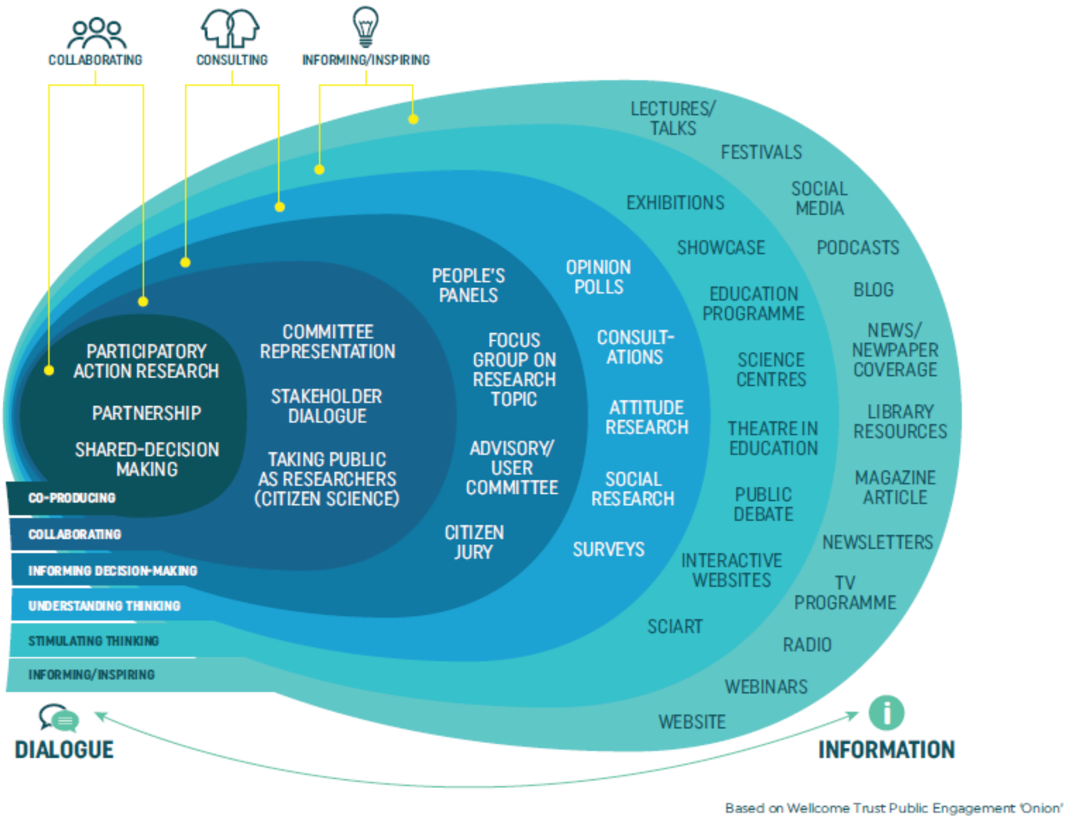


Fig. 32 Onion framework, adapted by UCD EPE team based on Welcome Trust model
(UCD, 2018)

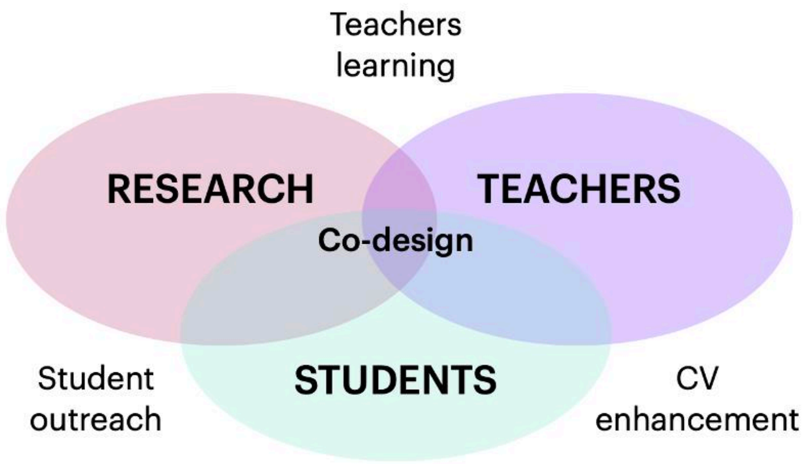


Fig. 33 Collaboration between experts and teachers for students (Dolan, 2008)

Even though being an expert in a subject does not necessarily mean knowing how to teach, it is the synergy among teachers and researchers/experts that can be more beneficial. Research suggests, in fact, the importance of experts' involvement in school. Experts can motivate learners and create connections between theory and the real world (Dolan, 2008).

Teachers can have a multiplier effect, Dewey said "Teachers are not just teaching children as individuals – they are helping children to live in society and shaping society as a whole" (as quoted by Pound, 2018). In participatory EPE programmes, teachers bring their ideas and expertise. Engagement opportunities based on design and co-design value teachers as professional contributors and defer from the scenario where teachers are given a script to follow to implement a programme in school. Including teachers in the dialogue promotes the integration of new knowledge into their curriculum and the creation of meaningful and usable tools and resources for them (Roschelle, Penuel and Shechtman, 2006). Co-design can be explained as a *collaborative design* *thinking* process in which people ask questions and find solutions together to improve their situation (Steen, 2013).

Moreover, open access information can enable best practices to reach and have a positive impact on far more people. UNESCO suggests that access to education could ensure a more inclusive knowledge society (Havemann, 2016). ICT improved and developed this possibility to provide online resources free for anyone. Open education is a way to engage more and more teachers and to promote sharing and learning together, representing a way to encourage a community of learners (Belawati, 2014).

Ultimately, understanding the effectiveness of an EPE programme needs the design of an evaluation framework that defines who the stakeholders are and what their expectations are. The evaluation is then related to availability and type of data collected, and how these data are analysed (Dolan, 2008).

2.9 Scoping literature review

2.9.1 Scoping literature review design

In educational research is possible to identify as distinct two processes: literature review and research. However, literature review can be viewed as a research process itself that requires a structured design to avoid bias and to ensure reliability as it is used to inform the research study. Therefore, a scoping review can be conducted beside a narrative review to outline a method in finding answers to a specific research question (Klaveren and Wolf, 2019). A scoping literature review was conducted which focused on the overarching research question and approaches I was the most interested in.

> **[RQ 1]** What are the characteristics of an Education and Public Engagement (EPE) action focused on teachers, for creating effective learning opportunities both for primary school teachers and children to promote Artificial Intelligence (AI) literacy and awareness?

I analysed my research questions using the Population, Intervention, Comparison, Outcome (PICO) framework (Sayers, 2008). It considers the population of the study, the intervention, the outcome, and the comparison (Sayers, 2008). For my study I used the PICO framework to understand the main themes to focus my scoping research (Table 2). The population included in my study are firstly primary school teachers and secondly children. The intervention is a learning programme for teachers based on co-design, TPCK, and constructionism. The expected outcome is children's awareness on AI through effective EPE actions focused on teachers. Derived keywords are listed in Table 3, and do not include the comparison theme because it is not of primary focus for this research.

Population / Problem	Intervention	Comparison / Context	Outcome
Primary school teachers Primary school Children	Co-design TPCK Constructionism	(Ireland) (Italy) (EU)	Children awareness of Artificial Intelligence

Table 2 PICO framework for scoping literature review

Primary school teachers	**Primary school Children**	**Co-design**	**TPCK**	**Constructionist**	**Artificial Intelligence**
Teachers	Children	Design	PCK	Hands-on	AI
Schooling	Young people		Framework	Experiential	AI for good
Teaching	Kids			Activities	Machine learning
Learning	K-12				Emerging technologies
					Data science
					Data analytics
					Data literacy

Table 3 Key words for my study

2.9.2 Databases searches

Searches were conducted in the following databases Scopus, ERIC, and Google Scholar. The researches were conducted using keywords in string together with AND horizontally and OR vertically (Table 3).

The first syntax used was: **Teach* AND co-design AND "Artificial Intelligence" OR AI OR "data literacy" AND construction* AND TPCK**

However, it was too narrow so I adopted a simplified one as follow:

Teach* AND co-design AND "Artificial Intelligence" OR AI OR "data literacy"

I conducted the searches on different databases (Scopus, ERIC and Google Scholar) on the 28/04/21. Research results are presented below in Table 4.

Database	**Research string**	**Results** (28/04/21)
Scopus	Teach* AND co-design AND "Artificial Intelligence" OR AI OR "data literacy"	15
ERIC	Teach* co-design "Artificial Intelligence" AI "data literacy"	155
Google Scholar	Teach* AND co-design AND "Artificial Intelligence" OR AI OR "data literacy"	72
Total references found		242

Table 4 Research results from different databases

2.9.3 Screening

I then conducted a screening of the 242 resources found using the criteria listed in Table 5.

Inclusion criteria	**Exclusion criteria**
Last 10 years (2012-2021)	Published before 2012
K-12	Not K-12 (higher edu, preschool)
Framework	AI as a tool to improve teaching and learning (sw)
Activities for teachers or children	Not programme for teachers or with teachers
Development programme	Thesis, opinion pieces

Table 5 Screening criteria

Title and abstract screening using exclusion criteria results in 10 references. In Fig. 34 is highlighted the scoping literature review process and results.

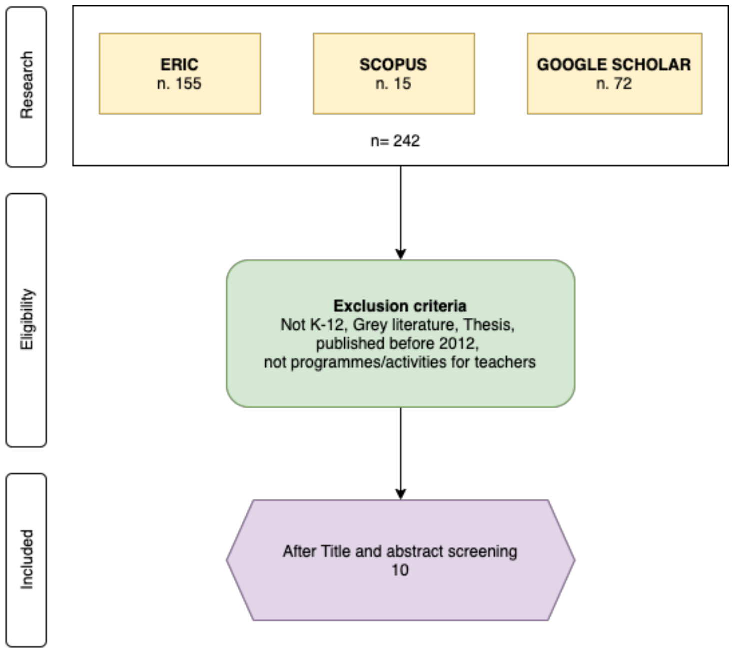


Fig. 34 Scoping literature review workflow with results

2.9.4 Analysis

The ten papers which remained following the review process were read in full and analysed. Particular attention was paid to the methodologies and frameworks used and the connections with the research questions.

1_Supporting teachers' technological pedagogical content knowledge of fractions through co-designing a virtual manipulative.
(Hansen, Mavrikis and Geraniou, 2016)

This study highlighted how co-designing resources for children can be an effective learning opportunity for teachers. Teachers are "agents of change" in teaching practices and part of a community. Teachers together with software developers designed digital online resources for children in relation to mathematics. Research methodology was iterative design-based research. While the study is focused on developing children's skills it also investigated design impact for teacher learning. Data were collected from small group discussions during the design sessions. The TPACK framework was used to analyse the data dividing teachers' reflections collected into topics (technology knowledge, pedagogy knowledge, content knowledge). The article concluded asking how such initiatives can impact teacher professional development.

2_Co-designing a conversational interactive exhibit for children.
(Candello *et al.*, 2020)

This study discussed co-design to create a museum exhibition on AI to engage children in informal learning. The group involved included participants with different skills and backgrounds. The methodology used was design-based research. Human centered and participatory approaches underpinned this study.

3_Co-designing machine learning apps in K-12 with primary school children.
(Toivonen *et al.*, 2020)

This research studied children's engagement in technology design as a learning opportunity. Children were involved as designers and creators. Tool used was Google Teachable Machine. Children were engaged first in an introductory session then in a brainstorming activity and through the whole design process. Participants were 12-13 years old children. The study highlighted the versatility and good functionality of Google Teachable Machine.

4_Engaging Teachers to Co-Design Integrated AI Curriculum for K-12 Classrooms.
(Brummelen and Lin, 2020)

The study investigated how K-12 teachers' considerations are addressed in designing AI curriculum and how AI can be integrated into core subjects within the curriculum. The research project consisted of a two day long online workshop with 15 K-12 teachers (from USA, Canada, Italy, Turkey and North Africa) of various subjects to design AI curriculum integrated with other subjects. During the workshop teachers were introduced to AI, asked to brainstorm potential links to core subjects and design a lesson plan that integrates AI and a non-computational subject. The study highlighted the need "*to collaborate with teachers when designing AI curriculum, as well as the potential for AI to be integrated into K-12 core curriculum*".

5_Creativity-focused Technology Education in the Age of Industry 4.0
(Cropley, 2020)

The study analysed the need for technological fluency based not only on computational skills but also on creativity and critical thinking to ensure best use of AI. The importance of "two dimensional" teaching of technology where both industry 4.0 skills and technology knowledge are included.

6_Educing AI-Thinking in Science, Technology, Engineering, Arts, and Mathematics (STEAM) Education
(How, Loong and Hung, 2019)

This paper recognised the importance for STEAM students to possess skills in AI and data literacy. It refers to "*AI-thinking*" as a skill that draws from mathematics and computing.

7_Data Science for High School Computer Science Workshop: Identifying Needs, Gaps, and Resources
(Baston et al, 2020)

This workshop highlighted the importance of data literacy for everyone to "*enlighten 21st century citizens*". This paper discussed definition of data science and data literacy and recognised the teacher engagement as a key aspect for moving forward.

8_Teaching Tech to Talk: K-12 Conversational Artificial Intelligence Literacy Curriculum and Development Tools
(Brummelen, Heng and Tabunshchyk, 2020)

Researchers ran a pilot study and a full study with 35 students recruited on a voluntary basis by 7 teachers. Students were from 6 to 12 grade (11-18 years of age). The project was 12,5 hours long online (through Zoom) programme (2,5 hours a day for 5 days). Day 1 introduced students to the tool (MIT App inventor extension), day 2 was on AI big ideas, day 3 Data were collected with surveys, students slide decks describing their final projects and debriefing discussion with teachers.

9_Designing AI Learning Experiences for K-12: Emerging Works, Future Opportunities and a Design Framework
(Zhou, Van Brummelen and Lin, 2020)

This paper reported an exploratory review of existing works. It suggested an extensive framework for AI in K-12 with eleven guidelines that include teachers' and parents' involvement, active children engagement, diversity and inclusion considerations, and AI in core curricula.

10_Learning machine learning with very young children: Who is teaching whom?
(Vartiainen, Tedre and Valtonen, 2020)

This study described an empirical work with a small group of children (6-9 years old). The study investigated participants reactions in engaging with Google Teachable Machine (machine learning web platform) in an informal setting. The study discussed how participants learn through teaching to a responsive tool and while tinkering with machine learning.

2.9.5 Conclusion

The scoping literature review highlighted how studies both for teachers and children relating to teaching and learning of AI are in their infancy. The papers identified were very recent, showing both an interest in the field and gaps in the literature regarding EPE on AI for teachers and children. The papers analysed stated the importance of the involvement of both teachers and children in AI literacy and show interventions with different tools and with different methodologies both online and face-to-face. Some of the studies which focused on AI literacy have not treated the methodology used to engage with teachers in much detail. Furthermore, only a few used co-design as an approach. Specifically, a gap emerged in relation to co-design with teachers for teachers.

The paper "*Supporting teachers' technological pedagogical content knowledge of fractions through co-designing a virtual manipulative.*" (Hansen, Mavrikis, and Geraniou, 2016) resulted to be aligned with this PhD study in relation to methodology. The researchers described a study based on design-based research and used TPCK framework in relation to mathematics. Hansen et al., 2016 highlighted that only a dearth of studies which were based on design research were also focused on teacher learning. From the results of the study emerged that involving teachers in design resources could be viewed as a professional development opportunity for teachers. Similarly, the study "*Engaging Teachers to Co-Design Integrated AI Curriculum for K-12 Classrooms"* (Brummelen and Liu, 2020) highlighted that designing AI curricula increased teachers' confidence and familiarity with AI. This paper also claimed that embedding AI into core subjects could represent a strategy to reach more students.

3. Research methodology

Embarking on a research study means developing knowledge in a specific domain. Therefore, it is important to be aware of personal mindset, way of thinking, and way of seeing the world to acknowledge that (Saunders et al., 2007). The research onion helped me structure this chapter. As argued by Guba and Lincoln (Saunders et al., 2007, p.100):

> *"Questions of method are secondary to questions of paradigm, which we define as the basic belief system or worldview that guides the investigation, not only in choices of method but in ontologically and epistemologically fundamental ways."*

Therefore, before starting to illustrate methods and approaches that are at the centre of the onion, there are outer layers to deepen first as ontology and epistemology. My view of the world and approach to this study is summarised, in Fig. 35 and discussed in-depth in this chapter.

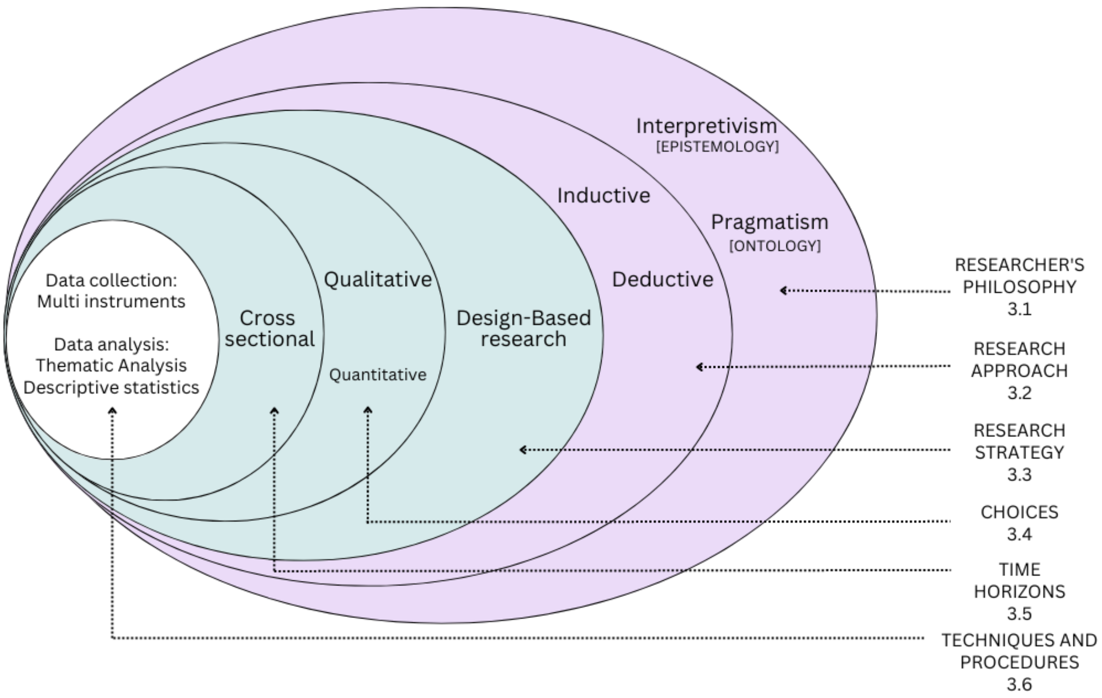


Fig. 35 My research onion, that is based on "The research 'Onion'" (Saunders et al., 2007)

3.1 Researcher’s philosophy

3.1.1 Constructivism

Epistemology identifies what is considered relevant and significant in a specific study or domain (Saunders et al., 2007). I acknowledge that my epistemology is **Constructivism**. Constructivism’s mother is interpretivism (Adom et al., 2016). I specifically see the complexity of a context or knowledge domain and I am particularly interested in empathetically understanding all the different participants’ points of view (i.e., teachers, experts in the domain, children) (Saunders et al., 2007). Constructivism’s points that knowledge and understanding of the world is constructed by people through experiences and reflection on those experiences (Honebein, 1996 as quoted by Adom et al., 2016). Learning happens when *“the learner discovers the knowledge through the spirit of experimentation and doing”* (Kalender, 2007 as quoted by Adom et al., 2016, p. 2).

3.1.2 Constructivist rationale

I was born in a family and country culture where challenges can be faced with creative and divergent thinking. With a strong passion for crafting and arts I could not imagine learning without doing. My region, Emilia Romagna, is home of automotive and automation industries as well as education vanguards too. After my bachelor's in Mechatronic Engineering, I started to engage with children in schools, libraries, and maker spaces with workshops and activities on creative technology and educational robotics. Though, when I first stepped into the classroom, I found the exact same environment I had memories of from my childhood. I was far from school for nearly ten years and barely nothing had changed. So, I started to think about how STEAM (Science technology Engineering Art Mathematics) activities could be a means through which started to bring into schools new approaches and methods. I began then to engage more and more with teachers and educators and now technology education and teacher learning are my deep interest and passions. Through my journey I learnt from teachers, makers and designers. My way of thinking about learning and living is therefore underpinned by design and constructionism. *Creating* is the way for me to learn in-depth and in a meaningful way. I consider myself the *designer* of my knowledge that I develop through "*objects to think with*" (Papert, 1980), which could be simple materials, programming languages, a project, or this thesis.

3.1.3 Pragmatism and transformative

Ontology frames how a researcher perceives reality (Saunders et al., 2007). It is **Pragmatism** that better describes my view, as I am more focused on what I can actually see and understand around me (Saunders et al., 2007). Specifically, the "how" and "what" questions influenced how I tackled my research problem (Creswell and Creswell, 2018). Moreover, interventions implemented during my study included design and co-design, that claim, in turn, pragmatism as a conceptual scaffold (Dalsgaard, 2014). I must acknowledge the **Transformative** paradigm as well even if it is not as dominant as the Pragmatic paradigm. Developing knowledge of emerging technologies, such as AI, in fact, can lead to developing awareness and critical thinking about it, enabling skills and abilities to challenge these new technologies and question, to a certain extent, our rights related to them (Craglia et al., 2018).

3.2 Research approach

The approach I adopted varied during my study. The research suggests that even though induction and deduction are often presented as divided approaches, mixing the two is not only feasible but also advantageous (Saunders et al., 2007). In the iterative design process of this study (PHASE 2, 3, 4) I mainly relied on **Deduction**, i.e., formulating a conceptual framework (teacher learning on AI) and testing it with data through several iterations (Saunders et al., 2007). The main reason for that was the need to better understand how to frame teachers' learning on AI and how to collaborate with them. To narrow the area to investigate I focused on testing the validity of constructionism, design and Technological Pedagogical Content Knowledge (TPCK) principles.

Towards the end of my study, on the other hand, my thinking was more **Inductive** (developing theory). With induction "*researchers use a series of empirical cases to identify a pattern from which to make a general statement*" (Mertens, 2018). I relied on induction especially in generating guidelines and writing the discussion and recommendations from an EPE perspective (how to better engage with teachers to promote AI literacy and awareness). In line with my epistemology though, I *"do not claim to offer an exact picture but rather an interpretive portrayal of the phenomenon studied"* (Charmaz, 2014 as quoted in Kennedy and Thornberg, 2018, p.5)

3.3 Research strategy

3.3.1 Design-based research

Unlike empirical research, DBR's aim is not to test hypotheses but rather to develop solutions that are improved iteratively. Last, DBR's ultimate goal is both the planning for the implementation of the solution and the refinement of design principles (Huang et al., 2019). DBR is an iterative and collaborative approach to educational research that emphasizes the development and refinement of educational interventions within authentic learning contexts (Christensen and West, 2018). There are several approaches to DBR in the literature. The model proposed by Reeves in 2006 effectively describes DBR in four stages (as shown in Fig. 36). This model appeared to be appropriate to frame my work as the aim of this study was to focus on co-creating with teachers a learning programme for teachers and children to promote the learning of AI big ideas. Moreover, Reeves's model captures a comprehensive reflection on the process and product to derive theoretical and practical insights (Christensen and West, 2018).

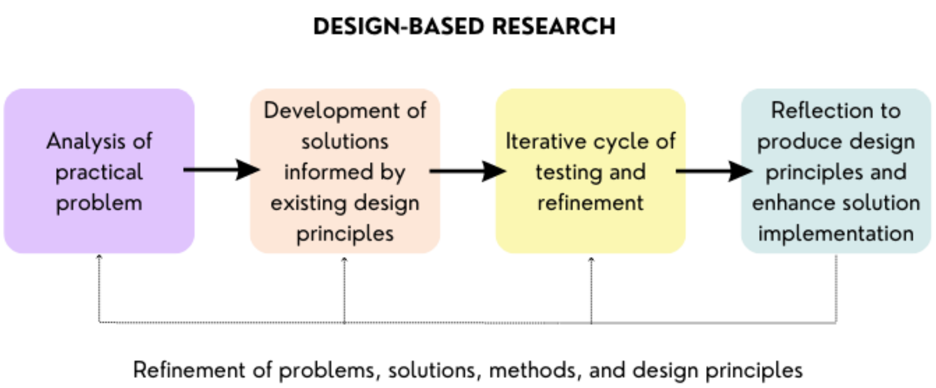


Fig. 36 Design research adapted from the Reeves model (Huang et al., 2019)

The first phase consists of the **analysis** of an educational practical problem, where researchers identify it and collect data to understand the educational setting's context and needs. The **design** phase follows, where potential solutions or interventions are generated based on the analysis. The design is then **iteratively implemented, tested, and improved** in context. Each iteration can have its own research questions and evaluation that allow researchers to conclude if the project meets research expectations or if another iteration is required (Plomp and Nieveen, 2013). Finally, in the last phase, the researcher should **reflect** on the process to draw both theoretical and practical recommendations (Christensen and West, 2018).

Even though DBR is an innovative approach to research that enhance design interventions and theory, merging designers' competencies and research-derived knowledge to improve interventions and theory, engaging in DBR may present some challenges (Christensen and West, 2018). Firstly, DBR's main issue is related to the inconsistency of its use in academia which leads to different uses of terminology and a lack of definition and clear process guidance. Secondly, the multitude of roles the researcher adopts is demanding and can be problematic, from being the researcher and designer of the solution to being the manager and evaluator of the process (Christensen and West, 2018).

I decided to use design as a strategy for my research primarily because it aligned with my research objectives: **having a real impact and solving real problems, with a long-term effect** (Plomp and Nieveen, 2013). Design-based research, thanks to its creative and iterative process, encourages learning and building on knowledge, improving at each stage. It is also a framework for achieving useful and practical outcomes (Edelson, 2002). Furthermore, educational design research serves as a research approach for tackling challenges in educational practice, particularly when no existing guidelines offer step-by-step solutions and it is a method tailored to explore and develop innovative strategies to address these complex problems effectively (Plomp and Nieveen, 2013).

According to Plomp and Nieveen (2013), the outcomes of a high-quality educational design research study should possess certain characteristics. Firstly, they should be **relevant**, which was achieved in this study through comprehensive narrative and scoping literature reviews that deepened the understanding of existing knowledge and identified a gap in the literature regarding guidelines and methodologies for engaging teachers in emerging technologies, specifically AI. The study's outcomes are valuable to both teachers and AI experts. Secondly, the outcomes are **consistent**. To ensure construct validity each study's phases were designed to address each research question and bespoke data collection instruments were designed to gather different types of data for each cohort of participants and specific context. Furthermore, the outcomes are **practical**, directly providing a ready-to-use learning programme and resources on an open-access website focused on AI for teachers on a national and international level, as well as an EPE toolkit for research groups working on emerging technologies. Lastly, the study has proven to be **effective**, with its outcomes enabling teacher advisors to independently conduct an AI course for new teachers and the publication of EPE guidelines and a learning program on an open-access website. Additionally, the findings informed professional learning workshops for post-primary school teachers as part of the European AI4T (AI for and with teachers) project, demonstrating the study's potential for widespread impact.

3.3.2 Research questions

This research aims to identify what needs to be included in an EPE framework designed for research groups working on emerging technologies, to ensure a long-term and effective dialogue with the general public. The focus of the research is on collaborating with teachers to better understand how to engage with them to enable them to learn about AI and develop the competencies needed to create meaningful learning opportunities for children. As it is of vital importance to engage people from a very young age to build solid and valuable foundations of our "*Onlife*" culture, in order to be citizens who are aware of what is shaping the digital era now and for the future (Floridi et al. 2018 and EU, 2015).

The overarching question for my research has been developed on the structure of a typical designed-based research question (Plomp and Nieveen, 2013): 'What are the characteristics of an <intervention X> for the <purpose/outcome Y> in <context Z>?'. Where the <intervention X> is an EPE action focused on teachers, the <purpose Y> creating learning opportunities to promote AI literacy and awareness in the context of upper primary school teachers and children. Therefore, the overarching question of this study is:

[RQ 1] What are the characteristics of an EPE action focused on teachers, for creating effective learning opportunities both for primary school teachers and children to promote AI literacy and awareness?

To tackle this question, I designed a research study based on multiple iterations. Consequently, I defined narrower and different research questions for each iteration, as follows. Findings from each PHASE informed the following one from PHASE 2 to 4. PHASES 5 and 6 aimed to be a proof of concept and addressed [RQ 1]. PHASE 1 focus was on literature review and developing research skills and competencies.

[RQ 2] Can a short online introductory programme, focused on AI key ideas and competencies, underpinned by the TPCK (Technological Pedagogical Content Knowledge) framework and constructionist learning principles, be an effective way to engage and develop preservice teachers' AI literacy?

Where effective engagement for preservice teachers is defined as follows:
[T1] It enables them to develop their own understanding of AI key ideas
[T2] It encourages them to positively and successfully engage with AI tools that they can use with children
[T3] It allows them to realise the importance of teaching AI in school

[RQ 3.1] Can a programme of professional learning underpinned by the TPCK framework and constructionist learning principles effectively engage teachers in developing their own understanding of AI?

[RQ 3.2] Can a design-based approach foster teachers' content and pedagogy knowledge of AI?

[RQ 4.1] How can we design learning opportunities for students to enable them to creatively and collaboratively explore AI key ideas and competencies within the classroom?

3.4 Choices

Most data collected for this study were **qualitative**: data collection instruments and techniques that generate or use non-numerical data (Saunders et al., 2007). As this study was focused on a new area, qualitative data was considered the best choice to better investigate participants (teachers and children) developing knowledge and learning. Qualitative data gave me the opportunity to dive deep into teachers' ideas and beliefs. Moreover, since I engaged with small cohorts, qualitative research methods were more suitable. Limited quantitative data were collected through online survey.

My research choice for this study was to predominantly collect and analyse qualitative data. Quantitative data, instead, were a large minority and I used them in a descriptive/qualitative way, not enough to consider this study based on mixed-methods. Therefore, I can conclude my research choice was qualitative, specifically, a **multi-method qualitative study** (Saunders et al., 2007). It is important to acknowledge that each method has intrinsic limitations and assumptions that influence the results. Consequently, research suggests using different methods to try to minimise the "method effect" (Saunders et al., 2007). Methods used for this research are described later in this chapter.

3.5 Time horizons

Lastly, the time horizons for my study were **cross-sectional**. I studied the field in a specific historical time, and I worked on different phases and iterations in the range of four years of my study. However, I was not interested in tracking changes or development regarding the same cohort over time (Saunders et al., 2007).

3.5.1 Iterations

A **step-by-step overview** of my research process is described in Fig. 37. In this study, preliminary research was conducted to build researcher's knowledge and outline a research design with a holistic view of AI, EPE, and Learning (PHASE 1). This step was crucial to be able to narrow my research, define my area of investigation and identify the best research approach and techniques (Mackenzie and Knipe, 2006). I then developed a prototype of a learning programme on AI and Data for teachers that I piloted with preservice teachers. I tested and evaluated it with two cohorts of preservice teachers (Dublin City University and Milan Cattolica University students) in PHASE 2. Data gathered from this phase enable me to develop a more comprehensive learning programme for primary school teachers to promote AI and data literacy and awareness. In PHASE 3, 5, and 6 of this study, I iteratively tested the developed learning programme with teachers and teacher advisors. Moreover, a learning programme for children co-created with teachers in PHASE 3 was also implemented in school during PHASE 4.

During each phase of the project, a set of key activities were undertaken. These activities encompassed the design or refinement of the intervention and data collection instruments, the implementation of the intervention itself, the collection of relevant data, the subsequent analysis of that data, and finally, the documentation of the findings. These findings played a crucial role in informing and shaping the subsequent iterations of the project. By engaging in this comprehensive and iterative process, the project aimed to continuously improve and enhance its intervention and data collection methods, ensuring a robust and informed approach throughout its various phases.

In parallel, I started to disseminate my work by writing papers (on PHASES 2, 3, and 4) and participating in conferences to share my work. I had the opportunity to explore a different international context through a study visit in Slovenia with the Slovenian Ministry of Education, the University of Lubiana, and Maribor, IRCAI (UNESCO Centre for AI).

Lastly, reflecting on the whole process I could develop guidelines and frameworks on EPE and teacher learning of AI, which are discussed in detail in Chapter 6. The final part of my Ph.D. was then focused on writing the thesis and working on creating a printable handbook for teachers and an open-access website to share the handbook, resources, and guidelines.

3.5.2 PHASE 1 - Learning in context

This study is focused on learning and finding the best way to engage the public through creating learning opportunities for teachers and children to raise awareness of AI. I as a researcher am a learner as well. Therefore, I was privileged in this first phase to participate in postgraduate modules, workshops, and conferences to develop my understanding of both the academia/research field and the AI domain. I had the hands-on opportunity to foster my communications skills through participation in the "Tell it straight" competition. I developed a two-minute video on my research for a general audience where I was nominated among the finalists (Amplo, 2021). As a learner myself, being part of a "*community of learners*" gave me the opportunity to gain invaluable insights from a network of colleagues and experts ranging from AI, education, and ethics fields. In PHASE 1 I learned in context and conducted preliminary research with a narrative literature review on AI, machine learning, and EPE and a scoping literature review to narrow the study and define research questions. I outlined my research design and submitted it for ethical approval. PHASE 1 empowered me with the tools to conduct design research and fostered my skills and knowledge of AI and EPE.

RESEARCH STUDY STEPS	PHASE 1
Broad notion of the discipline, of my paradigm, of research methods	Building a network with experts. Modules on research methods and academic writing.
Determine my area of investigation	Education and Public Engagement through and with primary school teachers and children to promote Artificial Intelligence and Data (AI) literacy and awareness
Identify the approach	Design-based research
Conduct literature review	AI (narratives, computer science, machine learning and reasoning, AI in Education), Data, Learning, Teacher learning
Determine data types	Qualitative
Ethical approval	The research proposal that was approved by the Dublin City University Research Ethics Committee, reference number **DCUREC/2021/043**

	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
Identify: when and where data come from	GROUP A-B **Pre-service teachers (DCU-Italy)**	GROUP C **Primary school teachers**	GROUP D-E **Teachers** with 9-12 years **students**	GROUP C-D **Teachers** and teacher **advisors**	GROUP C-F **Teacher advisors** and **STEM teachers**
Choose and design data collection instruments	Pre-Survey Post-Survey Mindmaps Worksheet Notes	Pre-Survey Post-Survey Mindmaps Focus group Notes	Interviews Design Journal Observation	Focus group Notes	Interviews Observation
Intervention design	**Learning programme for teachers first draft**	**Extensive learning programme for teachers**	**Programme for children on AI and Data**	**Replicable and scalable learning programme for teachers and children**	
Intervention and data collection	Pilot programme online for pre-service teachers	Programme for teachers online and live co-design	Teachers implemented in primary school classes	PDST advisors ran autonomously a programme for teachers	
Data analysis and writing findings	Extensive programme needed, Data AI for good focus, experts	Resources, support, AI integrated with curricular subjects	Time needed to "think-AI", basics of computational thinking/coding could help	Confidence, empowerment, design support	

Outcomes	**Learning programme for primary school teachers and children on Artificial Intelligence and Data integrated with curricular subjects.** **Handbook** for teachers with resources and **Website**. **Guide lines** on Education and Public engagement on AI through co-creation with teachers.

Fig. 37 Step-by-step overview of my study

3.5.3 PHASE 2 - Pilot with preservice teachers

In PHASE 2 I designed and delivered a first intervention with preservice teachers, a programme of two workshops online (2 hours + 2 hours) on AI for university students. As outlined in the most recent initial teacher education standards (The Teaching Council, 2020), student teachers should have opportunities to explore new and emerging technologies. The pilot workshop I designed, focused on AI, was appropriate to be incorporated into the SG403 module of the Digital Learning Specialism, which is coordinated by Prof. Deirdre Butler. Furthermore, it was offered as an extra curriculum for students of Università Cattolica Sacro Cuore, Milan, future teachers. This pilot online program with preservice teachers was designed to be a learning opportunity to develop university students' own understanding of AI using a constructionist approach as described in Chapter 4. I designed the content of the module and the instruments to collect data. Data were collected through pre- and post-survey, students' mind maps, and researcher's self-reflection journal. Data were analysed to redesign the workshop format, content, and tools.

GROUP A: DCU STUDENTS (Ireland)	**GROUP B:** CATTOLICA STUDENTS (Italy)
Pre-service teachers: DCU students, Final year students in Bachelor of Education programme (Primary) Students enrolled in the module SG403- Designing, Learning with Digital Technologies. Age: > 18 years	Pre-service teachers: Università Cattolica del Sacro Cuore, Milan Students from Bachelor of Education (Primary school teachers) Age: > 18 years
First workshop participants: 19 Second workshop participants: 21	First workshop participants: 15 Second workshop participants: 11

Table 6 Participants in Phase 2

Students were asked to fill in a pre-survey and a post-survey to gain insights on how perception, knowledge, and confidence can change following the intervention. Qualtrics™ software was used to generate the surveys and collect the data. The surveys (Appendix D) included Likert scale questions and open-ended questions on AI as a technology and how it affects our lives and teaching, i.e. *“Can you describe the relationship between data and AI?”*, *“What was the aspect of the programme you enjoyed the most and why?”, “Artificial Intelligence is a technology based on Mathematics”, “Artificial Intelligence is a technology based on Coding”, “I think AI is relevant for my course of study”.* During the workshops, participants were asked to use a mindmap to take notes as mindmaps are useful to see connections between ideas, how ideas evolve, and how thoughts and concepts develop. (Kara, 2015). In addition, participants were encouraged to draw and sketch to share their ideas, as “draw-and-write” techniques allow participants to express themselves (Kara, 2012). Moreover, students were engaged during the sessions using shared Google Jamboards (blank participatory digital canvas where anyone can contribute by writing text or adding pictures). Finally, the researcher took notes during discussions and feedback. Data collected are summarised in Table 7.

GROUP A: DCU STUDENTS (Ireland)	**GROUP B:** CATTOLICA STUDENTS (Italy)
First workshop participants: 19 Second workshop participants: 21	First workshop participants: 15 Second workshop participants: 11
DATA COLLECTED • Pre- survey • Post- survey • Mindmaps • Series of self-directed challenges with open-ended self-reflection questions • Shared Jamboards • Researcher’s notes	**DATA COLLECTED** • Pre- survey • Post- survey • Mindmaps • Shared Jamboards • Researcher’s notes

Table 7 Data collected during (Phase 2)

3.5.4 PHASE 3 - Learning programme for teachers

In PHASE 3 I designed an improved learning programme for teachers underpinned by the literature and findings from data analysis of PHASE 2. The learning programme for teachers was intended to give teachers all the tools and knowledge needed to create effective learning opportunities for children on AI. I tested the prototype with a small group of teachers drawn from the Professional Development Services for Teachers (PDST) advisors and associates. The expected outcomes from this phase were as follows: data on the learning programme itself collected through pre- and post-survey, mind maps and researcher (as a participant) observation notes and focus groups interviews; tested prototype of a learning programme for teachers (a blended course with an interactive introduction on the content run online and a design session in person with focus group interviews of teachers working in groups); activities for children on AI co-designed with teachers. The latter was used in PHASE 4 in school by a subgroup of teachers of this phase. A final co-design session on the programme was then part of PHASE 5. Data analysis was conducted to iteratively improve the teachers' programme and resources teachers could use in the classroom with children. PHASE 3 findings enabled me to start working on a web platform to support teachers.

GROUP C: PDST teachers
4 associates (one was a special education class teacher, one was a learning support teacher, and one was a home liaison teacher) and 2 advisors from PDST
Participants first workshop online: 6 Participants second workshop online: 6 Participants third workshop online: 4 Participants final workshop face-to-face: 6

Table 8 Participants from GROUP C

Data collected from this phase were qualitative, and from diverse sources. To collect data bespoke data collection instruments were designed (Appendix D). Qualtrics™ was the software used to generate the surveys and collect the data. Pre- and post-surveys aimed to gain insights on how perception, knowledge, and confidence can change following the intervention. The surveys included open-ended questions and some multiple-choice questions on AI and on the programme (i.e. Can you describe the relationship between data and AI?, "What was the aspect of the programme you enjoyed the most and why?). During the first online session, teachers were encouraged to start a mind-map that were then collected. A "mid-survey" was sent to the teachers after the third online session to gather feedback and insights on the first part of the programme that was conducted online. Questions were designed to highlight learning outcomes achieved so far and to investigate teachers' perceptions of the programme (i.e. Describe machine learning workflow in your words, Was there a good balance between lectures and hands-on activities?).

A focus-group was held at the end of the one-day face-to-face session. A set of questions was prepared for it with the intention of keeping the conversation open and free flowing in order to capture participants' thoughts. The aim of the focus group was to collect some final considerations regarding the learning programme in general and to deepen the efficacy of the design session. The focus group interaction was recorded and then transcribed. In addition, activities designed by the teachers in pairs were collected at the end of the face-to-face session. I took notes during the discussion and feedback sessions.

3.5.5 PHASE 4 - Implementation in school

In PHASE 4 a small subgroup of teachers involved in PHASE 3 implemented the co-design AI programme with one class of children in their school. The purpose of this stage of the implementation was to understand how children engage with key ideas and resources in order to inform the redesigning of the final stage of the AI learning programme for teachers. Data are collected through teachers' observation (framework provided) of how the AI was implemented in their classrooms, and individual semi-structured interviews with the sub-group of teachers from PHASE 3. Data were analysed to inform the re-design and improvement of the AI programme.

GROUP D: PDST teachers	**GROUP E:** Primary school students
Sub-group of PDST teachers (GROUP C) from phase 3. Age: > 18 years	Primary school students from schools that the teachers (GROUP D) from Phase 4 are teaching. Age: 9 - 12 years
Participants: 3	Participants of the case study with teacher A: 20

Table 9 Participants from GROUP D and E

Bespoke data collection instruments were designed to gather feedback and insights from both the students and the teacher. Qualitative data were collected through an observation framework which was designed to help the teacher to describe the experience in class. A design journal template was designed and provided to students to be used during the design sessions to keep track of their ideas. And lastly, a semi-structured interview was conducted with the teacher at the end of the programme.

The observation framework provided to the teacher consisted of a one-page template that the teacher filled in before, during, and after each session of the programme. At the top of the template, the teacher specified the title of the activity. Then during the workshop, the teacher was asked to note examples of children's questions or reflections shared during the activity. The last part of the template was focused on a reflection from the teacher which was written after the session. Some prompts were given e.g., any important aspects to highlight (including feedback on the activity, anything that needs to be changed), one thing your children really enjoyed about this activity. Some of the semi-structured interview questions were listed upfront as a support for the researcher. During the interview, conducted online, the researcher tried to create a comfortable space for the teacher to share ideas. Questions were focused on the programme implementation, on the programme itself, on children's perspective and learning, and on teacher experience in leading the programme. Lastly, a printed design journal was provided to students during the design sessions as a scaffold for the design process. Prompts were written as simple tasks from finding ideas to designing a solution, as listed in Table 10.

DESIGN JOURNAL FIRST PAGE	DESIGN JOURNAL SECOND PAGE
RESEARCH AND DEFINE Brief description of the problem you would like to solve Target (for whom)	**PROTOTYPE** Describe your solution in detail Describe the dataset you need
IDEATION Our solution (brief description, drawings/ sketches)	

Table 10 Description of the Design journal template

3.5.6 PHASE 5 - Co-design

Teachers who implemented the AI programme in school reported back to the entire cohort of teachers involved in PHASE 3. A co-design session face to face was organised to redesign an improved learning programme for children and teachers. Data were collected with researcher notes and individual interviews with teachers who implemented the programme in school. Data analysis was conducted to finalise the format of the programme for teachers before sharing content (open source) with the public (website) and making all the learning resources developed available for the PDST to include in their Digital Learning development modules for teachers. Data collected during this intervention were Jamboards and recordings of the focus group, transcribed.

GROUP C: PDST teachers
1 advisor from GROUP C and one teacher associate from GROUP D

Table 11 Participants in Phase 5

3.5.7 PHASE 6 - Proof of concept

The last iteration of the design cycle was a proof of concept for a scalable and replicable learning programme for teachers in relation to AI, that in the future it could be run on a larger scale. Two PDST advisors who participated in PHASES 3 and 5, with my initial support, ran autonomously a one-day long workshop on AI on their own with a completely new cohort of teachers. Most of the material and resources were prepared upfront based on previous phases. Slides and speaker notes were also designed to support the trainers. It was the opportunity to test some of the activities co-designed as part of the development of the handbook for teachers. Data on this experience were collected through a final focus group with the advisors and their written observations, together with pre- and post-surveys completed by the participants.

GROUP C: PDST advisors	GROUP F: PDST STEM advisors
Advisors from GROUP C Age: > 18 years	New cohort of PDST advisors with background in STEM education. Age: > 18 years
Participants: 2	Participants: 11

Table 12 Participants in Phase 6

Following the course provided to the teachers (GROUP F), I gathered data with a survey (Appendix D), collecting 10 responses from 11 participants. After the programme, I also met Advisors A and B (who led the programme for teachers Group F) for a focus group. This was recorded, transcribed and analysed.

3.5.8 Communicate findings

The final research thesis documents the whole education design research process to develop EPE guidelines to engage with teachers and children on emerging technologies. An open-access website (teachingAI.eu) provides resources to support teachers in developing learning opportunities for students on AI. A handbook for teachers was designed and printed but also made available online on the website. The website also includes short videos on research on AI for good from experts. Guidelines on how to better engage teachers on emerging technologies are part of the website and open access. These guidelines could potentially support research groups and policy makers world-wide who are working to provide opportunities to raise awareness of emerging technologies.

To conclude, Fig. 38 represents an overview of the timeline of my Ph.D. study showing the different phases of the process, from 2019 to 2023.

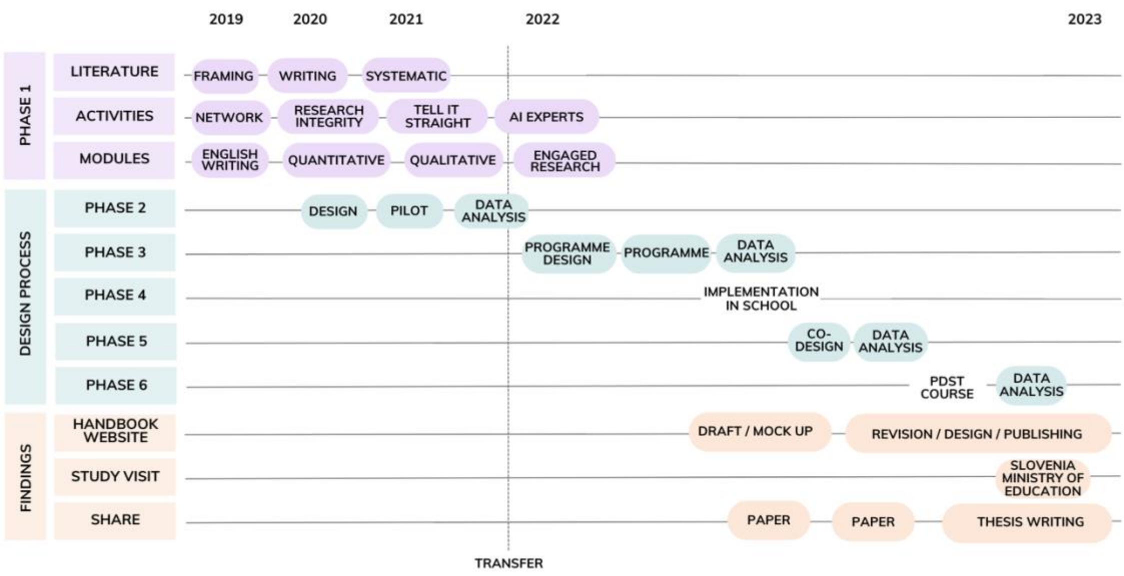


Fig. 38 Ph.D. study timeline

3.6 Data collection instruments

Constructivist qualitative research encourages the use of multiple methods to dig deep into participants' understanding, ideas, and beliefs from different perspectives (Maxwell, 2018). All the instruments used are listed in Table 13 under each of the four basic types of qualitative research procedures: observation, interviews, documents, and audio-visuals or digital materials (Creswell and Creswell, 2018). Each type of procedure has its own strength and weaknesses (Creswell and Creswell, 2018), as illustrated in Table 13.

I decided to go beyond observations and interviews with other forms of data to gather the information that might be missed (Creswell and Creswell, 2018). I specifically, designed reflective questions in worksheets (PHASE 2), lesson plans template (PHASE 3), and design journals (PHASE 4). Moreover, I used a shared digital canvas to engage with participants (PHASE 2, 3, 5) and collected mind maps (PHASE 2) I also took pictures (PHASE 3) and asked participants to take them when I was not present (PHASE 4 and PHASE 6). I also used surveys (PHASE 2, 3, 6) with a qualitative approach to better illustrate later in this chapter.

Data collection procedures	Instruments used	Advantages	Limitations
Observation	• Notes • Observation frameworks	The researcher can experience with participants and record insights (I also asked teachers "as researchers" to observe children in class, in PHASE 4).	Researchers can be felt as intrusive and gaining a positive rapport might be challenging (this improved collaborating with the same teachers, PHASE 3, 4, 5, 6).
Interviews	• Semi-structured interviews • Focus groups • Survey	Interviews were useful when I could not directly observe participants (PHASE 4, 6). Surveys were useful to gather data on ideas and prior knowledge and feedback on programmes (PHASE 2, 3). With focus group I encouraged discussion and reflection (PHASE 3, 6).	These instruments provide information filtered by the interviewees. It is not always possible to conduct interviews in the field. In the presence of the researcher responses might be biassed and lastly, not everyone is good at articulating and communicating.
Documents	• Worksheets • Mind-maps • Lesson plans • Design journals	The researcher can gather written words from the participants. Represents data to which participants have given attention. Data can be accessed by the researcher at any time and does not need a transcription.	Not everyone is equally articulate and perceptive. Materials may be incomplete. Requires scanning (I collected pictures of sheets).
Audiovisual or digital materials	• Photographs • Canvas	Provides an opportunity for participants to directly share their reality with pictures. Digital collaborative canvas is creative in that it captures attention visually.	May be difficult to interpret. The presence of an observer may be disruptive and affect data.

Table 13 Data collection procedures and used instruments, with their advantages and limitations (Creswell and Creswell, 2018)

Instruments for data collection were designed and chosen for each PHASE of the study to better address research questions (Mackenzie and Knipe, 2006). Data collected in each PHASE and for which cohort of participants are listed in Table 14 and Table 15. **The data collection instruments used are reported in Appendix D.**

PHASES	Cohorts involved	Data collection
PHASE 1	Developing researcher's knowledge	n.a.
PHASE 2 Pilot with preservice teachers	**GROUP A - Preservice teachers (Ireland)** Preservice teachers, Dublin City University: Final year students in the Bachelor of Education programme, enrolled in the module SG403-Designing, Learning with Digital Technologies. Age: > 18 years	• Survey (pre, post) • Mind maps • Shared Jamboard • Researcher's notes
	GROUP B - Preservice teachers (Italy) Preservice teachers: Università Cattolica del Sacro Cuore, Milan. Students from Bachelor of Education (Primary school teachers). Age: > 18 years	• Survey (pre, post) • Mindmaps • Shared Jamboard • Researcher's notes
PHASE 3 Teacher learning programme	**GROUP C – Teachers** Teachers from Professional Development service for teachers (PDST) associates and advisors. Age: > 18 years	• Survey (pre, post) • Mind maps • Focus group • Lesson plans • Researcher's notes

Table 14 List of cohorts involved during PHASE 1, 2, 3 and data instruments used to collect data

PHASES	Cohorts involved	Data collection
PHASE 4 School implementation	**GROUP D** – **Teachers from Group C** Sub-group of PDST teachers (GROUP C) from PHASE 3. Age: > 18 years	• Observation frameworks • Interviews
	GROUP E – **Students** Primary school students from schools that the teachers (GROUP D) are teaching. Age: 9 - 12 years	• Design journals
PHASE 5 Co-design	1 PDST teacher advisor from **GROUP C** and 1 teacher who implemented in school from **GROUP D**	• Researcher's notes • Focus group
PHASE 6 Proof of concept	**GROUP C** – PDST advisors Two teacher advisors from GROUP C Age: > 18 years	• Observation frameworks • Focus group
	GROUP F – Teachers STEM teachers from PDST with two teacher advisors from GROUP C. Age: > 18 years	• Survey (post)

Table 15 List of cohorts involved during PHASE 4, 5, 6 and data instruments used to collect data

3.6.1 Observation

I took notes during the phases of the study using pen and paper but I also wrote digitally and sometimes recorded reflections right after the interventions. I conducted observation shifting positions from participant to observer (Creswell and Creswell, 2018) during the learning programme for teachers which I led in PHASE 2 and 3, taking notes both digitally and on paper and also being part of the co-design in PHASE 3 and 5.

I designed a bespoke observation framework for teachers to use in school as a word document that could be either printed or filled in digitally (PHASE 4). Classroom observation is a method to investigate teaching and learning effectiveness in the classroom. The designed framework consisted of open-ended questions to lead teachers' observations and support them in taking notes (OLeary, 2020). Examples of prompts are:

- *Example of children's ideas/reflections on the tools used*
- *Example of children's ideas/reflections on AI big ideas*
- *What did your children learn?*
- *Anything important to highlight (including feedback on the activity)*

3.6.2 Interviews

Semi-structured interviews also called in-depth interviews are one-to-one discussions, with questions prepared upfront. However, in this interview, the researcher is free to change the questions' order and rephrase them if needed depending on the responses (Ritchie and Lewis, 2003). Therefore, I tried to be open-minded and prepared for unforeseen outcomes. I considered the interviewees as "experts" of their experiences. Interviews were used with teachers who participated in PHASE 3 programme and were involved in PHASE 4 with their trial in school.

Focus groups represents an opportunity to see how people reflect and share ideas on a topic during a group conversation (Ritchie and Lewis, 2003). So, I conducted focus groups with small groups of teachers (after PHASE 3, 5, and 6). I prepared some questions in advance but then again as for the interviews I let participants freely express their thoughts and views and build on their responses. Rechie and Lewis, 2003 suggested that in the interview structure, there should be a question that leads to open the discussion, questions to create a positive and non-threatening atmosphere moving from a general to narrower topics and focused on feelings and personal views, and finally, wrap-up questions that can prompt participants to share a summary of their experience and conclude the discussion in a positive way the whole discussion (Ritchie and Lewis, 2003). Below are my questions prepared upfront for the focus group conducted in PHASE 3 with teachers.

Example of opening question:

1. Did you find that the design process of designing the activities helped you to understand better AI key ideas?

From general to narrower questions:

2. In which way the design process helped you learn more about AI?
3. Did this design session help you to see how AI can be integrated into subjects?
4. What was the challenge in designing activities that integrate AI into standard subjects?
5. Did you appreciate your role as expert?

Wrap-up question:

6. Did you enjoy being part of the design process and not receive something prepared by others?

Surveys are often associated with quantitative research methods only, however, a survey can be used to gather valuable qualitative data if underpinned by qualitative research values. A survey can include open-ended questions in which participants can reply in their own words, representing a valuable and flexible instrument to gather in-depth data (Braun et al., 2021). Online surveys were used for PHASE 2 and 3, phases that involved adults (preservice teachers and teachers). Moreover, they were used as a practical instrument to use in the online setting. The first draft of the online pre and post-survey were piloted in PHASE 2 and then revised for and in PHASE 3 and 6, online qualitative surveys often require an iterative design process, through testing and refinement (Braun et al., 2021). In Table 16 presents an example of the development of the same question through a number of iterations.

The qualitative part of the survey consisted of questions crafted to cover some specific topics (i.e. key ideas understanding, and preconceptions) and to investigate ideas and beliefs, examples are “Can you name one thing or more that you use in your daily life that uses some kind of AI system?” or “Why do you think we should introduce AI to children?”

	Description of changes	**Question**
PHASE 2	Likert scale question	“Nowadays Artificial Intelligence (AI) is more intelligent than humans. Strongly disagree (We are very far from there) Strongly agree (We are nearly there)”
PHASE 3	From Likert scale question to open ended question	“Do you think nowadays Artificial Intelligence (AI) is more intelligent than humans?”
PHASE 6	I introduced the use of the world “articulate” to prompt reflections and helped in collecting in-depth responses.	“Do you think nowadays Artificial Intelligence (AI) is more intelligent than humans? Articulate”

Table 16 Example of a survey question development

Together with qualitative open questions I also included some multiple-choice questions and Likert-scale questions to describe a trend in the cohorts involved. Variables were chosen to describe ideas and investigate understanding.

The majority of the variables were therefore categorical and ordinal. Categorical variables (from multiple-choice questions) were used to collect information on teachers’ understanding and levels of knowledge. Some questions allowed us to select more options as the one in Fig. 39 while other questions allowed only one answer as in Fig. 40. Surveys questions are included in the Appendix D.

Ordinal variables were used to collect and investigate teachers' opinions and feedback with different scales of acceptability or agreement. Two examples from Qualtrics™ below, in Fig. 41 and Fig. 42. The software used to create and share surveys was Qualtrics™. Where I could test the surveys, have feedback on them, and personalise the layout.

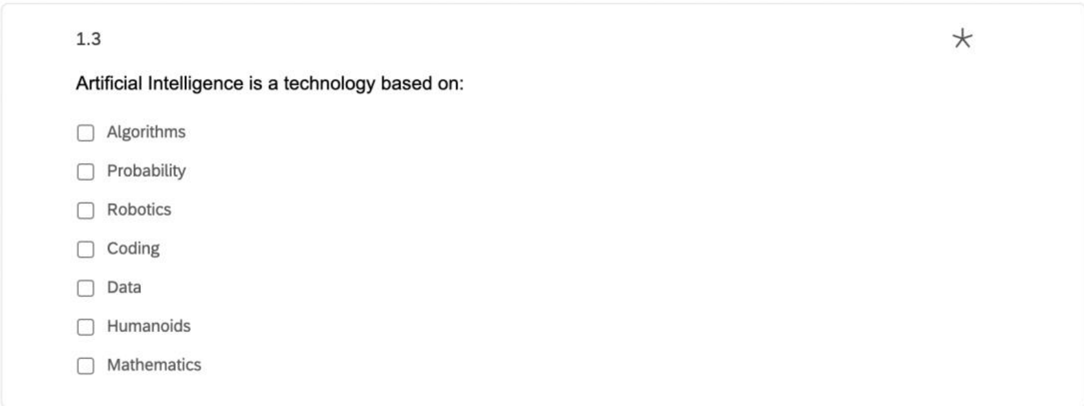
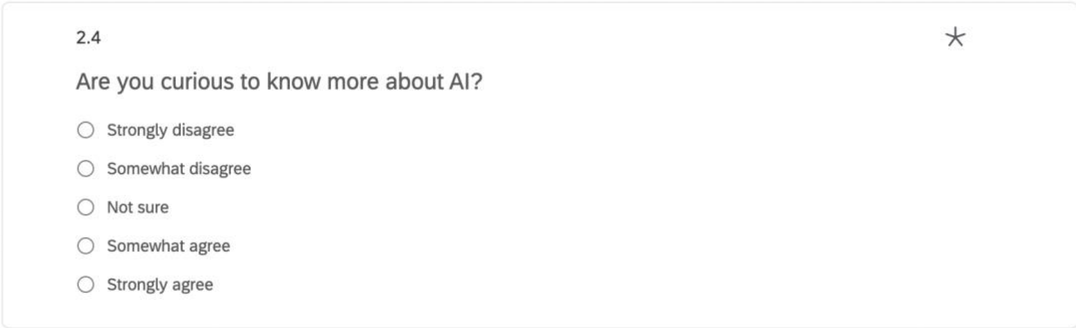


Fig. 39 Multiple choice example

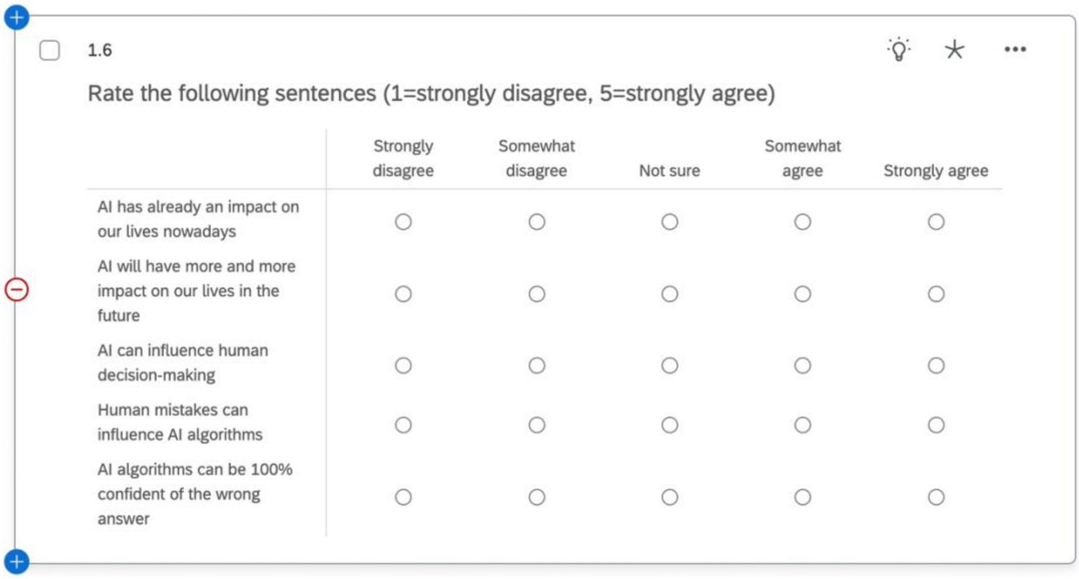
Fig. 40 Categorical variable example in a question that allowed only one answer


2.4

Are you curious to know more about AI?

- Strongly disagree
- Somewhat disagree
- Not sure
- Somewhat agree
- Strongly agree

Fig. 41 Example of ordinal variable


1.6

Rate the following sentences (1=strongly disagree, 5=strongly agree)

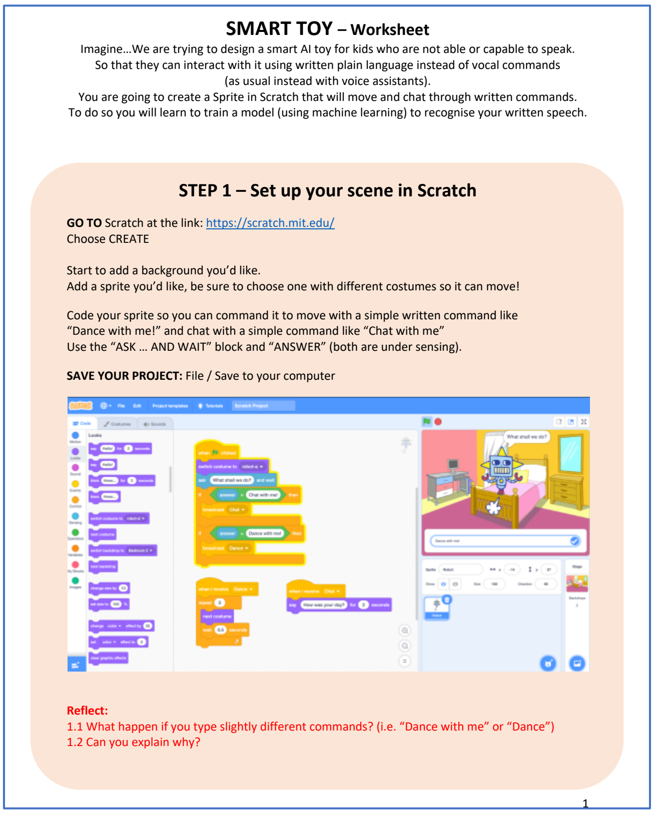
	Strongly disagree	Somewhat disagree	Not sure	Somewhat agree	Strongly agree
AI has already an impact on our lives nowadays					
AI will have more and more impact on our lives in the future					
AI can influence human decision-making					
Human mistakes can influence AI algorithms					
AI algorithms can be 100% confident of the wrong answer					

Fig. 42 Example of ordinal variable used to monitor level of agreement

3.6.3 Documents

Mind maps usually start from a point on paper focused on the topic and with lines and arrows the concepts are expanded. Mind maps show connections among ideas and help participants to organise a new concept. Developing a map demonstrates learning and is a form of active learning (Cheryil and Miertschin, 2006). I thought mind maps could be particularly useful in PHASES 2 and 3 with preservice teachers and teachers, as I was interested to see how their understanding of AI evolved. Therefore, teachers were encouraged to start a mind map on paper and keep expanding it during the course. To prompt them to start the mind maps the first activity of the programme consisted of asking participants to draw "Artificial Intelligence". This activity allowed me to understand teachers' preconceptions. Data gathered through sketches can, in fact, give insights into participants' thoughts and how they evolve. The "draw-and-write" technique is very helpful to let participants express themselves (Kara, 2012).

During PHASE 2 I piloted a self-directed task **Worksheet** with participants (see Appendix G). At the end of each task, I added in red some open-ended questions in red to prompt teachers' reflections on the activity Fig. 43. The worksheet was shared in word format online as it was easier for participants to fill it in digitally.


SMART TOY – Worksheet

Imagine…We are trying to design a smart AI toy for kids who are not able or capable to speak.
So that they can interact with it using written plain language instead of vocal commands
(as usual instead with voice assistants).
You are going to create a Sprite in Scratch that will move and chat through written commands.
To do so you will learn to train a model (using machine learning) to recognise your written speech.

STEP 1 – Set up your scene in Scratch

GO TO Scratch at the link: https://scratch.mit.edu/
Choose CREATE

Start to add a background you'd like.
Add a sprite you'd like, be sure to choose one with different costumes so it can move!

Code your sprite so you can command it to move with a simple written command like "Dance with me!" and chat with a simple command like "Chat with me"
Use the "ASK … AND WAIT" block and "ANSWER" (both are under sensing).

SAVE YOUR PROJECT: File / Save to your computer

Reflect:
1.1 What happen if you type slightly different commands? (i.e. "Dance with me" or "Dance")
1.2 Can you explain why?

1

Fig. 43 Example of questions in red to prompt reflection

Lesson plan templates were provided to teachers and used together to co-design activities that integrate AI with other subjects (PHASE 3). The template helped to concentrate on the concept of the activity and to develop ideas from brainstorming to a more articulate written concept.

Design journal template was created to lead children in their experience of the design cycle and as an instrument to collect ideas and information from participants (PHASE 4). It consisted of printed templates to be filled in on paper, to gain not only words but also in sketches and drawing form. At first it was created with Word and then after iterations developed and improved, Fig. 44. As claimed by Park, 2003:

> *"The learning journal approach does encourage independent thinking by the students, and it also encourages them to take responsibility for their learning. In this way, it makes them more autonomous and more active learners."*

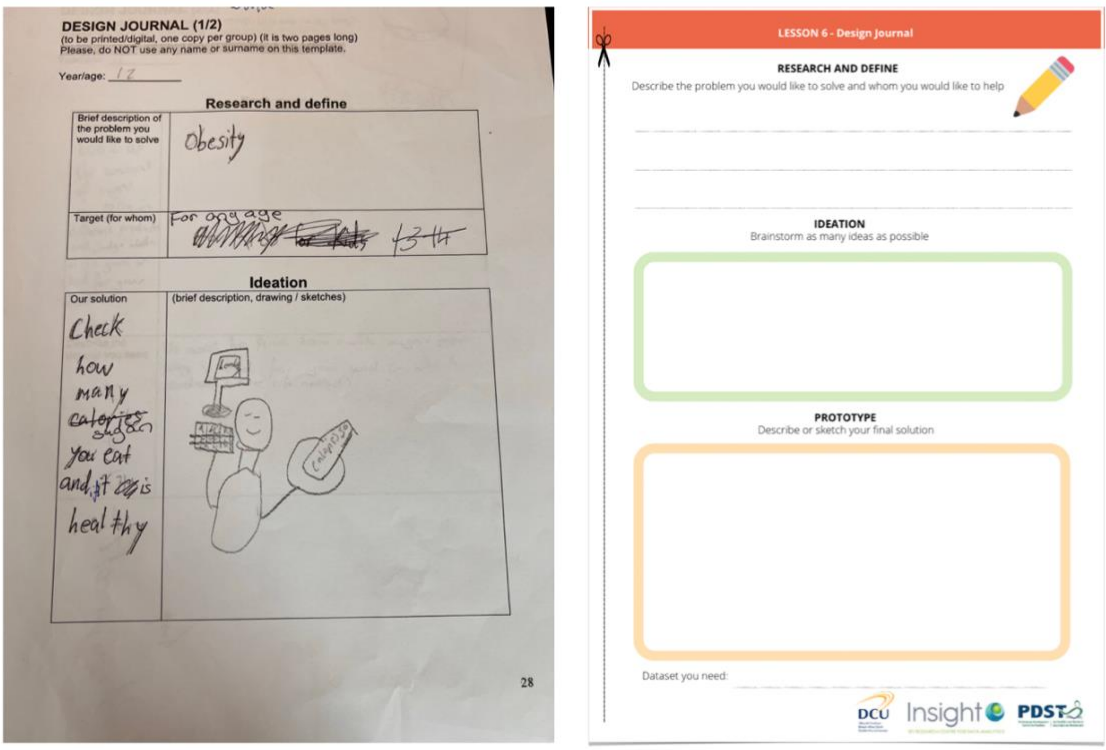


Fig. 44 Design journal draft (on the left-hand side), improved journal included in the handbook (on the right)

3.6.4 Visual data and digital materials

I used digital **Canvas** with participants in a cooperative way to give them a safe space to share ideas (PHASE 2, 3) and/or to take notes together during co-design (PHASE 5). Shared cooperative boards online allow students to collaboratively share ideas and build on others (Draucker & Siena, 2021 as quoted by Khoiriyah et al., 2022). I used Google Jamboard prepared in advance with titles and prompts, with anonymous contributions from participants. It turned out to be a more effective data collection instrument with younger preservice teachers (PHASE 2), while teachers who were in a very small group were more likely to share ideas through speaking out (PHASE 3).

I used **Pictures** to document PHASE 3 co-design sessions on campus. I also asked teachers to take pictures during interventions were I could not directly be present (PHASE 4, 5, 6).

3.7 Data analysis

3.7.1 Thematic analysis

Thematic analysis was the approach used to conduct qualitative data analysis. Braun & Clarke (2006) as quote by Maguire and Delahunt, 2017) offer a six-step strategy to conduct thematic analysis which I followed for phase from 2 to 6. Analysis is deepened after each phase, as the approach was iterative design-based research, findings from each phase informed the following iteration. The six-step strategy is not linear, and I found myself going back and forth between stages, however, having a framework really assisted me with the analysis.

Step 1- Become familiar with the data: After each intervention, I started to become familiar with the collected data. Organizing them in folders and preparing them to be uploaded in Nvivo®. In this phase I also manage the transcription of Interviews.

Step 2- Generate initial codes: Codes were then used to label pieces of data throughout the entire qualitative dataset. The database of labelled data was created using Nvivo® which helped to code and retrieve data (Mason, 2002 as quoted by Ritchie and Lewis, 2003).

Step 3- Search for themes: Themes found in data are presented in-depth in the methodology paragraph of each phase in Chapter 4. However, below (Table 17) is a screengrab from Nvivo® showing codes used in PHASE 5 (analysis conducted after teachers trial in school).

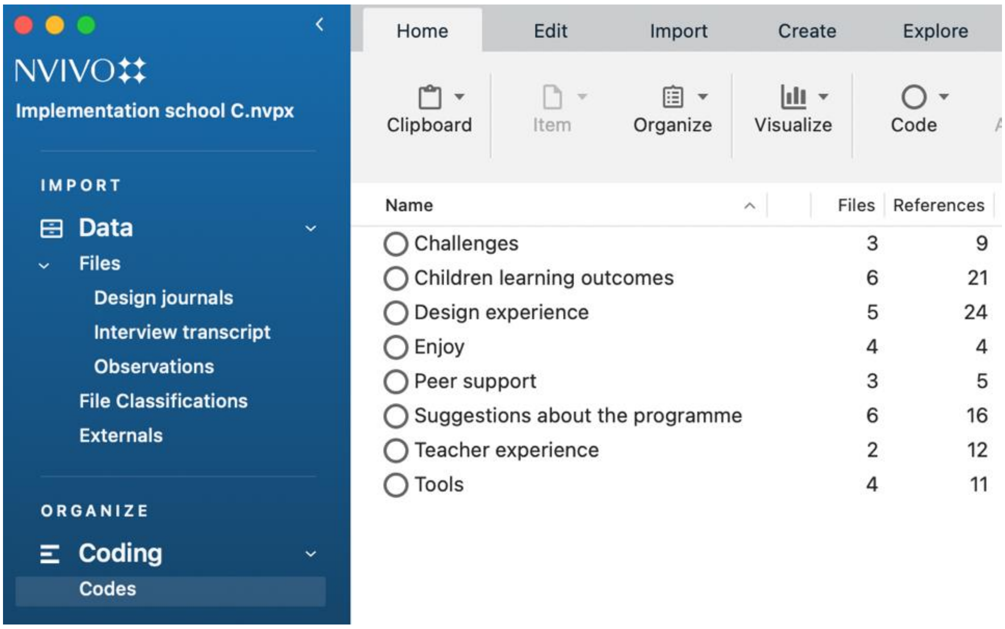


Table 17 Example of codes used in PHASE 5 data analysis

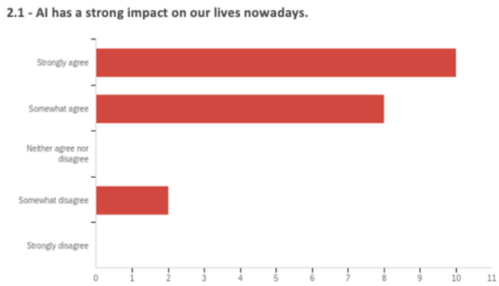
Step 4- Review themes: It took a bit of time and a number of iterations to revise codes and themes as they emerged.

Step 5: Define themes: Once themes were defined, I aligned them to research questions and then revised to include considerations that emerged.

Step 6: Write-up: Lastly, qualitative data collected were interpreted using **self-understanding** and cross-sectional analysis. I tried to interpret meaning and understanding from participants' words (written, transcribed from interviews or documented in researcher's notes). "*Self-understanding where the researcher attempts to formulate in condensed form what the participants themselves mean and understand*" (Kvale, 1996 as quoted by Ritchie and Lewis, 2003). Very much in line with my constructivist philosophy, writing was a key part of the analysis itself that helped me build up my understanding.

3.7.2 Descriptive statistics

Statistics is based on numerical data; its aim is to retrieve meaningful information from data. Descriptive statistics is a way to summarise information using charts or graphics, creating visual summary and graphics is one of the best way to investigate and share data (Singler, 2018). Quantitative data were analysed using descriptive statistics as a way to better communicate relevant findings or concepts. I mainly used charts from Qualtrics™. Qualtrics™ software, which I used to design and share online surveys, automatically generates histograms from quantitative question responses (multiple choice, Likert-scale). Below (Fig. 45) is an example of a Qualtrics™ report for a Likert-scale question. I also used Google Sheet for some simple explanatory diagrams.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	AI has a strong impact on our lives nowadays.	1.00	4.00	1.70	0.90	0.81	20

#	Answer	%	Count
1	Strongly agree	50.00%	10
2	Somewhat agree	40.00%	8
3	Neither agree nor disagree	0.00%	0
4	Somewhat disagree	10.00%	2
5	Strongly disagree	0.00%	0
	Total	100%	20

Fig. 45 Example of QualtricsTM report of a quantitative question responses

3.8 Validity

Clarification on researcher philosophy and stating with clarity data collection instruments and analysis procedure represents the effort of the researcher to maximise objectivity in working with data (Creswell, 2009). Although every effort was made, it is important to acknowledge how the researcher’s biases may influence data understanding and interpretation. Biases are due to the researcher's background, previous experiences, and beliefs (*clarification of researcher’s bias*) (Creswell, 2009). As strategies to ensure objectivity, I tried to be open to new ideas and perspectives throughout the study. I analysed data collected with different data instruments (*triangulation of data*) and I was committed to involving different cohorts of participants and domain experts in most phases of this study (*participatory modes of research*) to ensure an exchange of views and interpretations and conclusions (Creswell, 2009).

3.9 Ethical considerations

This study was approved by the Dublin City University Research Ethics Committee, reference number DCUREC/2021/043, after submission of the Ethical approval form describing how data would be collected from participants and managed and stored by the researcher.

A Plain Language Statement (PLS) was prepared for each cohort of participants. The PLS included the aim of the project and how the project could be beneficial for participants. In the PLS was also stated that participation in the research project was voluntary and how data were collected, managed, and stored. No personal information such as names and surnames or other identifiable information was asked of the participants at any time. They were not identified in any notes or in any write-up of the research. All data were anonymised.

Data will be deleted within three years after the end of the research project. However, it must be noted that the confidentiality of information provided can only be protected within the limitations of the law. Only the researcher and the supervisors have access to the data gathered, which are password protected and safely stored on Dublin City University (DCU) cloud storage.

An example of a PLS and a consent form for adult participants can be found in Appendix E.

Examples of PLS and consent for children can be found in Appendix F.

4. Iterative design and findings

4.1 Introduction

The iterative design of this study facilitated the development of a learning programme for teachers to promote AI and Data literacy and awareness. It was co-designed with teachers for teachers and children, framed with TPCK, and based on constructionism and design. In this chapter PHASES from 2 to 6 are described in-depth. Each phase begins with its own specific methodology included for clarity (data collection instruments, data analysis and intervention design). Followed by findings and a summary where it is highlighted how results from each phase informed the next one.

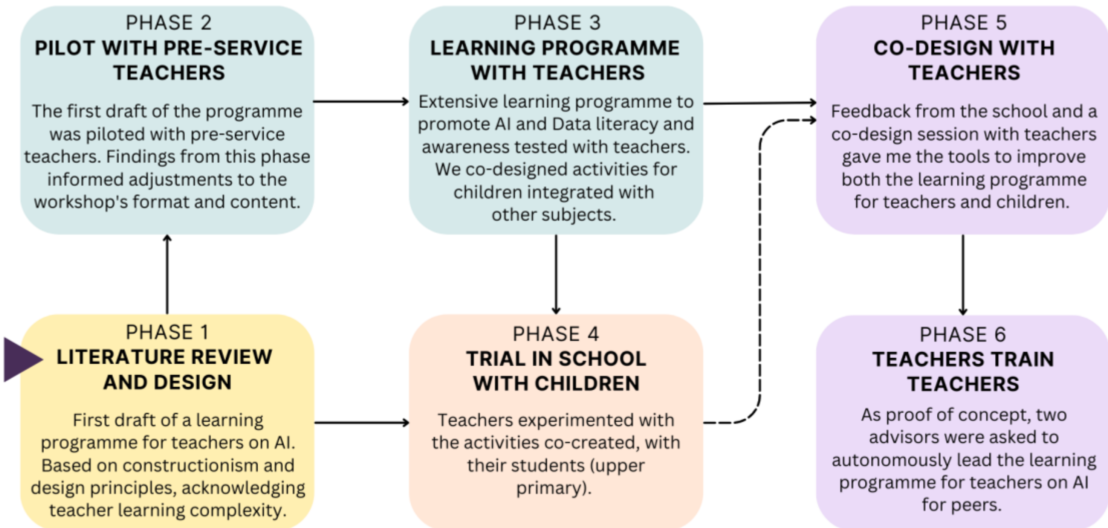


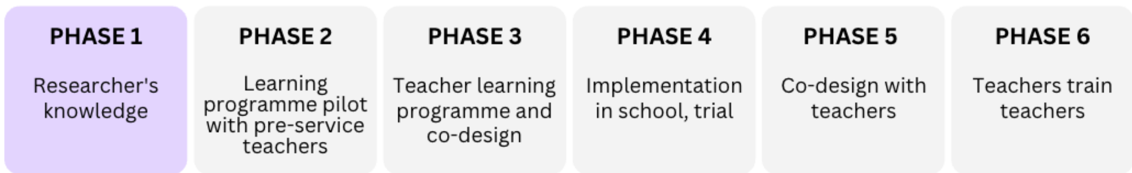
Fig. 46 Brief phases overview

The journey started, as summarised in Fig. 46, with preliminary research through a narrative literature review on AI and Education that enabled me to design the first draft of a learning programme for teachers on AI **(PHASE 1)**. This draft was **piloted in (PHASE 2)** with preservice teachers in two different contexts (Dublin City University (DCU) students, and Università Cattolica students). Findings from this phase informed changes to the workshop's format and content, specifically, the need for an extensive programme that could deepen some key topics, present experts' voices, and support teachers with examples of how to introduce AI and data literacy in school. **A revised extensive learning programme for teachers to promote AI and Data literacy and awareness was tested in PHASE 3**. I tested it with a group of teachers as a blended course with an interactive introduction online of three sessions and a full day face-to-face co-design session on campus. The outcomes of the programme were co-designed activities for children on AI integrated with curricular subjects. Data collected from this phase supported me in drafting the first learning programme for children on AI integrated within curricular subjects. In **PHASE 4**, Teachers experimented with the activities co-created during the course in PHASE 3 with their students (upper primary). Feedback highlighted appreciation of the practical approach and content covered, faced challenges as teachers, and possible programme improvements. Recommendations have been shared also on campus during a co-design session with the researcher in **PHASE 5.** During this phase I collected advice and ideas on how to improve both the learning programme for teachers and children (e.g., providing support templates, extending Machine Learning for Kids activities, and adding examples). After finalising the version of the handbook for teachers with all the resources to guide teachers on a learning programme for children on AI, I asked two advisors to lead a learning programme for teachers on AI for peers, as proof of concept

(PHASE 6). The aim was to see if a "train-the-trainer" was possible as it is desirable for a more scalable and sustainable professional learning programme for teachers. It was a successful example of how to collaborate with professional development service teacher advisors to enable them to continue to train peers on AI. The findings from this phase helped me to write this chapter and generate EPE guidelines on teacher engagement in AI and emerging technologies.

A learning programme for primary school teachers on AI such as the one developed in this research, demonstrated to represent an effective opportunity for teachers (even those without a background in Science Technology Engineering and Mathematics (STEM) or computational thinking) to develop their understanding of AI and to support them to introduce AI to children.

4.2 PHASE 1 – Researcher's knowledge



The first phase of my study was mainly focused on developing my knowledge as a researcher (Fig. 47). The expected outcomes of this process were understanding education and learning, specifically primary school teachers and children's learning perspective, while deepening AI under the umbrella of computer science (machine learning and reasoning basics, and data science basics), and developing skills and competencies on research practices and theories.

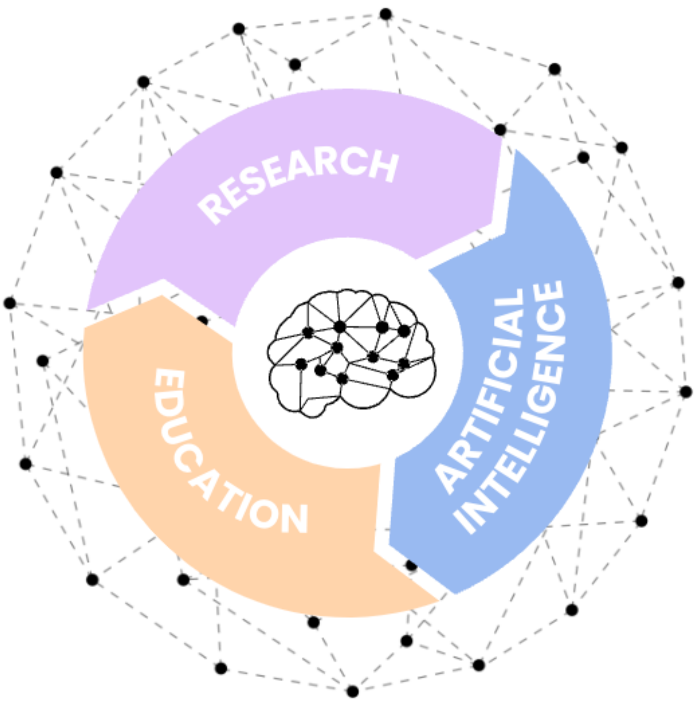


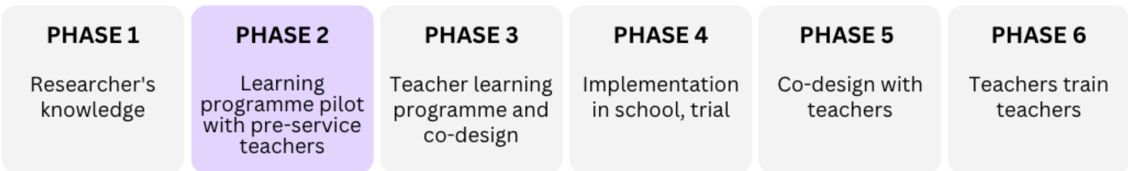
Fig. 47 Researcher's knowledge ecosystem

I attended modules and courses both at DCU and from other universities and institutions. During my academic journey, I successfully completed and obtained 20 credits (ECTS) by passing the following modules. Firstly, in IE603 - Quantitative Approaches to Educational Research, I was introduced to the application of quantitative methodology in educational research. This module provided a comprehensive understanding of statistics and data analysis. I had the opportunity to explore various tools and critically evaluate the suitability of the quantitative approach for my own research. In IE602 - Qualitative Research Methods, I delved into the realm of qualitative research. This module challenged me to contemplate the ontological and epistemological principles that underpin my worldview and research perspective. It broadened my understanding of different qualitative methods and approaches. NS5055 - Engaged Research proved to be a valuable module that equipped me with essential knowledge on engaged and participatory research practices. I gained insights into conducting effective interviews and developed a better understanding of collaborative research methodologies. Lastly, LC600 - English for Academic Writing was instrumental in improving my English writing skills, considering that English is not my native language. This module focused on the fundamentals of academic writing, enabling me to enhance my proficiency in expressing ideas effectively within an academic context.

In addition, I actively engaged in various workshops and courses that significantly contributed to my research progress and overall studies. The following activities held particular significance for me: Creative research methods, writing seminars and workshops, research integrity training, data protection sessions, media communication workshops, and the informative Elements of AI online courses offered by MinnaLearn and the University of Helsinki. These additional opportunities further enriched my research journey and provided me with valuable skills and knowledge across different disciplines.

Lastly, throughout the four years of my study. I attended several conferences and exhibitions both nationally and internationally, organised by universities and research groups (mainly online). They ranged from Explainable and trustworthy AI, the Future of AI, Ethics of AI, Education of AI, and AI for good. As a learner myself, being part of a "*community of learners*" gave me the opportunity to develop my knowledge throughout my entire Ph.D., and to gain valuable insights from a network of colleagues (peers) and experts. Discussing and sharing ideas with researchers and academics from AI, education, and ethics domain (acknowledged in Appendix C) was very helpful while working on my narrative literature review, designing my research, and narrowing down the research questions. As my study was on EPE, I thought it was important to understand how to better communicate its purpose. To foster my communication skills, I participated in DCU “Tell it straight” competition. My abstract was chosen among the finalists, so I prepared the script, recorded shots, and edited a two-minute video on my research for a general audience that was shared publicly during an official ceremony (Amplo, 2021).

4.3 PHASE 2 – Preservice teachers pilot



This pilot study represents the first iteration of an extensive research design process that aimed to develop an in-depth understanding of how to design effective and long-term engagement of teachers and children with the key ideas of AI. The aim of the pilot, from this Ph.D. research perspective, is to test the TPCK framework (Koehler and Mishra, 2006), constructionism, and design approach to introducing AI literacy to teachers; to gain insight into teachers' perception and preconceptions of AI; to test the feasibility of online workshops; and to analyse data from the pilot study, in order to inform the rationale for further studies on effective EPE on AI literacy grounded in education and learning research.

A requirement of The Teaching Council standards for initial teacher education is that preservice teachers/students should be aware of emerging technologies and should be able to embed their use into the design of learning activities for primary school children (The teaching council, 2020). Consequently, I identified two cohorts of preservice teachers for this pilot: 1. DCU students enrolled in the SG403 module (4th year students) and these workshops constituted part of the module content and 2. students from Università Cattolica in Milan who enrolled in these on a voluntary basis as these workshops were in addition to their coursework. Students engaged with hands-on and heads-in activities, to explore how to use a constructionist approach to design learning opportunities for primary school children centred on AI literacy. The aim of these pilot workshops was to introduce students to key ideas that underpin AI. It was designed to investigate preconceptions, de-mystify AI, and explore the science behind it.

The design of this pilot workshop was based on the TPCK framework and AI literacy principles and key ideas from Long and Magerko (2020) and Touretzky et al. (2019) introduced using a constructionist and design approach. There were 2 online workshops which were each 2 hours long. The first workshop is focused on the content [CK] and designed as an opportunity for the participants to develop their own understanding of AI. Starting with participants' pre-conception and perception of AI and building from them (Bransford, Brown, and Cocking, 2019). Participants were engaged in hands-on experience to foster critical thinking and ignite discussion. The second workshop was focused on the pedagogical approach [PK] that these preservice teachers could use in their future classroom practice to engage with children in developing the key ideas of AI. Informed by design thinking and constructionist learning principles the approach adopted was to model the process of how these preservice teachers could in turn work with their future students (Bransford, Brown, and Cocking, 2019). In both workshops, different AI tools were used as a means to understand AI literacy key ideas and develop competencies [TK].

For a comprehensive illustration of the programme designed for pre-service teachers, refer to Appendix L, which contains the detailed design.

4.3.1 Research question

Each iteration of a design research process can have its own research questions and evaluation that allow researchers to conclude if the project meets or not research expectations and if another iteration is required (Plomp and Nieveen, 2013). This pilot represented a first iteration of my study. Its purpose was to investigate if the framework and approach selected could be used as an effective strategy with teachers to promote AI literacy. For this reason, the pilot research question was defined as follow:

[RQ 2] Can a short online introductory programme, focused on AI key ideas and competencies, underpinned by the TPCK (Technological Pedagogical Content Knowledge) framework and constructionist learning principles, be an effective way to engage and develop preservice teachers' AI literacy?

Where effective engagement for preservice teachers is defined as follows:

[T1] It enables them to develop their own understanding of AI key ideas

[T2] It encourages them to positively and successfully engage with AI tools that they can use with children

[T3] It allows them to realise the importance of teaching AI in school

4.3.2 Findings

Codes and themes that emerged from data analysis of the data gathered in this phase are listed with examples of data coded, in Table 18. The findings of Phase 2 are in this section articulated.

CODES	MEANING	EXAMPLES
AI key ideas	Each time that an AI key idea was mentioned	*"There can't be any AI without data as that is how the algorithms are formed" "Yes, the model worked properly in recognizing data. I intentionally misspelt a few words and it still seemed to work most of the time"*
CK key ideas effectiveness	Feedback on how content was delivered	*"The simple way complex but interesting topics were presented*
AI in our life	Connections with personal experiences or current situations that show deep understanding	*"So, this is what happen in Instagram when I see predictions of advertisement of things I am interested"*
Aware citizens	Links to citizens responsibility and rights	See Fig. 48 *"Humans can object to computer made decisions"*
Machine Learning key ideas	Technical references on machine learning workflow or technical aspects	*"I think the percentage means how confident the model is in putting what you typed into the two different categories based on the data that we provided it with"*
Health	Connections with Covid time and AI for health	*"They can do prediction on health based on data collected"*
Robots	Drawings and references to robotics when talking or thinking about AI	See Fig. 49, which illustrates the many robots drawn by participants.
TK Tool understanding	Understanding of how tool works	*"Really enjoyed engaging with various software and seeing where it related to our everyday life" "I have learnt you can link machine learning for kids to Scratch"*
Hands-on learning	Appreciation of interactivity and creating	*"The hands-on part makes AI more accessible"*
PK	References to pedagogy	*"How can we talk about this matter to kids?" "Learning about AI has really shown me how it can be brought into the classroom to teach children about real world technologies"*
Want to know more	Feedback on the interest of continuing to learn more	*"I would have added beside hands-on applications for kids" "I would have loved another session"*
Impact	Teaching AI impact	*"Linking Scratch and machine learning opens lots of opportunities and it is very interesting to see how this could help children especially as their spellings may not always be correct"*
Implications	Teaching AI implications	*"How can I preserve my data?" "Machine learning is not always right"*
Empowerment	Self-efficacy	*"More confident with AI, was a bit scared" "Gaining a deeper understanding of AI"*
Expert role and characteristics	Feedback on expert acting as bridge between research and school	*"I enjoyed the enthusiasm that everybody had towards the 2 sessions" "It depends from experts to experts, because not any of them can teach to kids"*
Tools are needed	Needs for tools to introduce AI to children	*"A way to have it for children?" (Referred to moral machine)*
Suggestions	General feedback	*"I didn't enjoy the introductory piece as much the practical learning. It was still good but perhaps would be more engaging if there were videos"*
Enjoyed it	Positive feedback on the programme	*"It was an excellent workshop" "I honestly enjoyed everything about the sessions"*

Table 18 Data coding examples

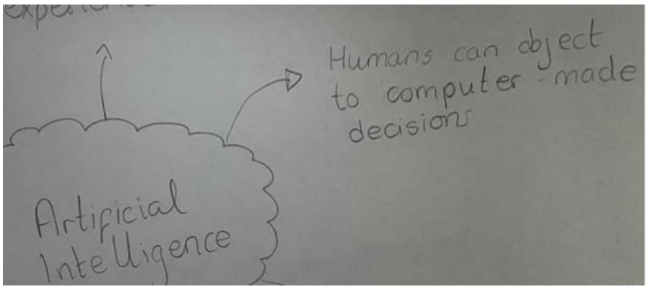


Fig. 48 Mindmaps on AI and citizens' awareness

Preservice teachers positively and actively engaged in the programme designed for them that included two interactive online sessions on AI, based on constructionism and framed by TPCK. To the question "What did you enjoy the most?" Many were students' responses on their own learning experience: *"Gaining a deeper understanding of AI", "I learned many concepts…"* or *"All the applications presented have been explained without leaving any details for granted",* demonstrating the programme to be an effective learning opportunity for them [F2.1]. Participants appreciated how the workshops were designed to allow everyone to feel included without being judged [F2.2]: *"Concepts and topics that were far from me, were explained and clarified and we were able to try them in practice without ever feeling unsuitable (not enough)".* Students also appreciated that the programme was scaffolded to take into account everyone's different skills and backgrounds [F2.3]: *"Competences demonstrated in dealing with them, since they are complex topics, but explained in an absolutely understandable way even to those who know very little about them".* Moreover*,* participants recognised the role of the researcher as a bridge being able to translate technical and ethical complex key ideas into inclusive activities, as captured in this statement

> *"Clarity and professionalism combined with the "smiling" and human way of talking with us. Concepts and topics that were far from me*

> *were explained and clarified and we were able to try them in practice without ever feeling unsuitable".*

Therefore, even though they were aware of the complexity of topics related to AI, they felt the workshops were accessible. They also particularly liked the hands-on activities and interactive tools used to ignite discussions without feeling judged and demonstrated appreciation and effectiveness of the approaches used [F2.5] as captured in this statement: "*I loved working on Scratch and training the AI. It was really practical and enjoyable!"*

A student however suggested, in the post-survey, including more videos covering AI key ideas and experts' voices, to enable more meaningful engagement with initial introductory content [F2.6].

Furthermore, participants expressed their desire for a longer programme to expand what was learnt *"...I would have liked to have another session.", "Too short", "I learned many concepts that I did not know before and if there had been more sessions I would have discovered even more"* and in particular deepen their knowledge of how to introduce AI literacy to children expressing the need for more support both in terms of resources and pedagogy, as also emerged from researcher's notes [F2.7].

From the data collected before the workshop (pre-survey), it emerged that preservice teachers recognise that AI will have an impact on their lives both in the present and in the future, however, they were less confident in saying that AI has an impact on their lives currently [F2.8]. During the workshop participants struggled to understand what technologies are based in some form on AI. When they were asked to find online examples of existing AI applications for good, the examples mentioned referred for example to "*Augmented communication for* *children*” and “*prosthetic arms*” that, currently are not, based on AI technology. At the beginning of the workshop participants were also asked to start a mind-map with a drawing with responses to this task: “*If I say AI, you draw…”.* From the mind-maps collected across both cohorts (n. 15), 80% of the participants drew a humanoid robot when thinking of AI. Just a few of them drew something else such as a computer, a device, a recommendation system, or a research engine, see Fig. 49, illustrating how AI narratives (i.e., sci-fi robots and super intelligence machines) can influence our ideas [F2.9]. One participant during the AI for good sharing ideas exclaimed *“I didn’t realise AI is everywhere…We need more clarity…It is difficult to find out where AI is used”.* Such comments highlight the confusion and struggle in differentiating narratives from the reality around emerging technologies such as AI and the need of a deep discussion to better understand everyday technologies, how they work and where AI might be used both in the present and in the future.

Fig. 49 Preservice teachers mind maps. Starting point highlighted, outcome of the task “If I say AI, you draw”

4.3.2.1 Understanding of AI key ideas

KI A. Demystifying AI

The activities in the first online session were designed to develop students' understanding of AI as a technology. Firstly, participants actively engaged with the AI history timeline. This was an activity they evidently enjoyed, as it was captured by this representative quote from a participant when asked, "What did you enjoy the most about the programme?": *"Learning about the history of AI".* Interacting with the timeline, students recognised people associated with AI they had encountered during their course of study or from personal knowledge, i.e., Seymour Papert and Ada Love Lace. Moreover, students also grasped what has changed from the past, as evidenced by this student's statement: *"AI is evolving because of new data and stronger computers".* Lastly, students were involved in training simple machine learning models using the Teachable Machine platform and discussing the ethics of AI with Moral Machine. To start the second session, I used a shared Jamboard where participants could share "takeaways" from the previous workshop. With their notes they demonstrated reflection and understanding of the content they engaged with, as illustrated in Fig. 50 for Group A: e.g., *"Algorithms learn from data", "Algorithms are only as good as data used in it", "Algorithms are based on probability and statistics in mathematics",* and *"AI is a type of science", and* as shown in Fig. 51 for Group B: *"Human and machine limits".* The programme also enabled participants to discover that AI is not new and it can help them critically reflect on the technology as a coded software and algorithms based on mathematics [F2.10].

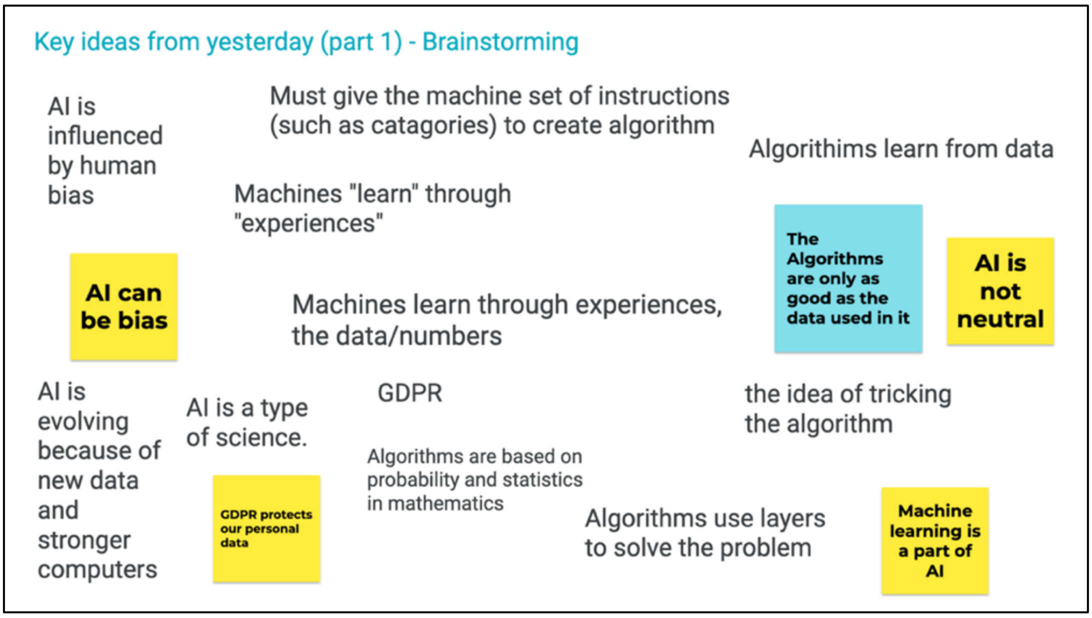


Fig. 50 GROUP A, Shared Jamboard with participants take-aways from the first session

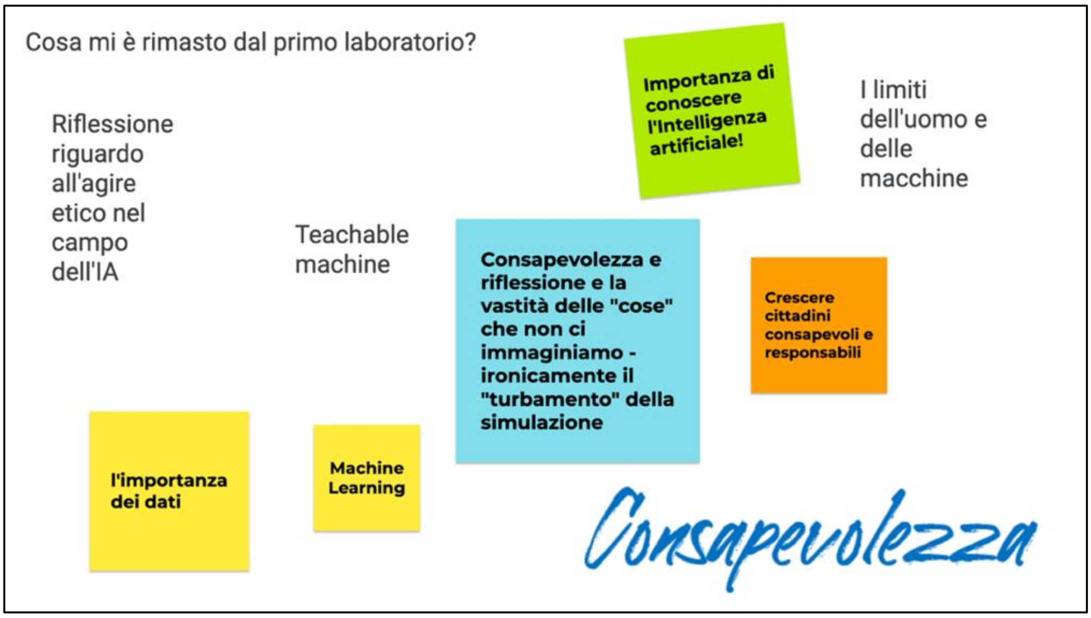


Fig. 51 GROUP B, Shared Jamboard with participants take-aways from the first session

From the left-upper corner: “Reflections on being ethical in the field of AI”, “importance of data”, “Teachable Machine”, “Machine learning”, “Awareness and reflections on the huge impact of things we do not even expect, ironicly the turmoil of the simulation”, “importance of AI knowledge”, “Raising aware and responsible citizens” “Humans’ and machines’ limits”, “awareness”

KI B. How computers learn from data

The activity with the Teachable Machine platform allowed students to explore the machine learning workflow to train a model. They created a dataset, trained the model on those data, and tested the model. Students could test the model with new objects experimenting with how a machine learning model can give predictions on data never seen before. As illustrated in Fig. 52 some of the students figured out by themselves how to improve data collection i.e., using white paper as a neutral background for their objects. During the activity, a student was able to link the machine learning model functioning to their personal life stating: *“So this is what happens in Instagram when I see predictions of ads of things I am supposed to be interested in”.* By sharing a connection from their own experience, they showed a deeper understanding of the process that demonstrates how this activity helped them in developing their knowledge of AI key ideas [F2.11].

Similarly, the “*Machine Learning for Kids*” activity was a constructionist learning environment for students to build their own knowledge of Machine Learning. In this activity, students coded a character (sprite) for children with disabilities that could be commanded by typing text input, to dance or chat, see Fig. 53. A student stated, “*Although this task was quite basic, it still helps explain how a more complicated program such as chatbots and other AI works that we would deal with on a daily basis.”* demonstrating how the activity was an effective opportunity for the students to reflect on actual AI systems. Moreover, another student reflected on the definition of accuracy writing: *“I think the percentage means how confident the model is in putting what you typed into the two different categories based on the data that we have provided it with.”* This statement demonstrates the deep understanding this participant had of “the classifier”, which is the machine learning model on which both Teachable machine and

Machine Learning for Kids activities were based, and the relationship between AI and data. On this latter point, participants gave very confident responses in the post-survey:

> *"AI is completely influenced and reliant on the data collected", "AI needs data and algorithmic thinking to function correctly", "Algorithms learn from data or experience", "There can't be any AI without data as that is how the algorithms are formed"*

These representative statements from students demonstrate the effectiveness of the workshops in creating opportunities for the students to build their own deep understanding of machine learning and computers learning from data [F2.12].

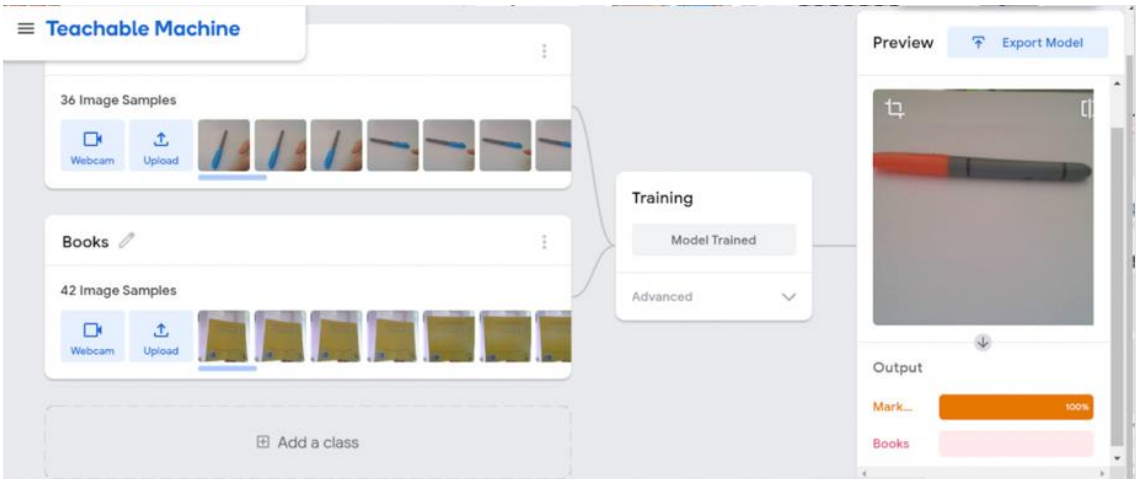


Fig. 52 Example of a screengrab of a Teachable machine model trained by a GROUP A student

KI C. AI applications can impact society

When students were asked to look for an example of "AI for good" on the internet, many chose health applications as illustrated by the posts on the shared Jamboard by Group B, see Fig. 53. While Group A students orally mentioned health examples when discussing their search results e.g. "*cancer screening*", *"health and DNA studies"* demonstrating reflections on how AI can have a positive impact on our lives [F2.13].

Fig. 53 Shared Jamboard on AI for good in purple references to health.

From left hand side "Entlic: the software will help to make radiologist work fast and to check radiography labelled as left hand from the doctors is not a right hand", "Protesi arti": prosthetic arms, "Google launched the project deepmind Health to speed up medical care processes"

However, it is important to acknowledge that the workshops were conducted during the COVID-19 pandemic and that may have influenced participants' choices. During this unique time, news feeds reported on health-related data, with policymakers and health workers taking decisions on behalf of the whole population based on collected data. This unique environment probably provoked students to ask themselves ethical and critical questions. for example, a student from Group B cited connections to the pandemic during the Moral Machine activity saying:

> *"There is no right answer, it only depends on your ethic/moral and beliefs. For someone it is only a matter of number: here 5 people die, in the other 3 people, so we choose the first, but can we base our decision only on numbers? As happens for Covid, where doctors were forced to choose who to save".*

Another student from the Group A mentioned, as AI for good: *"A Covid tracker, to have for example lockdown just in some areas"* demonstrating how the workshop provided them with an effective learning environment to reflect on positive applications of AI while enabling students to ask themselves questions and to make connections with their everyday life experiences [F2.14]. Moreover, while brainstorming ideas on "AI for good", some comments demonstrated critical thinking in relation to how the technology can be misused and how boundaries will be set, i.e. *"Even if, for crime prevention purposes, we still have doubts about data being collected from people"* [F2.15]. Similarly, the activity with Moral Machine effectively encouraged critical debate on ethical AI implications as indicated by this response in the post-survey: *"I enjoyed the morality machine game because I had not realised that morality was a factor when creating algorithms for self-driving cars".* Students embraced the group activity using Moral Machine, experiencing first-hand how hard it can be to find a common decision especially when there are many different stakeholders involved and all driven by different interests such as *"the economy, reputation, numbers",* as summed up in the words of a student in Group A. This activity was also effective for students in investigating different stakeholder roles and responsibilities: *"Policymakers have more power than others",* while as citizens *"I don't want to kill, I would save others, I have morals".*

Lastly, Moral Machine group activity appears to have been enjoyed by the students but it also appears to have had a strong impact on them [F2.16]. One participant wrote in the post-survey, referring to the programme: *"I liked everything, but the moral dilemma exercise was the toughest"* highlighting awareness of the possible impact, both positive and negative, of AI on our future. Research and discussion on AI-for-good were added to the programme after the first session because students were quite concerned by the negative impact misuse of AI and data could have on their lives, therefore necessitating that some research on AI positive applications for humans was needed to balance the negative atmosphere generated. I tried in this way to promote critical thinking towards the technology rather than scepticism that could lead to fear of the technology for the wrong reasons and consequent underuse of it (Floridi et al., 2018).

KI D. AI literacy relevance for anyone

The aim of this programme was to create opportunities for students to understand the importance of AI literacy for all. During the sessions, students expressed their views on how AI literacy is a tool to navigate our world where these technologies are used and will be increasingly used. One student highlighted that "*anyone that uses a laptop or phone should understand it can be used for artificial intelligence purposes. It is not just something for software engineers...*" while another participant wrote as a response in the post-survey that they particularly liked the aim of the workshop and the researcher's ability *"to make topics that are not normally accessible* [sic]*;* as well as *"the desire to open our eyes*". Furthermore, in the pre- and post-survey, participants were asked if they believed AI knowledge was only relevant for specialists and researchers; from the pre-survey data 75% of Group A participants somewhat or strongly disagreed with the assertion, though after the workshop this increased to 93%. Similarly, before the workshop 90% of Group B somewhat or strongly disagreed with the assertion, though after the workshop this increased to 100% [F2.17]. This highlights the programme's efficacy in sharing the message that AI knowledge is relevant to all of us as citizens and for this reason should be a priority for teacher learning. Moreover, the Moral Machine activity represented an opportunity for the students to reflect on the ethical implications of emerging technologies such as autonomous vehicles, which are coded and programmed by humans; however, who should have the right or duty to decide in case of an unpredictable event? Is there space for citizens' voices? Or is it solely a dialogue among policymakers, company owners, and research groups? During and after the activity, Group B's students shared their feelings about the choice they had to make in Moral Machine scenarios: responses included *"I feel guilty", "I feel responsible",* and *"Taking a decision is a huge responsibility".* These responses demonstrated in-depth reflection on ethical dilemmas and represented how the role-playing game activity was effective in encouraging them to empathise with the issue. At the beginning of the second session, participants were asked to write "take-aways" from the first session on a Jamboard (see Fig. 50 and Fig. 51). Participants' notes highlighted their understanding of the importance of AI knowledge: *"Awareness" (Consapevolezza), "Importance of knowing Artificial Intelligence", "Raise citizens, to be aware and responsible",* and *"Reflections on ethical act in AI field"* [F2.18]. Group A participants also mentioned "*GDPR*" and "*GDPR protects our personal data*". Both groups of students shared key ideas on rights and duties as citizens in the era of AI, demonstrating how the first session of the programme in particular helped them to build their knowledge and understanding of the importance of AI literacy not only as students or teachers but also as citizens themselves.

4.3.2.2 Engagement with AI tools

Preservice teachers engaged with different tools throughout the workshops that were chosen to promote hands-on and learning-by-doing i.e., Teachable Machine and Machine Learning for Kids. Appreciation of tools used emerged from Group A participants' responses. When asked to highlight aspects of the workshops that they particularly enjoyed they replied: *"There are lots of online programmes I was unaware of to teach children about AI and to give them a fun experience."* Or *"Really enjoyed engaging with the various software and seeing where it related to our everyday lives".* While a participant from Group B participants also highlighted that *"The hands-on part makes AI more accessible. A way to understand how to teach it in class, for kids"* [F2.5]. In particular, students worked extensively with Machine Learning for Kids and Scratch during their second session. It is important to acknowledge that participants of Group A already had experience of engaging with digital technologies (including Scratch) and how they can be used for teaching and learning in the classroom. In contrast, participants from Group B had very little digital literacy or computational thinking skills, with very poor or no knowledge of the Scratch coding platform. Consequently, an introductory session on Scratch had to be included for them and was appreciated, as stated by a participant *"[…] I really appreciate the guide in using scratch. Simple and clear explanation"*, indicating that they enjoyed the brief introduction on computational thinking and Scratch. In post-survey, students shared thoughtful feedback on the platform, i.e. *"I particularly like the fact that ML for kids can be linked to Scratch. And see potentials."* or *"I enjoyed the second workshop the most as I felt it was more at my level of understanding and was interesting to see how I could use it in teaching."* demonstrating a positive attitude towards the tool they engaged with while envisioning how to use it in class [F2.19]. As also emerged from a student's comment on the exercise: *"It would be a great extension to Scratch. For example, if you were teaching Scratch to children, using the machine learning model could be used for differentiation of quicker learners".* By the end of the second session, preservice teachers demonstrated increasing confidence in relation to the tool used: *"Children can understand the importance of AI from a simple task like this"* that *"Really show how AI will enhance coding"* and they imagined themselves in the future, introducing AI in class: *"It would give children a sense of achievement to see that the data they had input into machine learning worked in Scratch"*. At the end of the programme one participant asked if there could be the possibility to integrate AI tools such as Machine Learning for Kids with educational robots, demonstrating that they were making connections with other technologies they had experience of from their university coursework.

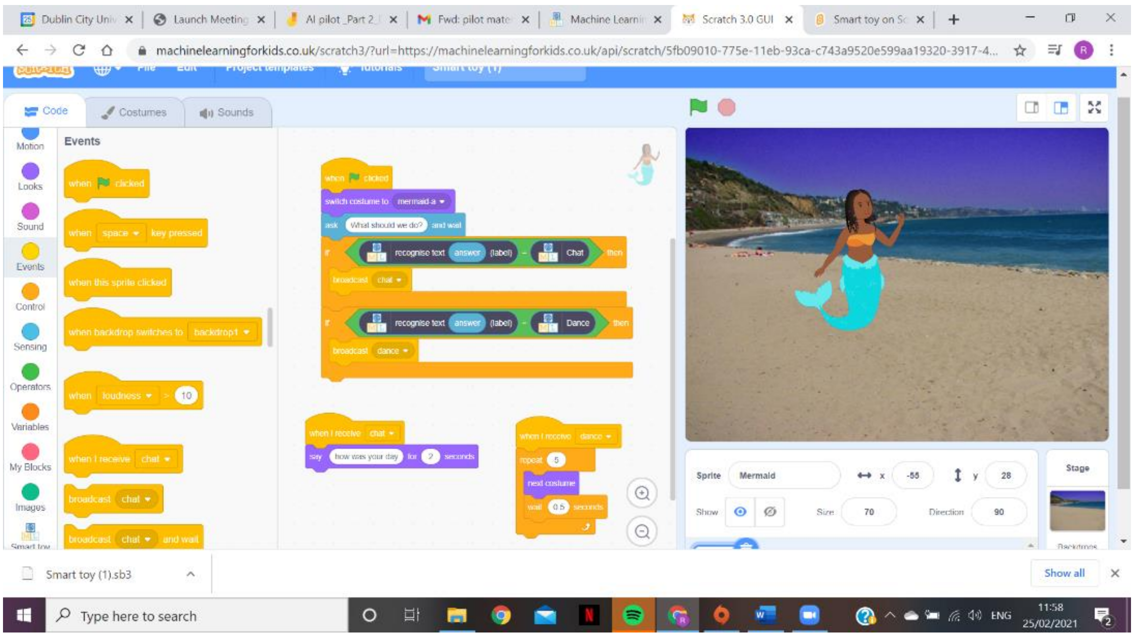


Fig. 54 Example of student's project

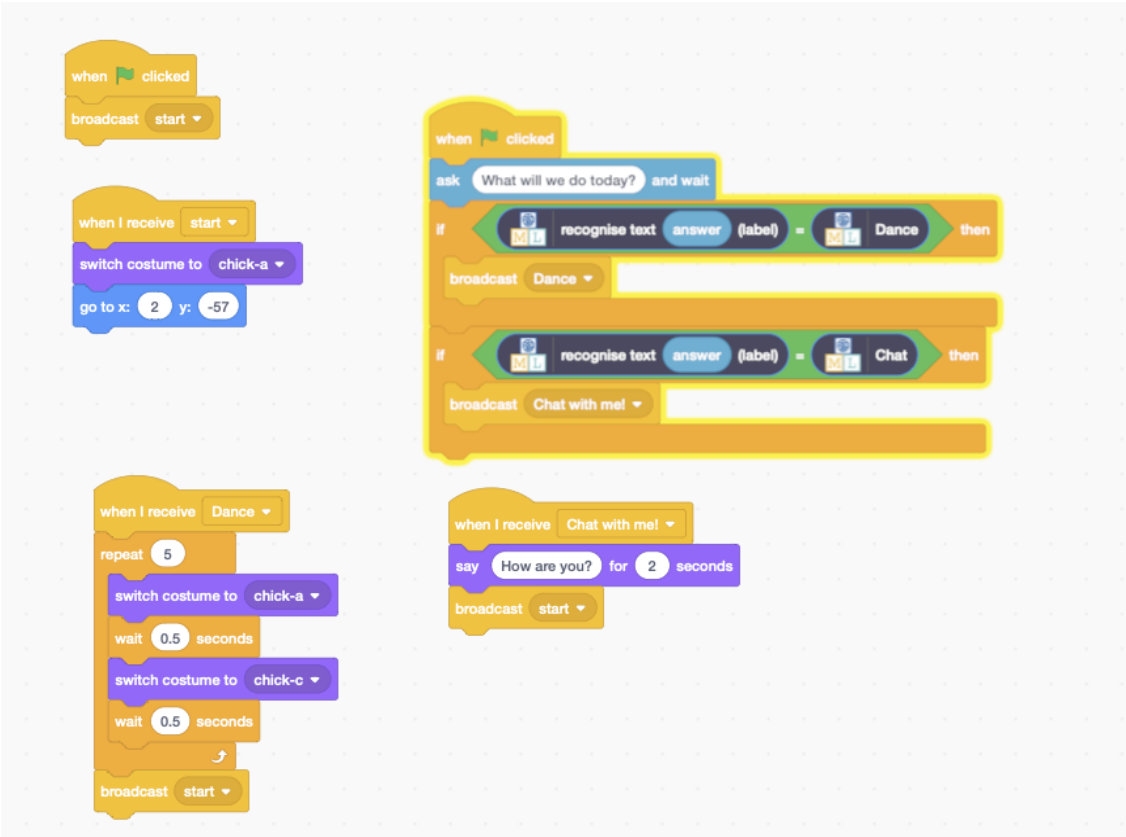


Fig. 55 Example of projects with optimisation and customisation of "dance" and "start" functions

4.3.2.3 The importance of teaching AI in school

Preservice teachers recognised the relevance of AI literacy for everyone as citizens beginning with developing this literacy with children. In fact, after the workshops 90% of Group A and 100% of Group B somewhat or strongly agreed on the relevance of AI literacy for their course of study in education [F2.20]. Demonstrating how aware they were of the importance of introducing AI in schools. Moreover, participants expressed the desire that AI literacy programmes should be introduced as part of their coursework as preservice teachers: *"I would expand the course and make it compulsory in the primary education science faculty".* Students also highlighted how teachers need to build their own knowledge on AI literacy to then be able to introduce it into school. This is a particularly powerful recommendation considering that in the pre-survey it emerged that although preservice teachers were not afraid to know more about AI, 47% of respondents were afraid it could be too difficult for them, a result that decreased to 17% after engaging in the learning programme [F2.21]. One student wrote about the programme *“[…] Learning about AI has really shown me how it can be brought into the classroom to teach children about real worlds technologies”* demonstrating their reflection on introducing AI and emerging technologies in school to their students.

4.3.3 Summary

The urgency of literacy in emerging technologies such as AI, that are increasingly part of our daily lives, is undoubted. Consequently, attention to teacher learning and knowledge of AI is paramount and in need of specific research particularly in the development of an AI literacy framework. Our introductory learning programme on AI framed by TPCK and underpinned by constructionist principles appears to be beneficial for preservice teachers as an opportunity for them to start to learn more about AI and develop the skills and competencies needed to teach it in school. Participants’ reflections on AI-for-good mainly focused on health highlighted how *health* itself could represent an effective theme to work on with teachers, as a strategic means to bring AI literacy into classrooms.

Findings from the programme demonstrate the potential for such programmes relating to the key ideas of AI to be integrated into preservice teachers’ course of study.

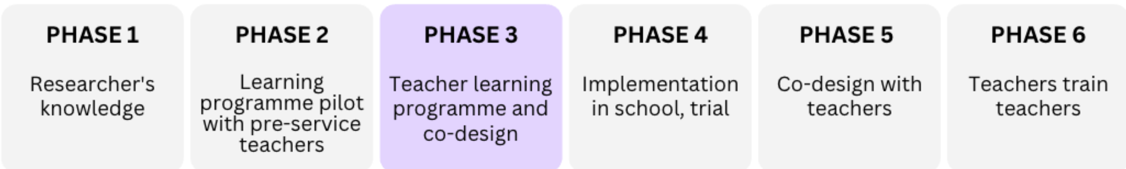
Moreover, the observed preservice teachers' "concern" about the introduction of AI in school, highlights how the approach adopted could represent a solid base to investigate further a teacher-centered framework of professional learning towards AI literacy.

Results from this phase (PHASE 2) influenced the design and development of an extensive learning programme for teachers (PHASE 3).

Key findings from PHASE 2 that informed PHASE 3 are here summarised:

1. The need for a more extensive programme that could deepen some key topics while helping teachers with examples of how to introduce AI and data literacy in school [F2.7]
2. Engage participants with experts' voices [F2.6]
3. The tools (Teachable Machine, Machine learning for kids and Moral Machine) used were effective and engaging (not too challenging) [F2.5, F2.19]

4.4 PHASE 3 – Teacher programme



PHASE 3 of the research was focused on teacher learning. Based on lessons learnt following the pilot study and the literature, I re-designed the teacher's learning programme for teachers to be interactive and participatory. The programme was based on constructionism and design to this time. Giving teachers the time and support to create new activities on AI big ideas integrated with other curricular subjects, was one of the main features of this iteration.

For a comprehensive illustration of the programme designed for pre-service teachers, refer to Appendix M, which contains the detailed design.

4.4.1 Research questions

With this phase, I specifically wanted to investigate the adoption of TPCK framework, constructionism, and design approach to enhance teacher learning in relation to AI. The research questions for this phase are as follows:

[RQ 3.1] Can a programme of professional learning underpinned by the TPCK framework and constructionist learning principles effectively engage teachers in developing their own understanding of AI?

[RQ 3.2] Can a design-based approach foster teachers' content and pedagogy knowledge of AI?

To tackle these questions, I ran the programme with a small group of primary school teachers, designed as a blended learning experience. Teachers participated in three synchronous online sessions (2 hours-long each) and one face-to-face day-long design session.

4.4.2 Findings

I started to become familiar with the collected data and defined some initial codes, see Table 19. Codes were then used to label pieces of data throughout the entire qualitative dataset. Revised themes are summarised in Table 20. In the same table, it is possible to see how codes evolved during the analysis compared to the initial codes defined, codes written in purple were added during the analysis. Themes are discussed in the finding section of this phase organized to address the research questions of this iteration.

[RQ 3.1] Can a programme of professional learning underpinned by the TPCK and constructionist learning principles effectively engage teachers in developing their own understanding of AI?		
Code	**Explanation**	**Example of data coded**
Programme pedagogy	Framework effectiveness, balance among content pedagogy and technology use	*"Yes, very useful and needed essentially. AI is quite theoretical and not something that educators would explore within classrooms. Having a design session makes it more real and practical."*
Hands-on	Appreciation of interactive involvement in activities to promote learning	*"You don't really get to figure it out till you start messing around with it."* *"One thing you liked/enjoyed of these three sessions online: Very interactive sessions"*
Learning outcomes	Take aways and key ideas learnt	*"I have a good foundation to start with and areas to bring students/teachers into to begin to explore AI"* *"More confident and have a deeper understanding"*
Needs	Face to face, design session together, confidence	*"I think I'd still like to think about it a bit more"* *"I would still have to distil the content further"*
[RQ 3.2] Can a design-based approach foster teachers' content and pedagogy knowledge of AI?		
Code	**Explanation**	**Example of data coded**
Developed knowledge	How design help teacher developing understanding	*"I felt it really made it more realistic today, because we were here in a face to face and we're talking about practical uses, across the curriculum, it was great to get such ideas from different areas"* *"So yeah, I can see how, after collaborating together, I can see how I could possibly use, like, do a lesson on AI with my students"* *"More confident and have a deeper understanding"*
Challenges	Challenges encounter in the design process	*"to narrow it down to make it activities was actually the hard part for me"*
Agency	How the design session empowers teachers to introduce AI to students	*"I can see how, after collaborating, I can see how I could possibly use, like, do a lesson on AI with my students, and for them to get they'll get a lot out of it"*

Table 19 Initial codes with explanation and examples

Defined themes	Codes	Research question addressed
Programme framework and programme design	Programme pedagogy Hands-on Developed knowledge Learning outcomes Prior knowledge	[RQ 3.1]
Design to support learning (integrated, personally designed encourage implementation)	Hands-on Developed knowledge Learning outcomes Challenges	[RQ 3.2]
Teachers' attitude (collaboration, challenges)	Teachers' attitude Challenges Potentials	[RQ 3.2]
Teacher's role relevance for children	Relevance for children Agency	[RQ 3.1] [RQ 3.2]
Online experience (challenges, pro)	Online Needs Challenges	[RQ 3.1]

Table 20 Revised theme list of Phase 3

This Ph.D. focuses on EPE with the aim of investigating how research groups in emerging technologies might build effective outreach actions through teacher-learning and teacher-engagement in developing learning programmes on AI and Data literacy for primary school students. Therefore, this specific phase which represents an iteration of the design-based research study focused on teacher learning tried to promote a rigorous approach when it came to developing professional learning programmes for teachers in AI. To do so, framing teachers' learning on new technologies (TPCK framework) [RQ 3.1] and creating an interactive environment for teachers to develop their knowledge underpinned by constructionist learning principles [RQ 3.1] and design [RQ 3.2] was paramount. Consequently, I stated the importance of firstly giving teachers the chance to understand AI as adult citizens of the 21st century and then as teachers.

The first three synchronous online sessions represented an introduction to AI and data key ideas for a group of teachers from very heterogeneous backgrounds and with limited prior knowledge of the domain. From the mid-survey responses collected after the first three sessions, most of the teachers agreed that this introduction demonstrated to be an opportunity for them to learn more about both AI and data. However, even though responses from the surveys, before and after the online sessions, could highlight the initial evolvement of teachers' thoughts and ideas on AI, reflections from the focus group after the face-to-face session showed the value of the design experience as a key opportunity for them to continue to build their knowledge and understanding of AI. The face-to-face design experience represented a very valuable opportunity for teachers to continue to build on their knowledge of AI and this emerged during the focus group when Teacher 1 stated

> *"I've got a better understanding now, of the course, you know, after applying, I suppose, in education purposes. I suppose, trying to think about how you deliver to the pupils. As I had to better understand myself in order to be able, to design something that the pupils could use. So definitely, today's session helped to connect all the dots from the previous three sessions".*

The design session proved to play a key role in teachers' learning [F3.1]. During the sessions, teachers were asked to collaboratively create activities on AI integrated with other subject topics. The session represented a "step back" moment needed for participants to reflect on their learning of AI so far. Participants were aware of their content knowledge, but at the same time, they showed the urgency to understand how to translate that knowledge in teaching AI to children [F3.2]. So, the design-based session helped to reach that goal. These findings resonate with previous studies claiming the importance of giving teachers agency in terms of teaching AI through their engagement in designing activities on AI integrated with other subjects (Brummelen and Lin, 2020). However, the face-to-face session was successful also thanks to the rigorous design of the whole programme which was framed by TPCK and underpinned by constructionism.

When teachers were asked to identify what they enjoyed about the three online sessions and about the whole course, many of the responses mentioned the interactivity and practicality of the programme and hands-on activities [F3.3]. Moreover, during the focus group when discussing the importance of learning programme for teachers on AI, Teacher 6 pointed out in simple words the importance of hands-on (“*until you start messing around with it.”*) to really understand a technology

> *“And kind of figuring out what AI is good at as well. Seeing problems, could AI solve this problem? […]and just be more sure of its kind of capabilities and limitations. And you don't really get to figure it out until you start messing around with it.”*

According to the results, that hands-on activities based on constructionist learning principles, could represent an effective alternative for introducing AI key ideas to teachers when compared to frontal lectures. The hands-on activities offered opportunities for teachers to develop not only content knowledge but also experiment with approaches and methods to teach AI in class. Finally, they created an attractive and enjoyable environment to get to know and practise with the technology.

Some activities and tools worked well online. An example was Moral Machine [F3.4]. It represented an effective hook to grasp teachers' attention and reflections on ethical aspects of AI because it resonated with teachers not only as teachers but as adult citizens [F3.5]. From researcher's notes teachers had difficulties in taking decisions, they discussed and surprisingly found a common strategy as claimed by a teacher *"choose the one that does not break the law could be of example for the future so potentially a benefit for more in the future".* Additionally, they acknowledged *"that finding an agreement among more people could be more difficult",* and *"especially with different backgrounds or cultures".* This was just an example that demonstrates how teachers enjoyed this activity during the three sessions online however, there were some challenges due to the online setting.

Having a synchronous but online introduction allowed teachers to easily participate in the programme. On the other hand, despite planning all the dates in advance it was hard to have consistency [F3.6]. A couple of teachers did not follow all three sessions for different reasons. In the beginning, teachers were a little bit shy, so perhaps having an icebreaker could have helped. Also during the activity on the inclusive smart toy, even though participants were all together in the same online environment it did not automatically create the atmosphere of a small group sitting in the same room at a round table side by side [F3.7], therefore the researcher had to ask for sharing screens and ask questions to promote sharing and discussion. Overall, the majority of the teachers involved in the programme were engaged and showed a positive attitude, especially during the face-to-face sessions when they had the chance to network with each other [F3.8], as captured by this representative quote from a participant: *"Yes, connecting the session to our own practice and being able to discuss with peers worked very well".*

For most of the teachers who participated in the programme the learning programme represents an interactive and challenging learning opportunity to develop their knowledge of AI. I believe that an important result of the programme was the effectiveness in conveying not only content and pedagogy key ideas but also raising awareness from a holistic perspective of the impact of AI technology on our lives. Teachers could deeply reflect on their role as teachers and the relevance of AI literacy for their students [F3.9]. This theme emerged spontaneously during the final focus group and revealed how important it is for teachers to understand the motivation i.e., learning about AI to develop skills and competencies needed to support children in their learning process to discover AI as a technology and its impact and implication for our society, as captured in Teacher 6’s statement

> *“So, it's important to understand that like AI is here, it's here for a long time. And we need to probably as teachers, […] kind of call on with the pupils. We can be seen as the experts and […] they* [the students] *are future generations, we have to learn with them and ensure that we are learning with them”*

To conclude, the programme that was designed with teachers at its centre, based on TPCK, constructionist learning principles, design, and led by a clear purpose and defined teacher role, to empower teachers with the confidence and curiosity to keep learning about AI and to introduce AI to their children, as evidenced by Teacher 3’s statement:

> *“after kind of last few sessions, I can be much more aware of the practicalities of AI within our own life, you know, it's something that I'd be comfortable beginning to explore with children at this stage, like in school, because I wouldn't have definitely before these sessions.”*

And echoed by this reflection *“after collaborating together, I can see how I could possibly do a lesson on AI with my students, and for them to get a lot out of it”* that represent the ultimate goal of the programme: positively engaged teachers in learning more about AI and lay the basis to introduce it in class with their students [F3.10].

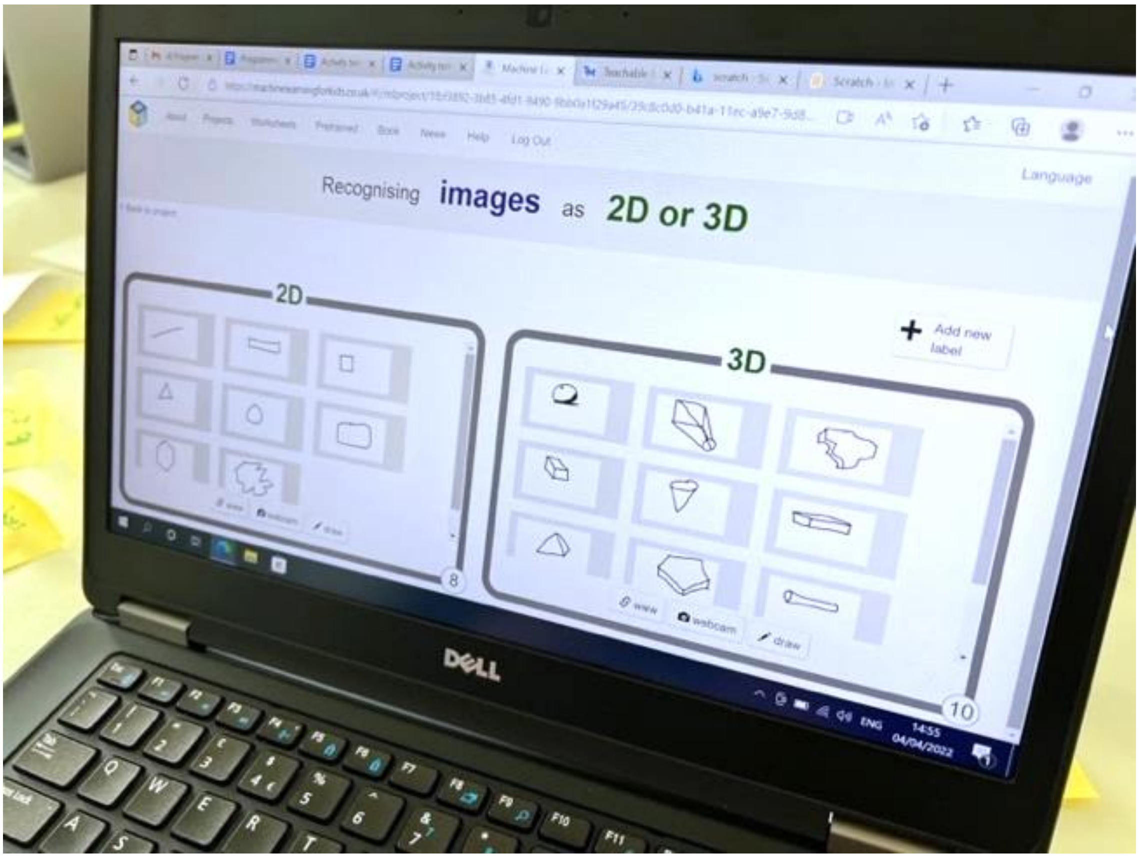


Fig. 56 Teacher testing an activity on geometrical 2D 3D shapes with Machine Learning for Kids: the dataset of the trained model

Fig. 57 Teacher testing an activity on geometrical 2D 3D shapes with Machine Learning for Kids: the teacher tests the model with a hand-draw cube on a sticky note

4.4.3 Summary

The aim of this phase was to investigate the effectiveness of a professional learning programme for teachers, underpinned by TPCK framework and developed based on constructionism and design principles to promote a critical and creative approach to AI literacy and pedagogy. The programme resulted to be effective in giving teachers the opportunity to develop their knowledge and understanding of AI and beyond that to empower them to introduce AI to the children in their schools.

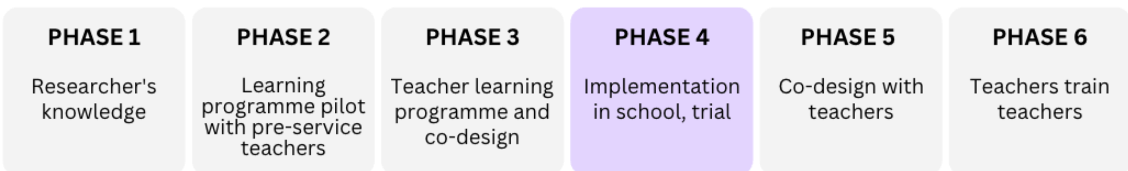
During the programme conducted in this phase (PHASE 3) I co-designed activities together with teachers. Those activities were revisited and developed in the first draft of a learning programme for children. The programme was tested by teachers in class (PHASE 4). After PHASE 4, I met again with the teachers for one last face-to-face co-design session to improve both the learning programme for children and teachers (PHASE 5). Consequently, thanks to feedback and insights from the implementation in school and teachers' expertise I finally developed a handbook with resources for teachers attached as Appendix I.

Results from this phase (PHASE 3) informed primarily PHASE 6 in which teacher advisors led a learning programme on AI for a new cohort of teachers.

Key findings from PHASE 3 that informed PHASE 6 are:

1. Designing activities as a means to develop knowledge and understanding [F3.1]
2. Teacher urgency to translate their knowledge in teaching AI [F3.2]
3. Appreciation of the practicality of the programme [F3.3]
4. Moral Machine effective in stimulating discussion [F3.4]
5. The synchronous online programme did not suit everyone [F3.6]
6. Online did not create the same atmosphere as occurs in a small group sitting at the same table [F3.7]
7. AI awareness developed at two levels, as teachers and citizens in the era of AI [F3.8]

4.5 PHASE 4 – Implementation in school



After the learning programme for and with teachers described in PHASE 3, three primary school teachers from that group, engaged with their students on AI. In order to do this, they used and tested as a reference a first draft of a learning programme for children illustrated in detail in Appendix N. The programme included activities where AI was embedded into curricular subject topics, co-designed by teachers together with the researcher during the last session of the learning programme for teachers conducted on DCU campus (PHASE 3). Teachers involved in the school trial came from very different backgrounds and engaged with very different groups of students. Teachers, students' age, and data that could be collected from their experiences are listed in Table 21. The transition between PHASES 3 and 4 was a bit challenging as one of the four teachers dropped out of the research project. However, conscious that *"It is always necessary to remember that while research is understandably important to researchers, for gatekeepers and participants it is just one of a myriad of competing priorities* (Weller, 2012 as quoted by Kara, 2012, p.77) I concentrated my efforts in getting the most out of the involved participants.

Teachers A collaborated and put a lot of effort into testing the programme in class and following the researcher's requests. Teacher B was really involved and put a lot of effort into testing the programme with their group of students with special needs. Teacher C tested some activities though they did not provide written data on class experience (no design journal, no observation framework). Therefore, the teacher who represented a mainstream experience was Teacher A. Teacher A engaged with 10-12 year old children during school time and from their experience, I could gather data from the teachers (Observation framework, semi-structured interview) and the children (Design journals). Therefore, I decided to focus the data analysis on this case, as a case study.

Teacher	Teacher's background	Students' age group	Data collected
Teacher A	**Learning support teacher**	**10-12 years of age (5th and 6th class) mainstream school**	▪ **Observation framework** ▪ **Students' Design journal (filled in by the students)** ▪ **Interview**
Teacher B	Special education teacher	14-15 years of age special needs	▪ Observation framework ▪ Students' Design journal (filled in by the teacher) ▪ Interview
Teacher C	Home liaison teacher, coding after-school club mentor	9-10 years of age (4th class)	▪ Interview

Table 21 Teachers involved with the implementation in school

4.5.1 Research question

This Phase of the study was focused on the implementation of a learning programme for children on AI. The programme activities were focused on AI big ideas and are integrated with curricular subjects. This programme was underpinned by constructionist learning principles and includes a DBL activity on AI for good, with a focus on health. Activities were co-designed with a small group of teachers together with researchers as part of a professional learning programme for primary school teachers (Amplo & Butler, 2023). In this phase I specifically wanted to investigate the impact of the programme on students (10-12 years old) in a formal setting, therefore this phase research question was: **[RQ 4.1] How can we design learning opportunities for students to enable them to creatively and collaboratively explore AI key ideas and competencies within the classroom?**

4.5.2 Findings

I started to become familiar with the collected data and defined some initial codes. Codes were then used to label pieces of data throughout the entire qualitative dataset (list of codes and example of pieces of data in Table 22). Then I tried to interpret the meaning and understanding from the teacher's words (both written and transcribed from the interview) collected during and right after the programme.

Code	**Meaning**	**Example**
Children learning outcomes	What did children learn from the activities?	*"They said they were beginning to see what's involved in AI. They also saw their own biases"* (from Teacher A's observation)
Design experience	How was the design experience?	*"And they did find it hard to kind of come up with an idea of, you know, the top of their head, like, you know, so, but they all did"* (from Teacher A's interview)
Peer support	Did children collaborate?	*"Basically, the ones who had a bit of experience kind of sat in with the ones (with less experience) […] Okay, well, maybe we could do it this way."* (from Teacher A's interview)
Tools	How were the tools used?	*"They learnt more about the process of training using Machine Learning for kids"* (from Teacher A observation)
Challenges	Difficulties that emerged both from children and teacher perspective	*"I think they've found difficult with the experience that they had in the things, to then make the leap to make something"* (from Teacher A's interview)
Teacher experience	How was leading the programme?	*"So I have to work out, I suppose a lot of that beforehand", "you kind of have to help them I suppose a bit with that, […] it was more just kind of pointing them"* (from Teacher A's interview)
Suggestions about the programme	General observation on the programme itself	*"Possibly have more lead in time to allow the students to explore possibilities with AI. They had just had tasters and were then expected to design a whole project but having said that all the 3 groups produced ideas that they agreed upon."* (from teacher A's observation)

Table 22 Codes used on data collected

Themes emerged	Codes
“AI-thinking” needs time	Design experience Children learning outcomes Challenges
Learning AI big ideas (human vs machine intelligence, bias, AI and data relationship)	Children learning outcomes
No background in coding required but could be beneficial for the design process	Challenges Peer support Design experience
Experimenting machine learning tools with different type of data require time	Challenges Suggestions about the programme
Identify the dataset, consideration on data in different activities	Children learning outcomes
AI activities integrated needs to be simple enough if they are the first one introducing AI tools and tested Or can be anticipated with simpler examples	Suggestions about the programme Challenges, Tools
Design journal could be improved Teacher mentor role to point students (ideation/brainstorming)	Design experience Teacher experience
Design is challenging a way to start practicing the process Enjoy the responsibility of group work	Design experience Challenges
Template with basic building blocks could support design	Teacher experience
Teacher’s preparation and taking control of the programme (agency)	Teacher experience

Table 23 Themes from coding

From the implementation in school emerged that the programme represented an opportunity for children to start to develop their knowledge of AI. Students built their knowledge gradually throughout the sessions [F4.1]. As Teacher A told the researcher during the interview while referring to students: *“it just took them a while to think about what they were going to do, you know because they just started, I suppose to think in the AI way”*. It takes time and practice to ignite "AI-thinking". It took a while to start thinking critically about what is behind AI and data and about what could work or not in training machine learning models. It is evident from the teacher's notes in the observation sheets, how students' learning evolved. From the first session, it became apparent that the children started to think about bias meaning and to make connections with their own way of thinking [F4.2]: *"They said they began to see what was involved in AI. They also saw their own biases in terms of orange carrots restricting their results."* Then from session 2 students developed their understanding of machine learning workflow that then led them to reflect on how computers perceive the world [F4.3], in session 3:

> *"They learnt about the stages of training, learning, and testing involved in AI. They also saw the limitations of how a computer sees the world and we talked about how we could so easily distinguish things the computer cannot."*.

During the design sessions, students developed their critical thinking in relation to AI design [F4.4]: *"There was some discussion about bias in AI and how it could affect health outcomes. There were also further comments on how different our intelligence is from AI"*. Throughout the programme Teacher A highlighted how students discussed multiple times how machine "intelligence" and power, up to now, are different from their intelligence and competencies, as humans [F4.5]:

> *"The children learnt the stages of developing AI projects. They understood the importance of the data gathering stage. They also saw the ease in which bias was introduced in the training stage. They also realised how different the computer representation of the world was from theirs."*

Knowledge development on AI requires time and practice as AI learning is quite complex. During the programme children developed competencies in terms of AI big ideas from a technical perspective, started to interrogate themselves on ethical issues, and developed skills in terms of new digital tools, as illustrated in Fig. 58.

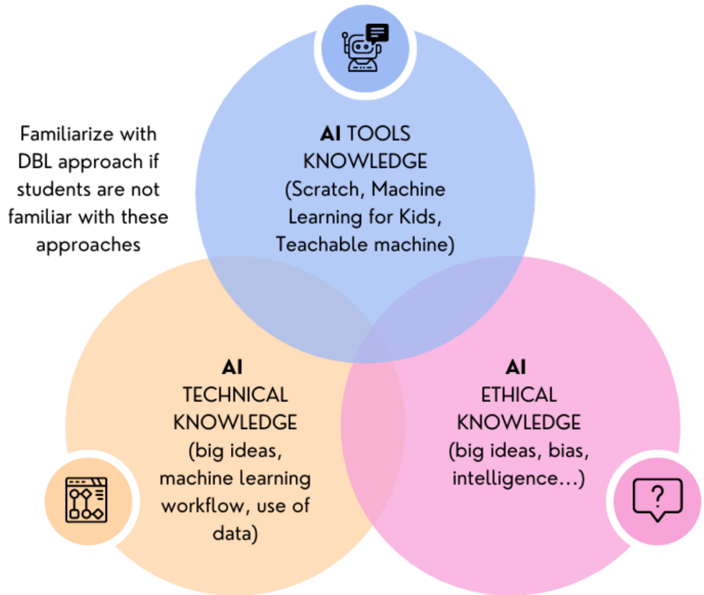


Fig. 58 Children AI developing knowledge complexity in the context of learning programme on AI in class

As highlighted in the previous paragraph, teachers mentioned how students started to make connections with the real world and to reflect on the meaning of concepts such as intelligence or perception. Therefore, children need more time to build their knowledge with all these new ideas while at the same time becoming familiar with the digital tools [F4.6]. Teacher A's notes clearly stated how a longer programme would have been beneficial, *"Possibly have more lead in time to allow students to explore possibilities with AI. They had tasters and were expected to design the whole project".*

The opportunity to reflect and tinker with AI activities longer could potentially lead to less challenging DBL sessions and support the creativity children really enjoyed. As indicated by Teacher A's reflective observations: *"Overall, they* (students) *said the activities were fun and they enjoyed the* *creative process, but they did feel that it was a lot to do in designing and building the project in the number of sessions they had".* In particular, having more time to get used to tools, trying different types of datasets, and having an introduction to coding with visual building blocks, could help to better prepare students for their experience with design. This emerged from Teacher A words:

> "*I think they've found difficult with the experience that they had in the things, to then make the leap to make something, you know, or to just come up with an idea to the AI to. So if they had a little more time to play around with their products, you know, with the website, like Scratch as well"*

Despite concerns about the balance between the programme content and time to better prepare children for the challenging design sessions, it emerged from the teacher's voice that students overall enjoyed the experience. Students especially appreciated the group work, playing around with tools, and mostly, as highlighted by Teacher A during the interview *"They enjoyed that kind of creative responsibility, I suppose of making"* [F4.7]. DBL represented both a challenging and formative AI learning opportunity for the children. As reported by the teacher in their observation, students *"Enjoyed the responsibility of creating something themselves. They liked having time to research but found thinking in AI terms difficult".* Design sessions were successful for the three groups of children who worked together to prototype AI for health projects. As mentioned in the teacher's notes *"Eventually they were all able to come up with project ideas"* and *"all the three groups produced ideas they agreed upon".*

One group worked on developing AI software that helps people to know more about the sugar or fat content of a specific food and advising if the values are too high for a specific user, the second group prototyped an AI-powered tool that could tell the user if a food is considered healthy or not, while the last group focused on designing an AI application that could monitor your sight and advise the user in case of bad or worsening sight as shown in Fig. 60.

All the students worked actively on their projects, as reported by the teacher, some of them focused on the machine learning model, and some of them worked on the interface of their prototypes. They then merged the coding works in one unique application using the Machine Learning for Kids platform with visual blocks.

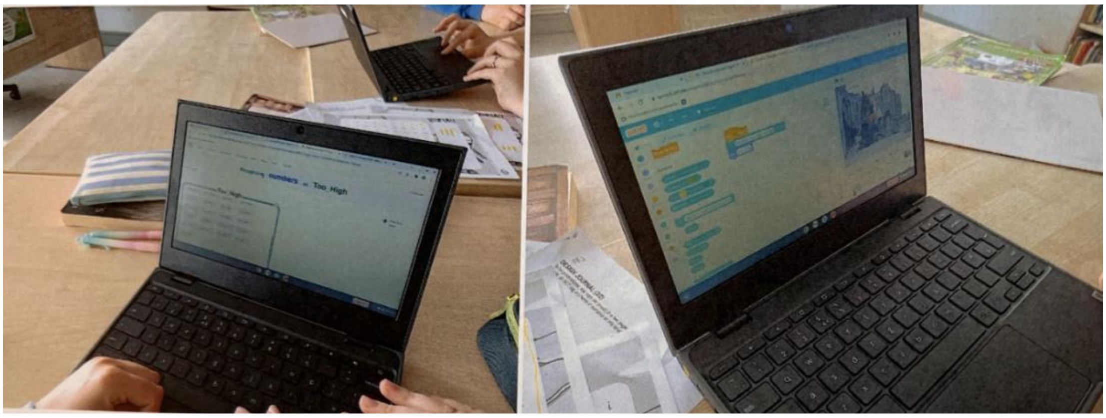


Fig. 59 Children working with Machine Learning for Kids training a model during their design sessions

When the teacher was asked about their experience in leading the programme the key aspect that emerged was the preparation required before the programme [F4.8]. The teacher mentioned that before starting the programme they prepared at home and tested the activities by practising with the tools "*so I knew how to how to code it and Scratch, you know, how to deal with the blocks that the machine learning was going to come up with*".

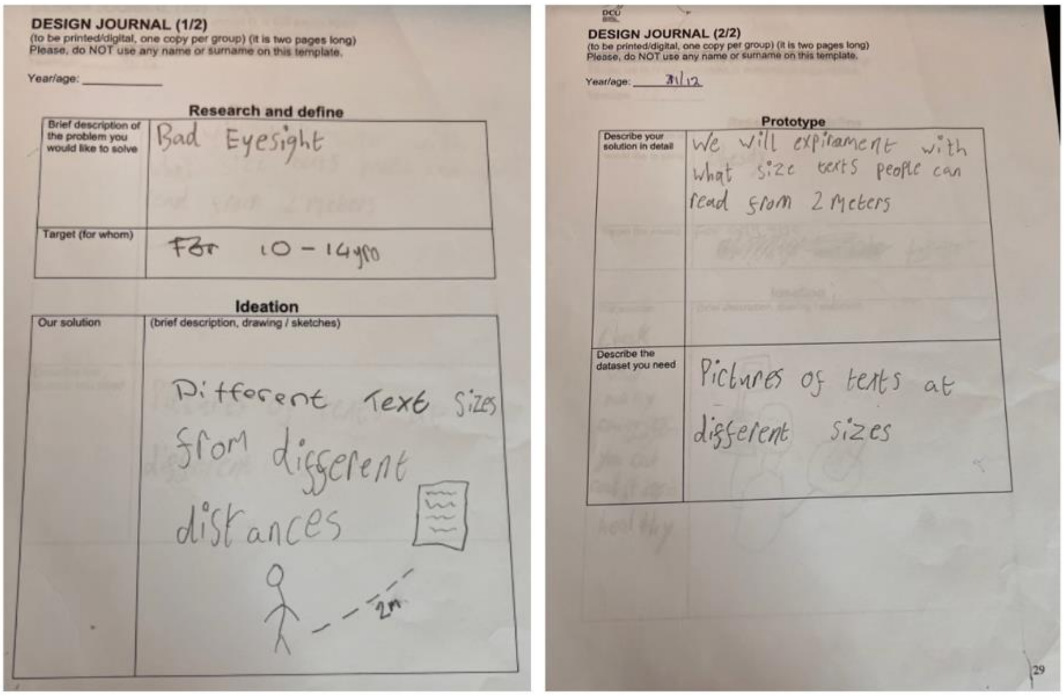


Fig. 60 Design journal of a group of students who decided to prototype an AI-enhanced system that can tell you if your sight is good or not

The teacher also felt empowered to twist the programme to better fit their students [F4.9] as highlighted during the interview: *"I thought I'd just get them to do something small for us that would work.*". Since the programme was the first opportunity for the students to explore AI, engaging them in exploring machine learning workflow with simple objects available in class felt more comfortable for the teacher and enjoyable for students as a smooth introduction to more complex dataset related to subjects. Lastly, the teacher also autonomously prepared some cards with examples of algorithms in Scratch to manage different type of data (images, sounds) that could be used to test the AI model trained with Machine Learning for Kids [F4.10], as visible in Fig. 61.

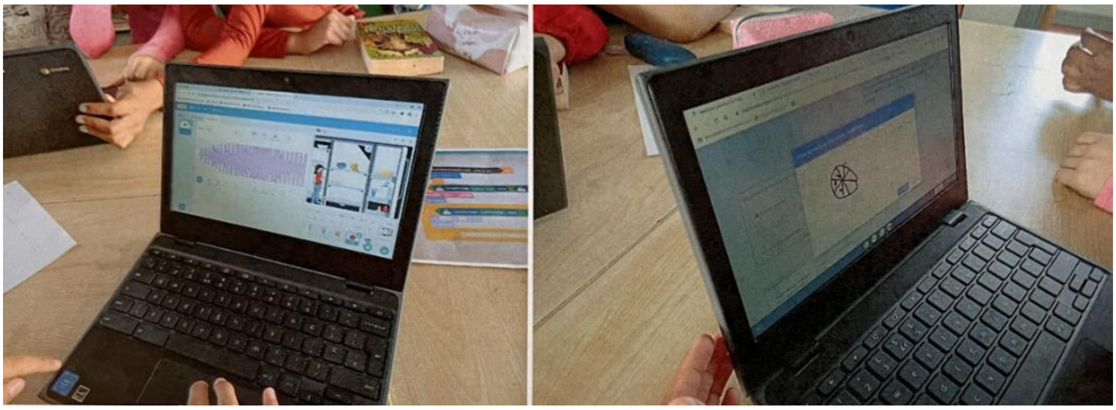


Fig. 61 Children working on their AI projects training a machine learning model on the right and working at a human-machine interface on the left, which was then used to implement the AI model.

4.5.3 Summary

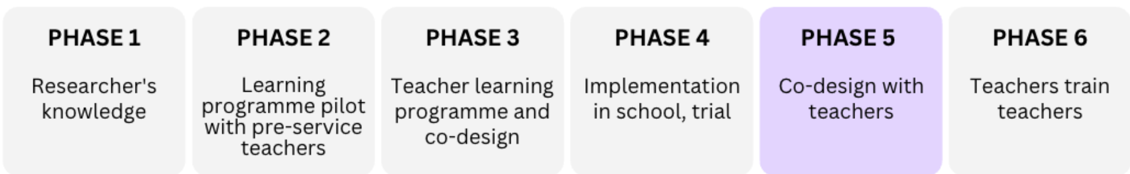
It is paramount to engage with children on AI to enable them to recognise both its impact and implication for our society. Students in K-12 should be engaged in AI key ideas (Touretzky et al., 2019) with a holistic perspective (Long and Magerko, 2020) so that they can develop the competencies to become creative, critical, and ethical designers and innovators but most importantly aware 21st-century citizens (OECD, 2021).

Even though this experience was underpinned by the literature on AI competencies for K-12 and design guidelines on learning programmes (Zhou et al., 2020), the aim of this phase was to investigate more about the pedagogy of AI. To tackle the research question, I co-designed with teachers a first draft of a learning programme for children with teachers, with AI integrated activities and DBL sessions on AI for good. Both constructionist learning principles and DBL approaches supported children in being designers and agents of their own learning of AI. Students showed they enjoyed the responsibility of creating something new and collaborating in groups even if they found the task slightly challenging. Therefore, despite being creative in AI requested extra effort, on the other hand, DBL fostered the development of knowledge on AI by providing students an opportunity to reflect and think about AI. DBL sessions on AI for good, supported students' teamwork and collaboration while encouraging communication, creative and critical thinking. Findings from this phase (PHASE 4) informed PHASE 5 in which I conducted a co-design session with teachers to improve both the learning programme for teachers and children.

Key findings from PHASE 4 that informed PHASE 5 are:

1. The need to give more time and space to practice with tools i.e., Machine Learning for kids before asking students to design a new project [F4.6]
2. Preparing template with Scratch main block algorithms for support [F4.10]
3. Improve the design journal layout (see journal developments in Section 3.6.3)

4.6 PHASE 5 – Co-design with teachers



The project involving GROUP C teachers, including teacher associates and advisors from PDST, can be summarized as follows. In the first part of the learning programme on AI and Data, teachers participated in three online sessions during PHASE 3. For the second part, there was a face-to-face session held during PHASE 3, where GROUP C teachers met on campus with a researcher to co-design AI-integrated activities for children as part of their learning programme. In PHASE 4, three teachers (selected from GROUP C) conducted a trial of the draft learning programme for children in their respective schools. The programme, provided by the researcher and including co-designed activities from the on-campus session, was implemented. Finally, in PHASE 5, Teacher A (from GROUP D) shared their insights, along with an advisor from GROUP C and the researcher, during the last co-design session held on campus.

During the on-campus session, the following agenda was followed: First, there was an introduction to the concept of AI for good. This was followed by Teacher A sharing their firsthand experience of implementing the AI learning programme in a school setting. The session then moved on to the first design session, where participants brainstormed ideas on enhancing the AI and Data learning programme for children. Subsequently, a second session was conducted to explore ways to improve the AI and Data learning programme specifically for teachers, including the development of a handbook as a resource. Finally, a focus group discussion was held to gather valuable insights and perspectives from the participants. This face-to-face session on campus provided an opportunity for collaborative engagement and fruitful discussions to improve the AI and Data learning programme for both students and educators.

4.6.1 Findings

Codes that emerged from data gathered are listed with examples in Table 24. Themes illustrated in depth follow.

Code	Meaning	Example
Co-design with teachers	Advisor perspective on co-design with teachers	*"Usually, you learn yourself and then you design a course. It's worth learning alongside the teachers to design a course. It's kind of a different way of doing things which is just very enjoyable actually"*
Feedback on the programme for teachers	Any advice on how to improve teacher programme	*"Try activities from children programme with teachers (so they have engaged already with them)"*
Feedback on the programme for children	Any advice on how to improve children programme	*"Add a data cycle activity"*
Teacher advisor take home	Advisor perspective of being part of this research learning programme	*"So it's good to have another area to point teachers to you know, so they can challenge themselves further and challenge their their pupils understanding further as well."*
Recommendations on the handbook for teachers	Advice on how to improve the handbook	*"Provide templates to use in Scratch"*

Table 24 Codes used on data collected

4.6.1.1 Feedback on children's programme

To kick start the first design session I asked Teacher A to highlight the main challenges of their experience engaging children with the programme, which were written on the board. Then together with Advisor A, we brainstormed ways to overcome the challenges and ideas to develop the programme, below is an example of the notes taken on the Jamboard, during the discussion Fig. 62. Teacher A reported it was not ideal to use data to train models that were not accurate, as a first introduction to Teachable Machine (i.e., using Teachable Machine to create a model that recognizes emotions did not work) [F5.1]. Therefore, Teacher A suggested starting the session with simple objects (a step that was included later in the handbook). On the other hand, I explained why a model that is not very accurate, is a valuable example and input to trigger the discussion with the students on how machines can be wrong and how challenging it could be to prepare data that can train a good model, or if there are strategies to improve a Machine Learning model.

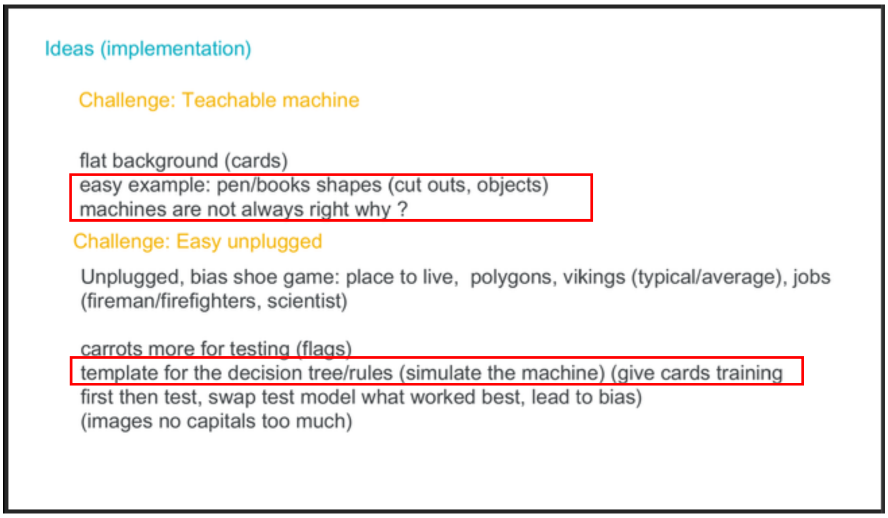


Fig. 62 One canva of the Jamboard used during the first design session

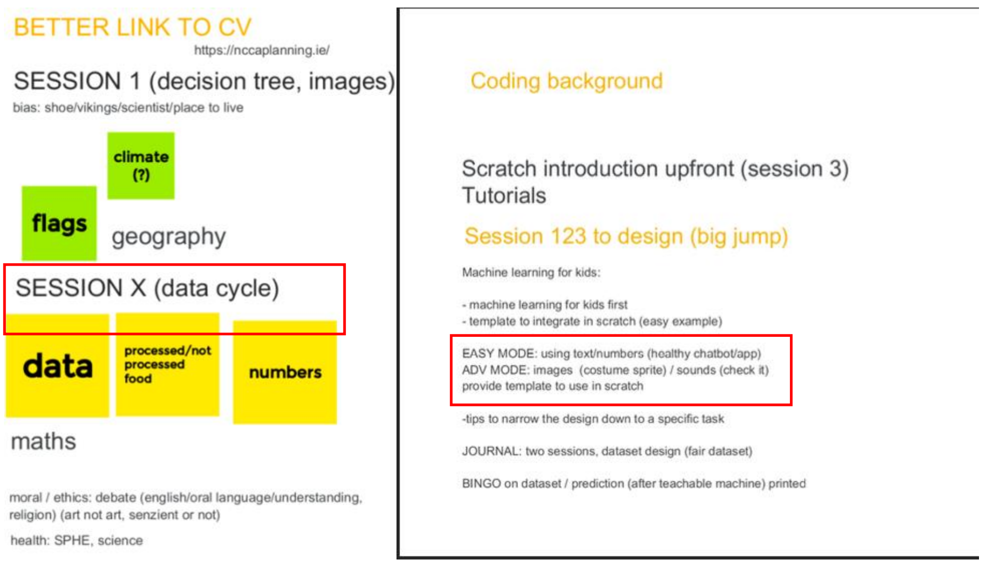


Fig. 63 Canva of the Jamboard used with Teacher A and Advisor A

Regarding the unplugged activities, Teacher A used the “bias shoe game” as an activity with the children. They experimented with this activity while completing the learning programme for teachers. I asked Teacher A and Advisor A about ideas of how this activity in the programme could be integrated into subjects. Advisor A came up with the idea of doing the drawing activity on Vikings linking to history, as Vikings are often stereotyped in our imaginations so it could be a good fit to show and discuss biased concepts (an activity that was later included in the final version of the handbook) [F5.2]. As can be seen Fig. 63, Advisor A suggested to have a session on data and data cycle [F5.3]. Moreover, Teacher A also raised the need for more support for the activity on decision trees. Specifically, Teacher A suggested a *“template”* and *“cards”* [F5.4].

The last challenge that emerged was the “big jump” between the first session of the programme (based on constructionism with the aim of getting to know more about AI and Data and machine learning) and the second part focused on designing AI for good. Teacher A mentioned that the transition in the programme could take longer if the students have no prior experience or skills in coding with Scratch, as they mentioned they had a Scratch introduction with tutorials before starting with the design [F5.5]. Teacher A suggested that templates could be useful with easy examples of the Scratch and the Machine Learning for Kids platforms [F5.6], and on how to integrate them together, as noted in Jambord canva in Fig. 63.

4.6.1.2 Feedback on the teacher programme

Notes from the brainstorming with Teacher A and Advisor A are shown in Fig. 64. Teacher A proposed allowing more time for teachers to tinker with the Machine Learning for Kids model with different types of data (*“data type examples”*) and to support them with its integration with Scratch (*"managing input/data”*) [F5.7]. Advisor A recommended highlighting learning outcomes and how links can be established to the standard curriculum, showing teachers the programme can be integrated (and is *“Not an extra layer”*) and relevant to everyone (*“explain with care connection with our life”*) [F5.8]. Lastly, Advisor A suggested that teachers try all the activities introduced during the learning programme for as the same activities (i.e., the ones from the handbook) could then be introduced to children [F5.9].

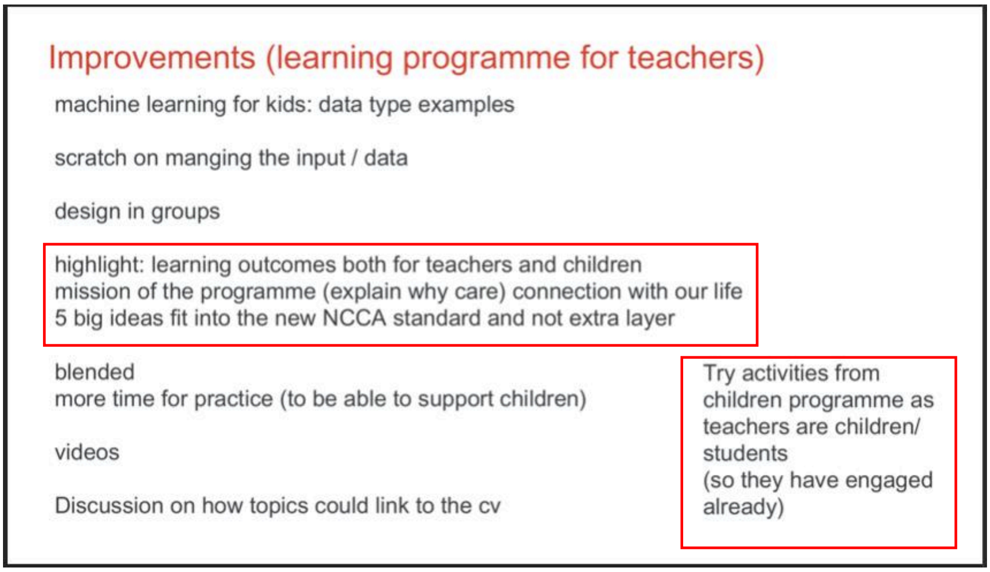


Fig. 64 Jamboard on teacher learning programme

4.6.1.3 Recommendations on the handbook

Before moving to the focus group, I asked Teacher A and Advisor A if they had any recommendations they wanted to share on the handbook for teachers (the final version of the handbook was then developed by the researcher, readable in Appendix I). From the figure below, Fig. 65, we can see they suggested providing a handbook to each teacher at the end of learning programme for teachers [F5.10]. Teacher A and Advisor A also suggested to include an introduction, extensions, and resources available online (i.e., videos) [F5.11]. Teacher A and Advisor A recommended designing coding examples (Scratch algorithms were later included in the handbook) and design journals

[F5.12]. They also suggested providing videos and *"questions to prompt discussion".* Teachers advised that having a dictionary at the end of the handbook would be helpful while having templates after each activity, and available to be printed online would also be helpful [F5.13]. Lastly, they suggested ideas to promote engagement including i.e., creating a competition for schools and certificates of completion of the programme [F5.14].

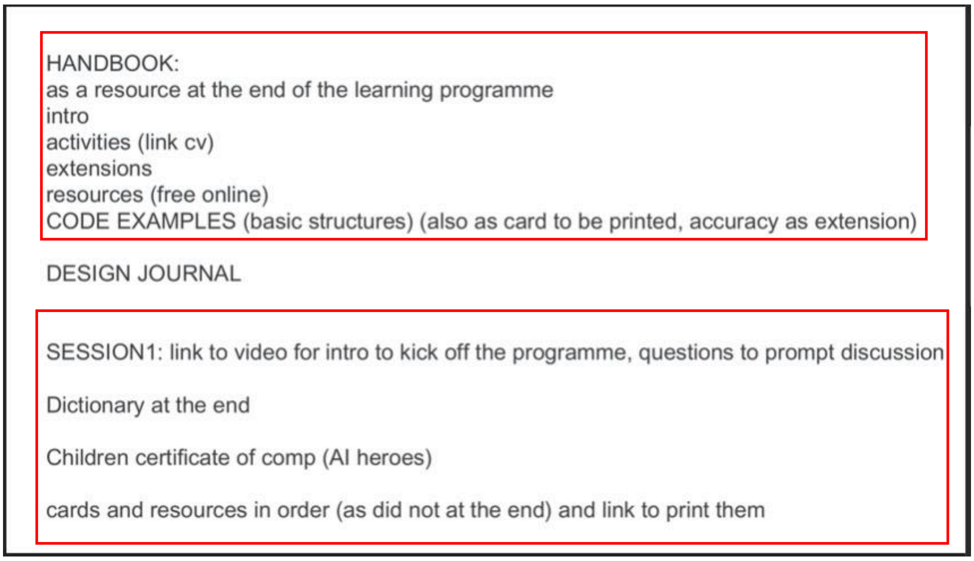


Fig. 65 Jamboard on Handbook recommendations

4.6.1.4 Reflection on teachers' experience

The focus group was a means of reviewing the process. Teacher A and Advisor A were first engaged with the learning program for teachers where they had the opportunity to reflect and learn about AI key ideas and explore some tools that they could use with children. Together with the researcher and other teachers, we designed a learning programme for children. After that, teachers went to school, and tried the program with their classes. Finally in this co-design session on campus (PHASE 5), we were back together to understand how we could improve the learning program for teachers and children. My first question was, "*did you enjoy being part of designing a learning programme, both for* *teachers and children on AI and data, instead of receiving a program ready to use? Did you enjoy being an active part of the design of both programs?"*

Teacher A appreciated the interactivity of the programme for teachers [F5.15],

> *"I suppose you learn more […] when you're involved at the initial stages […] it was interesting to engage with the big ideas of AI and stuff, and then try and, you know, integrate them into a program, you know, so yeah, from our point of view it was very different from just being presented with a program",*

and the space to improve and made changes to the programme for children if needed as the programme allows teachers to do so as they pointed out [F5.16]:

> *"I suppose, what I also felt, we could adapt it a little, like as we were doing it. That wasn't necessarily completely written in stone, so if there were some things that in the classroom, we thought it would work better, that we were able to do that, to make those changes"*

Advisor A echoed saying that they particularly appreciated the opportunity to co-design creating resources that could work better for primary school teachers as opposed to a premade presented course:

> *"if you were presented with the course, you know, because you haven't been given the opportunity to tweak it or change it. You might like some aspects of it, if you're given the course. But the fact that we could design in such a way that we felt it would be more applicable. […] It was great to be able to pick and choose what we know would work well."*

According to Advisor A, participating in such a programme that involved teachers and teacher advisors from the beginning, represented a new and valuable opportunity to collaborate with teachers and learn and co-design together [F5.17]:

> *"When we run a course we always look for teacher feedback. And then we usually make the tweaks. But I suppose in this design process, we had the teachers here at the table, so it's kind of good to be able to*

kind of bounce ideas off them in their various contexts and various schools"

An approach that was new for them as usually they are asked to study new topics by themselves and prepare courses for colleagues:

"Usually, you learn yourself and then you design a course. It's worth learning alongside the teachers to design a course. It's kind of a different way of doing things which is just very enjoyable actually"

Furthermore, Advisor A appreciated how they were involved in the role of experts from the beginning of the programme and were called to share advice on how to improve the programme for teachers [F5.18], as they said:

"I think that in order to be able to design something, and need to fully understand it, and the fact that you're designing for teachers and you're a teacher yourself, you can know what works well from other courses"

4.6.2 Summary

PHASE 5 represented a valuable opportunity for me to learn from the experience of both the advisor and the teacher who piloted the programme for children in school. The day represented an opportunity to wrap-up the whole journey designed to collaborate and engage with teachers to better understand how to involve them and children in learning more about AI.

Findings from this phase (PHASE 5) informed the further development of the learning programme both for children and teachers and the design and development of a handbook for teachers and a website (described in Chapter 5). All the resources produced were tested for scalability and sustainability and are ready to be adopted by PDST advisors to train new teachers (PHASE 6) or to use by teachers independently.

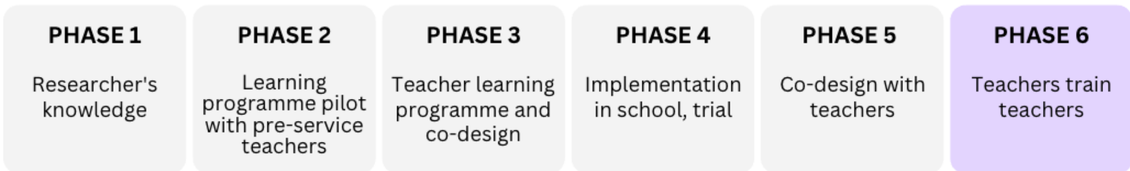
Key findings from PHASE 5 that informed PHASE 6 are here listed:

1. Providing the handbook to teachers [F5.10]
2. Highlighting the link of the activity to the curriculum standards [F5.8]
3. Lower threshold activities as an introduction to new tools [F5.1]

Key findings from PHASE 5 that informed the improvement of the Handbook and Website are here summarised:

1. More templates to support the design and learning [F5.6]
2. Highlighting the link of the activity to the curriculum standards [F5.8]
3. Lower threshold activities as an introduction to new tools [F5.1]
4. Data cycle activity [F5.3]
5. Certificate of completion [F5.14]
6. Links to videos [F5.5]
7. Glossary [F5.5]

4.7 PHASE 6 – Teachers train teachers



As the last phase of the design process of this study, I wanted to understand and examine the scalability and sustainability of the teacher learning programme. Therefore, I had the opportunity to organize an intervention based on the “train-the-trainer” approach asking teacher advisors to run a learning programme on AI for their peers: other teacher advisors from PDST.

After feedback from the schools (PHASE 4) and a co-design session with Teacher A and Advisor A (PHASE 5), I revised all the materials I had developed as a support for teacher training. I specifically created a digital pre-print version of the handbook and a website with video resources and useful links (in-depth presented in Chapter 5). After that, I met online with Advisor A and Advisor B both of whom took part in the learning programme for teachers of PHASE 3 (both from GROUP C). They voluntarily agreed to lead a trial of the learning programme for teachers with a new cohort. Together we reworked the programme materials, and I provided them with the handbook, the mock-up of the website, and slides with notes. The adapted new programme consisted of a full-day face-to-face learning programme on AI, led by the two advisors with a group of 11 new teachers (GROUP F). **The programme is outlined in Appendix O.**

At this stage, the researcher was not required in the role of the trainer, which was taken by Teacher Advisors A and B. The course took place at the PDST centre and involved a new group of teachers, GROUP F. The group consisted of 11 teacher advisors with STEM backgrounds.

Fig. 66 Picture of the room during the Phase 6 course for teachers led by the Advisors

4.7.1 Findings

The themes which emerged are discussed below in the findings. I used descriptive statistics for quantitative data (from Likert scale questions) to show and highlight responses to inform the analysis.

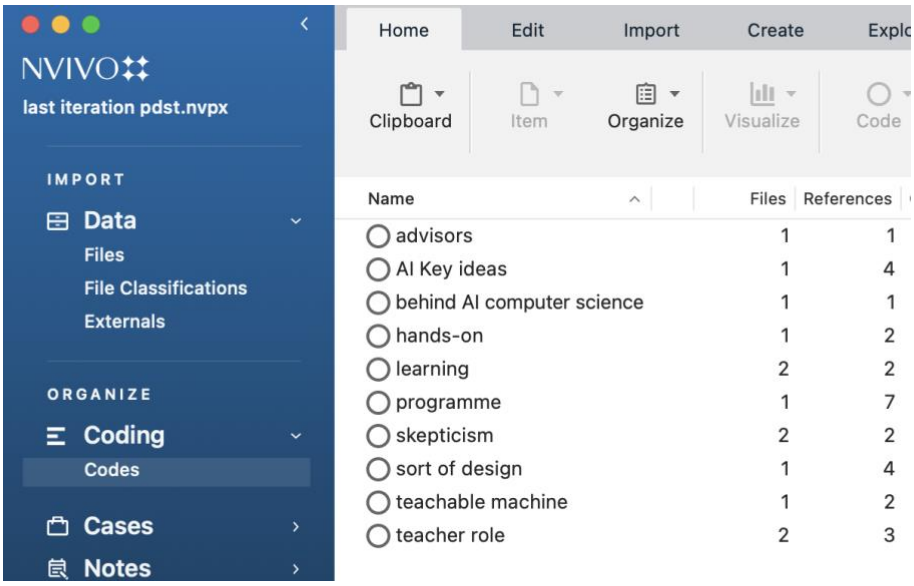


Fig. 67 Codes that emerged from PHASE 6 data collected, Nvivo® screengrab

The survey responses and focus group findings indicated the learning programme was a positive learning experience. Advisors A and B who ran the programme indicated how engaging with peers, GROUP F teachers who were advisors with a background in STEM, proved to be an opportunity to discuss and reflect in depth on AI big ideas [F6.1]. As Advisor A said:

> *"It kind of led to a lot more questioning on things and teasing things out really in the room, on, say, bias or morality. Or I suppose, the one that the unsupervised, the supervised learning, we had to tease out a little bit more because they really wanted to understand what the difference was, […] but then the activities kind of enhance their understanding of those as well. So, it was good. There were very good conversations, actually."*

When Teachers were asked in the post-survey if they enjoyed the workshop, they strongly agreed (10 out of 10 responses). Teacher 2 added a comment at the end of the survey that *"The content was excellent and very well presented by the advisors"* and Teacher 8 echoed: *"Very stimulating topic with lots of content that warrants further exploration"* [F6.2].

Data from the survey highlighted that the aspect of the learning programme that teachers liked the most was the opportunity to experiment, Teacher 3 wrote that they liked the *"The hands-on element of creating activities as pupils would"* and Teacher 3 said that they appreciated the *"Discussion with other teachers and practical tasks."* [F6.3]. As represented in Fig. 68, based on Teachers' responses, 6 out of 10 teachers mentioned they particularly appreciated the practical approach of the course, 3 mentioned the opportunity to discuss with peers, 5 of them acknowledged the tools used and 4 of them the resources and activities presented by the Advisors.

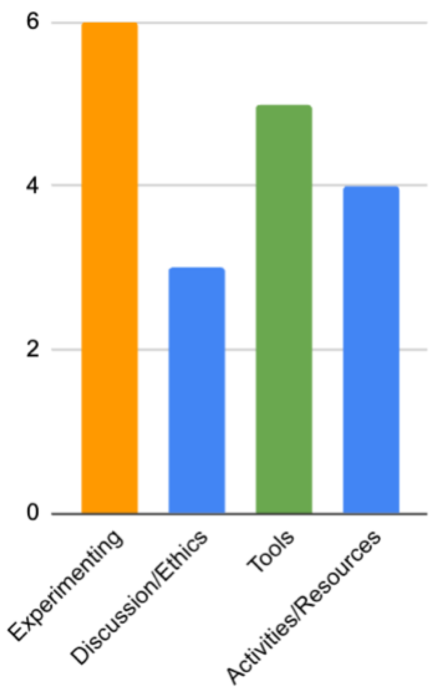


Fig. 68 What teachers enjoyed the most of the course

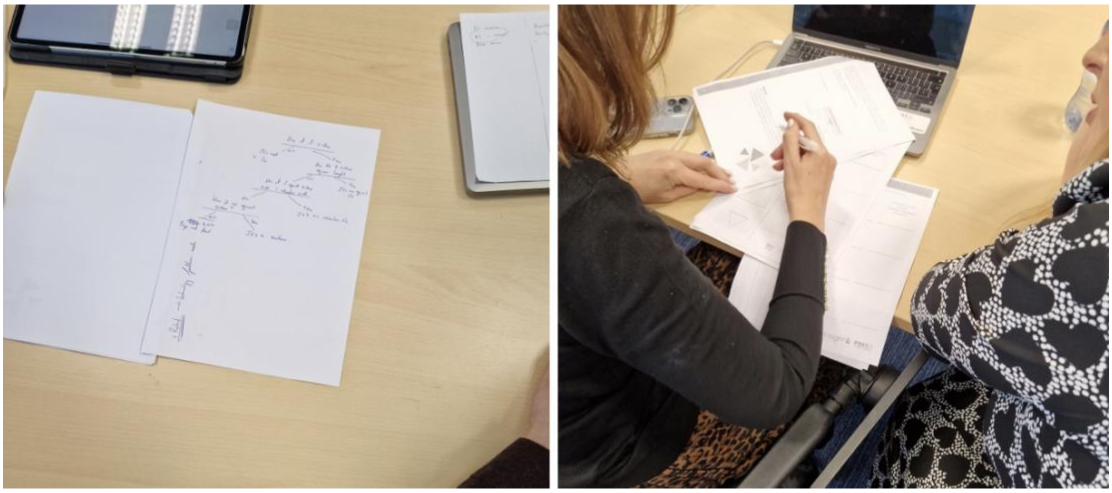


Fig. 69 Teachers trying decision tree activity from the handbook draft

One of the practical activities undertaken during the programme was a decision tree activity (Fig. 69). During the focus group, Advisor A remembered one of the teachers reflecting on the approach and saying how this activity could be used with children:

> "*One of them (participant) said to me that she had used something like decision trees in her classroom but never thought of getting the children to create a decision tree. It'd be better learning for them when they create their own."*

This feedback demonstrated how engaging teachers in practical activities enables them to experiment with an approach based on constructionism and design, enabling the development of their understanding of both the methodology and the content [F6.4]. 9 out of the 10 teachers strongly agreed that they learnt something new about AI and Data thanks to the programme.

Interesting responses to the question "Is AI more intelligent than humans?" were as follows: Teacher 4 wrote: *"Not necessarily, it relies on programming by a human. But there's more than one form of intelligence."* while Teacher 2 replied:

"I think this really depends on your interpretation of intelligence. Personally, I do not think so as I feel humans have more emotional intelligence which is important when making decisions and responding to situations. Yes, AI can be trained to acquire a lot of information but at this point, humans have the upper hand."

Both responses reflect in-depth thought about the meaning of intelligence and demonstrate an understanding of AI as a technology created and coded by humans [F6.5]. After the programme all the teachers who responded to the survey were able to mention a technique behind AI in computer science: 6 of them wrote machine learning, 1 coding, 1 coding/predicting, 1 reasoning, 1 abstraction, showing developing awareness of AI. Also interesting were Teacher 4's thoughts: *"Seeing how apps and websites can use your camera to collect data and how they use it to categorise you",* reflected an understanding of the functioning of systems based on AI.

The last section of the programme was focused on the activity of designing an inclusive smart toy using Scratch and Machine Learning for kids, the same activity I tested with pre-service teachers and teachers in PHASE 3. It is possible to see a teacher working on their programme in Fig. 70.

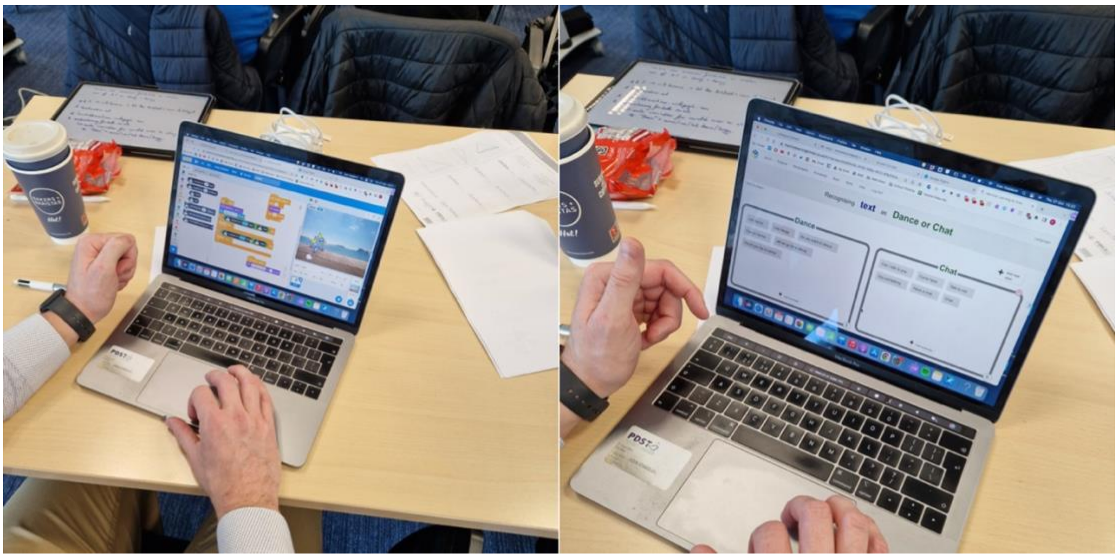


Fig. 70 Teacher is working on an " inclusive smart robot" activity

After this activity, it was planned with the Advisors to encourage Teachers, working in groups, to co-design an activity with some of the approaches or tools used during the day i which related to standard curricular subjects. Advisors reported though that they did not do this mentioning in the focus group that they saw the Teachers were tired. On the other hand, Advisors said that during the day, "*there was a huge "teachable" moment there. You know, what to bring it into kind of different curricular areas".* As mentioned by Advisor B even though Teachers did not exactly work on developing new activities, they started to think about how tools or activities could have been tweaked to cover other subject topics [F6.6]. As Advisor B added referring to Teachable Machine:

> "*Then they were using objects on the table, and then it was kind of into music, and the music curriculum kind of identified songs, notes, pitches, and then into kind of fundamental movements, in PE (Physical Education) has fundamental movement skillsets on you know if you're running, balancing, jumping, and so all of those they were kind of practicing those."*

This showed that teachers were tried to brainstorm ideas on how to integrate AI tools and ideas into other curricular subjects. Advisor B said that: "*if the first half was tinkering (with a new tool), then the second half was kind of focused on the curriculum rather than just the technology".*

Through the post programme survey, I asked Teachers why they think we should introduce AI to children and responses were well articulated sharing interesting feedback on the impact that such a programme could have on teachers. Teacher 1 wrote: *"So that they can be critically aware of the AI that is already present in their everyday lives and so that they become cognisant of the opportunities that AI offers"* acknowledging the importance of understanding AI and its opportunities [F6.7]. Teacher 2 mentioned the impact of AI on our decision-making and how it is paramount to know both the power and limitations of these systems: *“AI can assist with problem-solving which is a key skill in today's world. By exposing children to AI from an early age they will be more aware of its capabilities and limitations”.* Teacher 8 underlined that it is the teacher’s job to engage children by providing opportunities to experiment with how AI can be used for good, writing: *“It is already part of our everyday lives. Children need to be aware and capable of understanding how AI works and can be used to solve problems.”.*

Among the answers, there was one that demonstrated how it is fundamental to engage teachers in developing their understanding of AI, encouraging curiosity and critical thinking rather than fear and scepticism. The answer by Teacher 10 to the question was *“not yet”*. Moreover, the same feeling arises from Advisor A's words during the focus group, they said in relation to AI: “*they (Teachers) all seemed to get more of the negatives. […] So, we kind of tried to bring the background to more the education positives.”* showing there is sometimes fear of the new. This aspect should be considered when engaging with teachers, trying to balance the impact and the implications of emerging technologies [F6.8].

4.7.2 Summary

PHASE 6 represented an opportunity for me to examine the possible future of my research outcomes and findings. It fostered my understanding of how to frame teacher learning on AI and how to inform guidelines that could support research groups in emerging technologies willing to collaborate with teachers, building a meaningful bridge to the public. From the Advisors' experience, I saw how training-the-trainers requires solid support. Even though Advisors A and B were active participants in the PHASE 3 learning programme, I met them before running the programme and provided resources and slides, more support would be beneficial. I could see from their reticence in designing new activities with teachers that still required support from experts. Maybe having an expert from the domain, a professional AI expert collaborating in co-designing with teachers would be something to investigate further. On the other hand, teachers and advisors should not misunderstand the purpose of a learning programme for and with them. Its aim is not to "know/teach everything" but rather to give teachers the opportunity to undertake hands on experimentation about how they could engage children in opportunities to learn more about AI and other subjects designing and being creative.

4.8 Conclusion

The purpose of the 6 phases of this study was to understand in-depth how to better engage with teachers and children to promote AI literacy and awareness. PHASE 1 set the context, PHASE 2 was the first pilot with pre/service teachers, of a learning programme for teachers on AI. This phase was participatory and underpinned by TPCK and constructionism. PHASE 3 focused on design, development, and testing of an extensive learning programme for teachers with a co-design part in it. PHASE 4 constituted a case study on the implementation of the co-created learning programme on AI for children in school. Followed by PHASE 5, a co-design session to improve both the teacher’s and children's programmes was undertaken, and finally PHASE 6 set out to test the scalability of the programme (teachers-teach-teachers).

Key findings from this study are discussed in the following chapter, Chapter 6. The practical outputs of this study are described in the next chapter.

5. Communicating findings

5.1 Handbook

The findings from this study would agree with the literature claim that "*researchers and developers should consider the contexts of teachers and invest in additional supports to facilitate the accessibility of AI resources for teachers.*" (Brummelen and Lin, 2020). I specifically asked the participants, in the PHASE 6 intervention post-survey if a handbook could be a useful support for them in teaching about the big ideas of AI, and 9 out of 10 teachers strongly agreed (1 somewhat agreed) [F6.9]. Consequently, based on this feedback I developed a handbook to support primary school teachers in teaching AI.

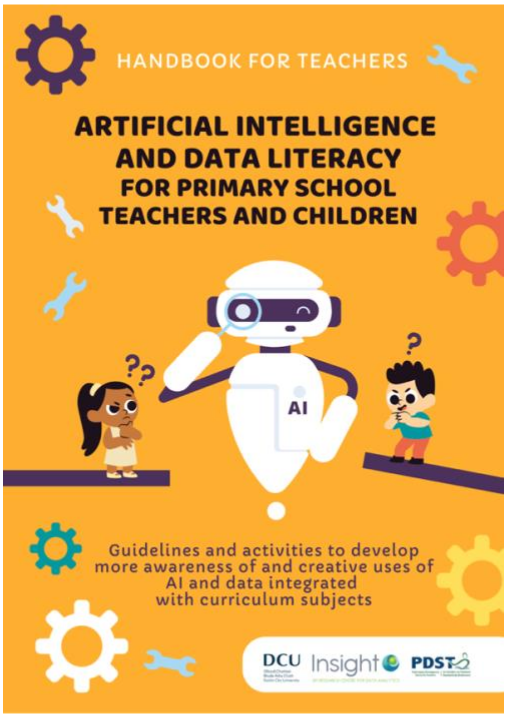


Fig. 71 Front cover of the Handbook for teachers

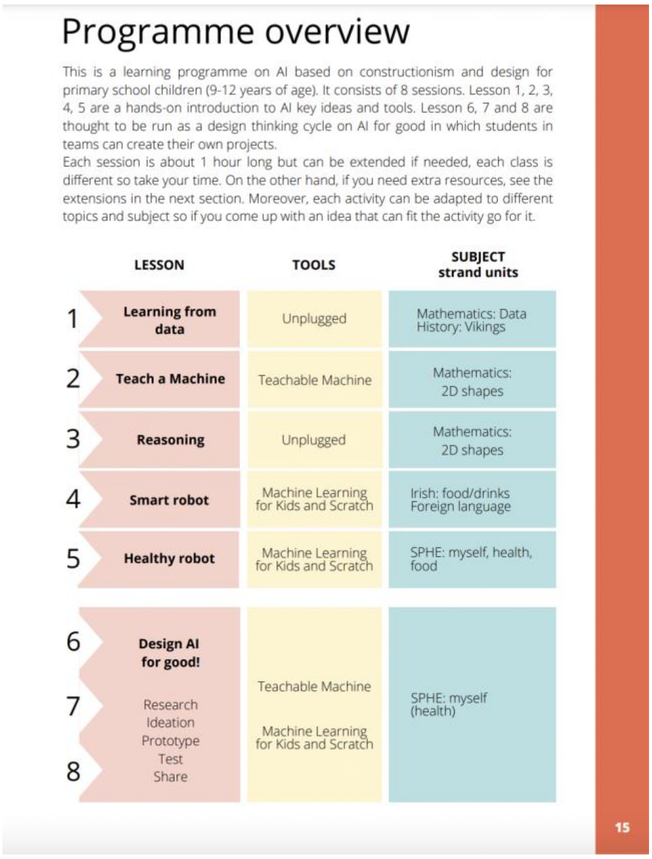
This handbook is the result of an iterative co-design process with teachers and teachers' advisors from the PDST (PHASE 3 and PHASE 5). It started in the form of a co-created (researcher and teachers) learning programme for children integrated with curricular subjects (PHASE 3). This programme was then piloted in school (PHASE 4), and further developed and improved following feedback and discussion with teachers in PHASE 5. teachers as experts. After PHASE 4 I started to create the handbook graphic and layout you can see now in the final version.

The layout and graphics were designed by me using the Canva platform online. From the design perspective, I decided to use, different colours for each part of the book. I chose friendly and positive images for teachers and children. I intentionally used both female and male children’s images with different characteristics to be more inclusive, maybe in the future it could interesting to consider adding representations of disabilities too. Below is the cover, Fig. 71.

The writing style of the handbook is not academic as it is written using user-friendly easy to understand language. The content is underpinned by this research study’s literature review and design process. The handbook includes an introduction on AI, data and education with a focus on creative and design-based learning. It includes an 8-session learning programme for children on AI integrated with curricular subjects. Additionally, I have included templates for activities that can be copied or cut out for use in the classroom as well as a range of extension activities, troubleshooting tips, and a multitude of resources. The list of content is outlined in Table 25 below.

The final version of the handbook includes modifications and improvements to the children's learning program, based on the results from PHASE 4 and 5. These changes comprise an expanded introduction to encompass literature on AI, data, and creative learning, graphically revised templates. Templates with basic Scratch algorithms were also added to provide extra support and the program was developed into 8 sessions to address the digital gap (Williams *et al.*, 2022) and offer more practice opportunities to children. Connections to subject curriculum strands were highlighted in accordance with the Irish curriculum. Lasty, extensions and additional resources were incorporated to enrich the learning experience.

A set of hard copies were printed for teachers and a digital copy is available to be downloaded online on the website teachingAI.eu that was created to communicate the practical outcomes of this study. Links are also included in Appendix H and I.



Programme overview

This is a learning programme on AI based on constructionism and design for primary school children (9-12 years of age). It consists of 8 sessions. Lesson 1, 2, 3, 4, 5 are a hands-on introduction to AI key ideas and tools. Lesson 6, 7 and 8 are thought to be run as a design thinking cycle on AI for good in which students in teams can create their own projects.
Each session is about 1 hour long but can be extended if needed, each class is different so take your time. On the other hand, if you need extra resources, see the extensions in the next section. Moreover, each activity can be adapted to different topics and subject so if you come up with an idea that can fit the activity go for it.

	LESSON	TOOLS	SUBJECT strand units
1	**Learning from data**	Unplugged	Mathematics: Data History: Vikings
2	**Teach a Machine**	Teachable Machine	Mathematics: 2D shapes
3	**Reasoning**	Unplugged	Mathematics: 2D shapes
4	**Smart robot**	Machine Learning for Kids and Scratch	Irish: food/drinks Foreign language
5	**Healthy robot**	Machine Learning for Kids and Scratch	SPHE: myself, health, food
6 7 8	**Design AI for good!** Research Ideation Prototype Test Share	Teachable Machine Machine Learning for Kids and Scratch	SPHE: myself (health)

15

Fig. 72 Programme overview

Section	Chapter	Description
Introduction	Mission	In this section, I highlight the relevance of the project. Teacher role and why it is important to introduce AI and what means being digital learners.
	What is AI?	Introduction on AI big ideas, Machine learning and Machine reasoning, and Ai for good.
	What about data?	Introduction to data cycle and data implications.
	Creative learning	Focus on learning creatively and creativity in education.
	Design thinking	Introduction to the design cycle.
	Computational thinking	Short syllabus on computational thinking key terms and concepts.
Learning programme for children on AI	Programme overview	Introduction to the learning programme on AI based on constructionism and design principles for primary school children (9-12 years of age).
	Expected learning outcomes	Outline of each session and the AI big ideas covered with link to subject curriculum.
	Lesson 1 - Learning from data	Unplugged activity on data cycle and bias with a template.
	Lesson 2 - Teach a machine	Introductive activity on machine learning using Teachable Machine.
	Lesson 3 - Reasoning	Unplugged activity on decision trees and template.
	Lesson 4 - Smart robot	Machine learning design with Machine Learning for Kids and Scratch, using text as data.
	Lesson 5 - Healthy robot	Machine learning design with Machine Learning for Kids and Scratch, using images as data.
	Lesson 6, 7, 8 - Design an AI	3 design sessions with a template for children to experiment with the complete design process.
Extensions	Poses, Bingo, Drawings, Farmer robot	Extra activities that can be used by teachers.
Other resources	Activity template	Blank activity template for teachers.
	Resources	Listing of a range of other resources that are available.
	Troubleshooting	Answers to common challenges.

Table 25 Handbook content overview

5.2 Website

Besides the handbook, I decided to publish the outcomes of my work in an open online website for teachers, educators, research groups, and policymakers. This again was in response to the post survey responses received from the PHASE 6 participants, when I asked their opinion about the availability of a website to support the teaching of AI. The responses were very positive as 9 out of 10 responses strongly agreed (1 somewhat agreed).

I developed a mock-up of the website to support the PHASE 6 teacher advisors who were conducting the programme for teachers, and to design the draft layout for the platform. Modifications to the website were made based on feedback from the advisors and published as teachingAI.eu. The idea behind the website is that it can act as a form of inspiration "think-tank" for teachers as it is a repository of useful links and resources to support them as they design learning experiences for their students around the big ideas of AI. It also includes frameworks and guidelines underpinned by this Ph.D. study as a reference for future researchers to use and/ or for those who are developing projects on AI with teachers. The URL of the website was deliberately chosen so it was not restricted to / or identified with primary school teachers and students but could be to further be developed in the future, e.g., adding a section for secondary school teachers or to be updated with new resources or tools. The suitability of these resources and website for teachers beyond the primary school setting is evidenced by how valuable and well received they were by another group of post-primary teachers working with in a European funded project, namely Artificial Intelligence for Teachers (AI4T).

5.3 AI4T

In January 2023 I was invited to participate at the launch event of AI4T Ireland. An Erasmus+ K3 project designed as a collaboration between France, Slovenia, Italy, Ireland, and Luxembourg. The aim of the project is to contribute to the professional learning of secondary school teachers and school leaders, on AI in education.

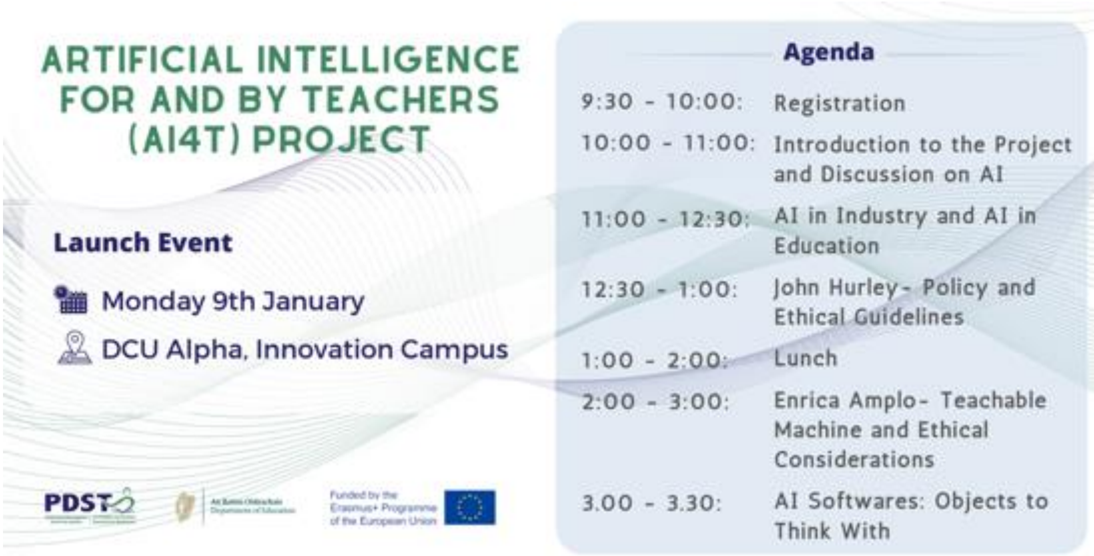


Fig. 73 AI4T Launch event agenda

I led a workshop on AI as a hands-on introduction to AI key ideas for teachers (e.g. teachers experimented with Teachable Machine (Google, 2022) and Moral Machine (MIT, 2022), as shown in Fig. 74). The workshop's goal was to ignite critical thinking and discussion on AI technology and its power and limitation.

Even though participants were post-primary school teachers, the activities and key concepts chosen to engage them were relevant and suitable. This evidence demonstrated how my study could resonate with educators in general not only with primary school teachers.

Fig. 74 Teachers discussing Moral Machine scenarios

5.4 Slovenia study visit

In March 2023 I was privileged to be part of a three week long study visit in Slovenia organised in partnership with the Digital team of the Slovenian Ministry of Education. I had the opportunity to visit different organisations and research groups working in STEM and digital education with a particular focus as well on AI (University of Ljubljana Faculty of Education and Faculty of Computer Science research groups, University of Maribor Ph.D. researchers and ZAMS research group on AI with Institute of Anton Martin Slomsek).

Researchers were particularly interested in the research journey and mission and it as very beneficial for me to discuss with peers, share ideas as it not only sharpened and clarified my own thinking about my PhD work but enabled me to develop my ideas and think about possible future collaborations.

Fig. 75 Republic of Slovenia - Ministry of Education and sport, Study visit, Noordung center, Vitanje. Exhibition tour

In addition to developing my thinking about the big ideas in AI and how to support teachers professional learning I also had the opportunity to investigate some organisations EPE strategies and outreach, as I visited Noordung centre focused on space EPE and the IRCAI group from UNESCO whose mission is AI research and engagement. These visits validated how valuable was the approach I had taken to designing the EPE strategy of this research study particularly the focus of EPE through and with teachers.

I also had the opportunity to work with the ministry's digital team for education, as I was asked to conduct a short workshop showing activities develop for my study. This for me was a very insightful opportunity as I could see the relevance of my work for policymakers too as they are also grappling with how best to introduce the concept of AI into schools and how best to design professional learning for their teachers. In keeping with the Constructionist principles underpinning my work I engaged these policy makers in thinking about the big ideas of AI by engaging them in a series of hands-on activities. This benefits were two-fold as not only did I initiate a fruitful discussion on the knowledge teachers needed to develop about AI and the pedagogical approaches they could use, but I could also test in person the handbook templates in their final version (e.g., “draw AI”, Fig. 76, to share key ideas and demystify AI starting from their pre-conceptions; Fig. 77, Bingo activity, linking datasets to AI systems; Fig. 78, decision trees).

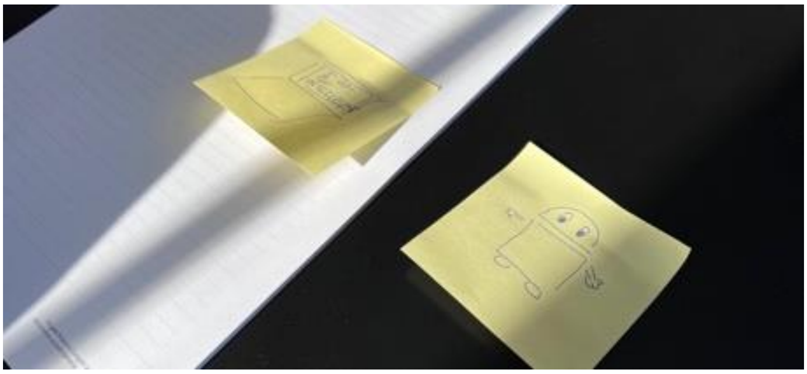


Fig. 76 "Draw AI" activity. Participants drew a robot and a computer with the words on the screen “I am intelligent”

Fig. 77 Participants using Bingo template on Datasets and AI systems

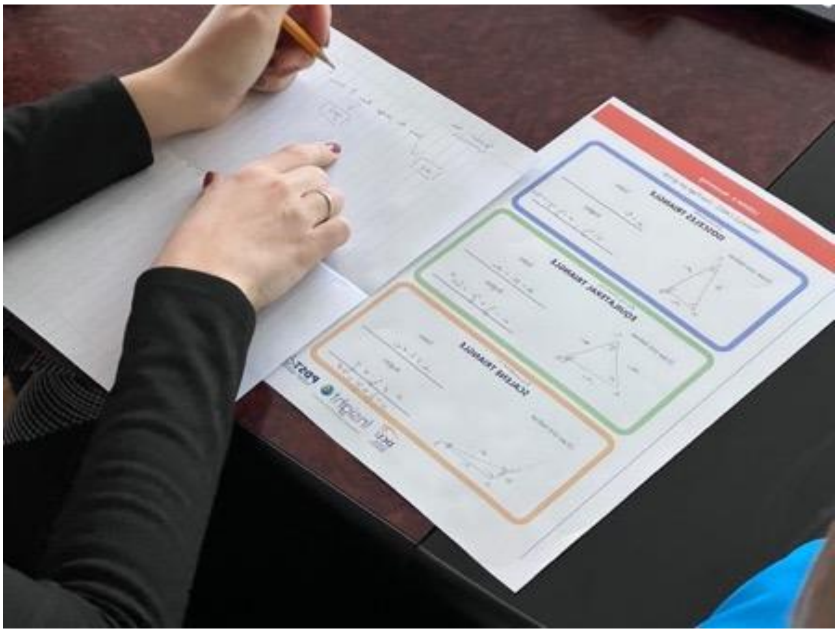


Fig. 78 Teams using decision tree activity template

In addition, during the last week of my stay, together with the Ministry's digital team I visited a school where I could engage with students. This was a real opportunity to try things out for myself with students as up to this due to Covid restrictions I had now been able to work in classrooms. They were a small class of upper primary school and working in pairs using laptops I lead and facilitated the Teachable Machine activity with them as they trained the models to recognise objects (Fig. 79) and poses (Fig. 80).

It was rewarding for me to see that the students and their teachers fully engaged with the workshops and were able to understand the ideas. This not only validated the programme I had co-designed with teachers in Ireland, but it also demonstrated that the programme could cross borders (and language) and be authentic and meaningful to these students and their teachers in Slovenian schools.

Fig. 79 Students testing the model with pencils

Fig. 80 Students testing Teachable machine models with T-pose

In conclusion, sharing and communicating findings with stakeholders from different backgrounds and contexts really helped me to develop my confidence in defending the choices and strategies I pursue in this Ph.D. research. Consequently, this visit was also very useful to broaden my view of EPE in AI and my thinking about this study's contribution to knowledge, which I discuss in the Conclusion chapter.

6. Discussion and Conclusion

6.1 Introduction

The purpose of this study was to understand how to collaborate with teachers in a meaningful way to promote AI literacy and awareness. The motivation behind this was to investigate how to bridge the gap between research in emerging technologies and the public through teacher learning and collaboration. Consequently, the main goal of this research was to design and examine a learning programme on AI for primary school teachers that acknowledged the complexity of teacher learning and their role as experts. The second aim of this research was to investigate constructionism and design as approaches for both primary school teachers and children to promote creative and critical thinking of emerging technologies (AI) from both a technical and ethical perspective. Lastly, this study set out to offer a practical contribution (i.e., a handbook for teachers, a website as a repository of resources, guidelines and frameworks for policy and research) to help towards understanding the big ideas of AI, which is an important emerging technology shaping our society.

This research set out to answer the following question: **[RQ 1] What are the characteristics of an Education and Public Engagement (EPE) action focused on teachers, for creating effective learning opportunities both for primary school teachers and children to promote Artificial Intelligence (AI) literacy and awareness?**

Consequently, this chapter discusses four main points: AI literacy for K-12 students, teachers' understanding of AI, teacher knowledge of emerging technologies, and EPE through and with teachers. The findings from this study could potentially constitute a guide to supporting research groups working on AI and ultimately other emerging technologies to address the urgent need and ethical responsibility of building a bridge between research and the public, through participatory teacher engagement.

6.2 AI literacy for K-12

AI literacy has recently been included in the DigComp 2.2 EU framework on digital competencies for citizens (Vuorikari, Kluzer and Punie, 2022) outlining the relevance of AI in terms of knowledge (i.e., recognising AI systems and their uses), skills (i.e. enabling day-to-day interaction with the technology), and attitude (being aware of both the negative and positive impact of AI) (Vuorikari, Kluzer and Punie, 2022). One of the first and most well-known research studies, AI4K12 addressed the key ideas of AI for K-12 students (i.e. students from primary to upper secondary school), outlining what they believed every child should know about AI at each school grade, from the perspective of the computer science curriculum (Touretzky, Gardner-McCune, Breazeal, *et al.*, 2019).

More recent studies focusing on AI curricula for middle schoolers have developed some methodology and design considerations. Specifically, Williams et al., 2022 suggest 5 design recommendations: focus on active learning, embed ethics, mind the digital gap, and consider unplugged activities together with designing projects. The “Design AI” programme for middle schoolers (Vartiainen et al., 2021) was also framed on the design cycle (i.e., contextualising machine learning, building ideas and skills, prototyping, sharing, and reflecting). These studies informed the development and improved version of the learning programme for children included in the final version of my handbook as described in Chapter 5. However, what was not considered in these studies was the importance of integrating such activities with curricular subjects. This key idea emerged, from PHASE 3 findings, as the teachers stressed how important it was that any new curriculum concepts or content should be integrated into existing curricular subjects, rather than being presented as an extra layer of curriculum content they needed to develop with their students.

Furthermore, the experience with teachers-training-teachers, in PHASE 6, resonates with that expressed opinion too. As findings from data gathered through the focus group with teacher advisors in PHASE 6 (Section 4.7.1) clearly illustrated teachers' immediate desire to translate their newly acquired knowledge of AI, into designing learning experiences for children related to other subjects. Lastly, while most of the studies in the field of AI literacy for learners have tended to focus on content, competencies, and pedagogy (e.g. Touretzky et al., 2019, Long and Magerko, 2020, Lindner et al., 2019), findings from PHASE 4 of this study draw attention to the complexity of children knowledge and understanding of AI (Fig. 58 Children AI developing knowledge complexity in the context of learning programme on AI in class).

Reports from recent years claimed that children should be ready to take on active roles in designing and using AI-enabled technology (UNICEF, 2020). However, when it comes to methods and approaches to promote AI literacy, there is a scarcity of studies relating to DBL (e.g., Vartiainen et al., 2021 and Tedre et al., 2021). Yet understanding and using the principles of design is a prerequisite for being able to design and use AI enabled technology.

It is noteworthy that in keeping with the results from Tedre et al. (2021), findings from PHASE 4 of this study, demonstrated how creative responsibility is appreciated by students and how design helped in connecting AI to potential real-world problems to solve, promoting connections between the world of the classroom and children's life beyond the classroom. Moreover, focusing on the health domain resulted in an interesting context to investigate further as a "playground" for exploring AI applications for good. This is evident in the findings from PHASE 2, which outlined participants' connections to their experiences and the role of AI and data in the very recent Covid 19 pandemic. In addition, children from PHASE 4 appeared to positively engage in exploring ideas for the potential use of AI for good in the health context as they worked on interesting projects focused for example on sight and nutrition.

To conclude, it is important to acknowledge that the research generally refers to K-12 (students from primary to secondary school) (Lindner et al., 2019) or large age groups (Dwivedi *et al.*, 2021) when addressing guidelines or study results on AI for school aged students. A possible explanation is the common use and understanding of the acronym K-12, and probably a way to drive attention to a study focused on school aged students' learning of AI. Nevertheless, it is paramount to highlight that it is not always possible to generalise learning programmes or design strategies for groups with a large age range. Each learner is unique. Therefore, for example, even facilitating the same programme in one class could take longer than in another class of the same age group.

As findings from PHASE 4 suggested, one possible strategy could be to design programmes in a way that leaves space for adjustments so that the programme can be tailored to the context and needs of the learners. However, to do this a teacher must be able to make these adjustments so it is of the upmost importance that appropriate professional learning opportunities are available for teachers to develop their own skills and competencies so that they feel empowered and enabled to tweak resources when needed, as teachers should be seen as the experts in their own context capable and confident to design learning experiences that meet the needs and interests of the learners in their classrooms.

6.3 Teachers' learning of AI

It is undoubtedly that there is an increasing interest in AI in education (AIED) as the domain of technical research that aims to develop software or AI-based systems to monitor or enhance teaching and learning experience is continuing to expand (Chassignol, Khoroshavin and Bilyatdinova, 2018). However, only very recent programmes focus on teacher learning (European Schoolnet, 2021 and ISTE, 2021) with even fewer peer-reviewed research studies (Brummelen and Lin, 2020 and Vazhayil et al., 2019). There is a gap in the literature on framing teacher learning on AI and teacher knowledge of emerging technologies.

Zhou et al.'s (2020) proposed framework and guidelines to support the design of an AI learning programme for K-12 underpinned PHASE 3 of this study. However, Zhou et al.'s (2020) framework was intended to support the design of a learning programme for students and was not teacher centered. Consequently, a focus on the theory that should underpin teacher learning methodology was missing. In other words, a framework or guidelines to support an AI programme for teacher learning was not available. Similarly, a more recent article on AI curriculum for middle schoolers (Williams *et al.*, 2022) mentioned engagement with teachers as co-designers. Although, the study acknowledged very briefly a teacher training programme conducted before and during the co-design intervention, it did not make reference to nor frame it from a theoretical perspective.

Results from PHASE 3 correlated positively with the findings of similar studies in terms of being effective in developing teachers' agency, enabling them to design learning opportunities for children to promote AI literacy and awareness through other subjects (Vazhayil et al., 2019 and Brummelen and Lin, 2020). However, these studies that focused on teacher learning on AI (Vazhayil et al., 2019) and co-designing with teachers learning opportunities for students in K-12 (Brummelen and Lin, 2020) have not treated the content and the methodology used when engaging with teachers in much detail. A possible explanation is that these studies were interested more in capturing the experience of teacher learning or co-designing with teachers as a means to create opportunities for children and introduce AI in school, rather than focusing on how to engage effectively with teachers and framing teacher learning.

The theoretical approaches to developing a teacher professional learning programme focused on AI investigated in this PhD study, (i.e., constructionist and design principles) and the subsequent programme that was co-designed with teachers proved to be very effective. The results of this research support the idea that a learning programme for primary school teachers focused on AI, teacher-centered and based on constructionism and design represents an effective opportunity for teachers to develop their understanding of AI. Indeed, the practicality of the programmes were very much appreciated by different cohorts of teachers (with and without a background in STEM or computational thinking).

A proposed framework for teacher learning of AI developed as part of this research study is outlined in Fig. 81. In Table 26, a rationale for each of the aspects highlighted in the framework is presented, drawn from both the research literature and findings that emerged from the data analysed from each phase of this study. It was created to summarise the characteristics such a learning programme for teachers on AI should have, supported by the finding of my research study. Specifically, a good quality professional learning programme for teachers focused on the big ideas of AI should acknowledge the complexity of teacher learning and should recognise the importance of the role of the teacher. It should be interactive underpinned by constructionist and design principles detailing approaches to introduce AI to children into class, empowering teachers with skills and competencies enabling them to create learning opportunities for children. Ultimately, the programme should promote the design or co-design of curriculum on AI integrated with other school subjects engaging teachers as experts.

AI and data key ideas every teacher should know based on the literature studied are outlined in Appendix P.

Framework for an effective learning programme for Teachers focused on AI

A	**ACKNOWLEDGE**: teacher preconceptions and teacher expertise and background
I	**INTEGRATED**: what AI can do for standard curriculum subjects, promote multidisciplinarity, and show examples of digital learning in the AI era
T	**TEACHER-CENTRED**: Be conscious of teacher knowledge/learning complexity. Design and lead the programme in a way that no prior knowledge in coding or computational thinking is required (starting from basics and then building upon them).
E	**EMPOWER**: It is important to empathically support teachers in their learning process. Underlining that the aim of the programme is not to "learn everything about AI" but rather to understand key concepts and get to know tools, activities, and approaches that could be introduced to children. Empower them as creative leaders.
A	**APPROACHES and ACTIVITIES:** Show examples of activities and approaches: teachers need to see how they could implement activities or use tools in their context (in class).
C	**CO-DESIGN:** Design with teachers as they are the experts in the classroom and curriculum. If not possible, create space to ignite discussion and brainstorm ideas on possible connections with other subjects (multidisciplinary and integrated). **CONSTRUCTIONIST** approach: use interactive hands-on activities instead of long frontal lecture times. Promote design.
H	**HOLISTIC** perspective on the content: Design the programme around big ideas (key concepts), with a holistic perspective (this helps to explain the purpose of the programme)
E	**ENCOURAGE** critical thinking and curiosity: Acknowledge the possible negative impact of the technology, but focus on the positive use of it. How AI can be used to enhance other subjects, solve problems in a multidisciplinary context, or even be used as a tool to encourage creativity and critical thinking.
R	Teacher **ROLE**: Teachers really need to understand the purpose of the programme: "why they need to know and teach something new". It is important to highlight how skills and competencies acquired in the programme are relevant to anyone, first of all as 21st-century citizens, and secondly, as teachers because thanks to their multiplier effect, they can positively influence children promoting AI literacy and awareness.
S	**SOFTWARE** and **TOOLS**: Use tools available/open/free for schools. Tools should be user-friendly, and "constructionist in nature" (i.e. software or devices that show what's behind the technology, how things work, and that allow building, creating, and designing personal projects), consider also unplugged activities.

Fig. 81 Framework for an effective learning programme on AI for teachers

	Teacher learning programme on AI framework rationale
A	It is important to be aware that every learner is not a blank canvas rather they have skills and different backgrounds (Bransford, Brown and Cocking, 2000), therefore it is key to acknowledge teachers' developing knowledge complexity when designing learning programmes for them. Expanded TPCK framework is illustrated in the next Section 6.4.
I	Being a learner in the era of AI means having the opportunity to learn how technology works and how to use technology to enhance creativity and critical thinking (NCCA, 2020). Consequently, research (Zhou, Van Brummelen and Lin, 2020) and findings [F5.8, F6.6] from this study encourage integrating new content with standard curricular subjects.
T	In designing a learning programme for teachers, it is teachers that should be at the centre. Creative learning theory (Resnick, 2017b), as discussed in Section 2.7.2, should underpin it in order to design effective programmes that are accessible for teachers with and without a background in computer science [e.g. as demonstrated in the pilot of this study F2.2, F2.3].
E	Findings from Phase 4 demonstrated that the design of the learning programme for teachers was effective in empowering teachers to tweak the programme for children [F4.9]. Therefore, a learning programme for teachers should positively engage them and empathically support them so that they do not feel AI is too difficult for them to teach [F2.21].
A	As emerged from this study teachers are constantly thinking how to teach what they are learning [F3.2, F6.6]. Therefore, a learning programme for teachers should include examples of activities and approaches on how to use tools or introduce new content to children.
C	Co-design with teachers is encouraged by the literature (Brummelen and Lin, 2020). Moreover, Phase 3 findings demonstrated how the design was an opportunity for teachers to continue to develop their understanding of AI [F3.1]. Constructionism as an approach to effectively teaching AI to students as claimed in the research literature (Section 2.7.3) and it also proved to be an effective approach for teacher learning as well [F2.5, F3.3, F6.3].
H	The literature review that underpinned this study illustrated how AI is a multidisciplinary field. Consequently, a learning programme for teachers should be designed around big ideas with a holistic perspective (Touretzky et al., 2019 and Long and Magerko, 2020).
E	Recognising that it is necessary to critically explore the possible risk related to AI, it is of the utmost importance that teachers explore the positive and creative uses of AI - this was an issue raised by the advisors in Phase 6 [F6.8].
R	Teachers need to be aware of the purpose of the learning programme that has been designed for them (Bransford, Brown and Cocking, 2000) to enable them to better understand their role as teachers in the era of AI and the impact they can have on our society [F3.9, F6.7].
S	I would like to encourage the use of free/open software to reach as many schools and teachers as possible. Considering unplugged activities is encouraged by the literature (Williams *et al.*, 2022) and using tools that are constructionist in nature can enhance teacher learning of AI [F2.19].

Table 26 Teacher learning programme on AI framework rationale

6.4 Teacher knowledge of emerging technologies

The literature highlighted the need for guidance in framing teacher learning in terms of AI (Kahn and Winters, 2021). This Ph.D. study argues that before you can offer guidance on framing a programme, acknowledging, and understanding the complexity of teacher knowledge is a key determinant to developing a learning programme that can address teacher learning of AI. Findings from this study have informed the design of an expanded version of the TPCK framework (Koehler and Mishra, 2006). Specifically, prior knowledge, ethics, and teacher role should be included as shown in Fig. 82.

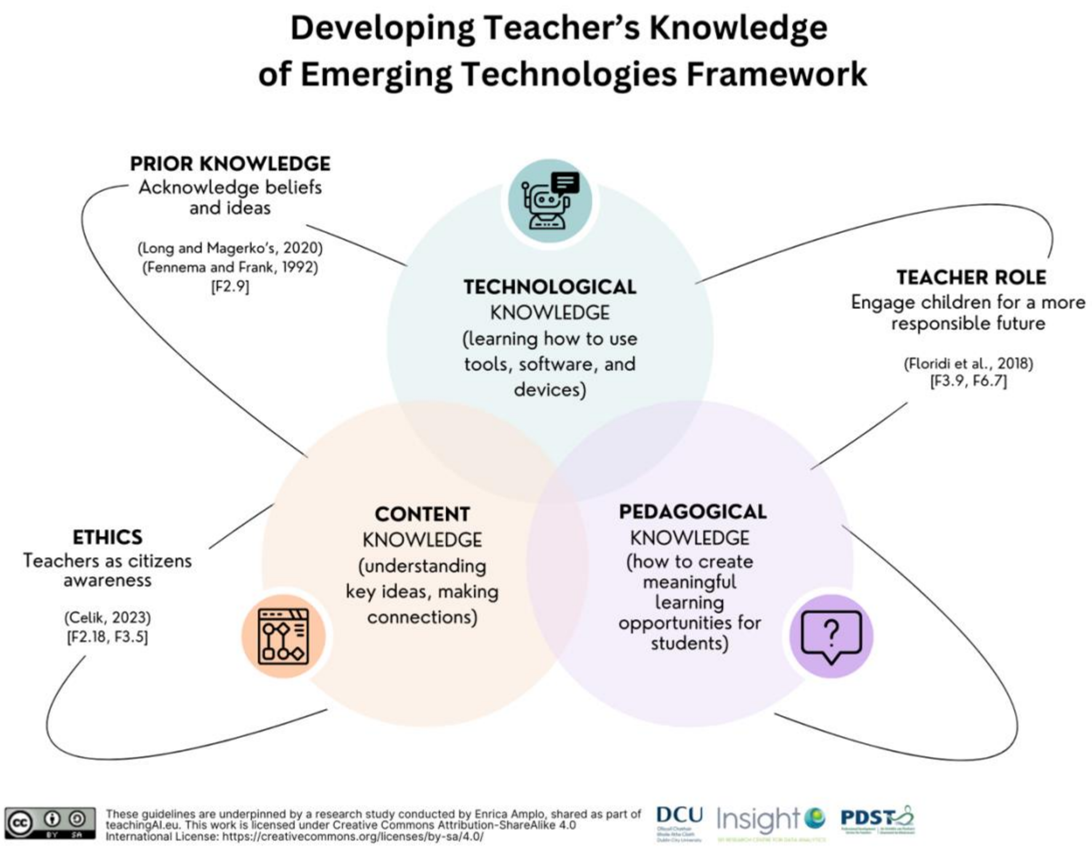


Fig. 82 Developing Teacher's knowledge of emerging technologies framework

TPCK was ideated to frame teachers' theoretical and practical developing knowledge of technology through design-based activities (Koehler and Mishra, 2006). Although TPCK underpinned the design of the learning programme for teachers developed for PHASES 2 and 3, results from those phases, demonstrated that TPCK was not adequate to describe all the aspects of teachers' developing knowledge of AI.

This study claims that it is by leveraging **prior knowledge** about emerging technologies that you can begin to support teachers to acknowledge their values and beliefs and support them as they discern what they understand and in particular how the different narratives are influencing their understanding. The model of the teacher knowledge developing in context (Fennema and Frank, 1992 as quoted by Asli Özgün-Koca and Ilhan Şen, 2006) although not specifically referring to the learning of emerging technologies influenced my thinking in relation to the importance of including this feature when trying to capture the complexity of the development of teacher knowledge. In addition, Long and Magerko's (2020) study, although not directed at teachers, highlighted the importance of **preconception** relevance when considering learning AI. Results from PHASE 2 of this work, illustrate that acknowledging teachers' prior knowledge can facilitate and enable teachers to discern between facts about emerging technology and its narratives and can promote a deeper and more critical understanding in relation to these technologies. Specifically, data gathered highlighted the strong influence narratives can have on our idea of an emerging technology (such as AI) and it is difficult to recognise where this technology has been used and what are its limits [F2.9].

While teachers are developing their understanding of an emerging technology, they cannot avoid questioning the impact and implication of such technology not only in their role as teachers but also as 21st-century citizens. Celik's (2023) study on *“intelligent TPCK”* emphasised teacher ethics and perception towards AI-powered technologies for education to drive the design of such technologies. However, Celik’s study examined the role of teachers’ **ethics** in the development and introduction in schools of AI tools (to enhance teaching and learning). Whereas this research study was focused on developing a programme for teachers to understand the “big ideas” in AI. The findings, to a certain extent, resonate with the *“intelligent TPCK”* (Celik, 2023) study in acknowledging the ethical component. Findings from PHASE 2 [F2.18] and PHASE 3 [F3.5] demonstrated that the ethical component is not only related to the implementation of AI tools in school as developing a deeper knowledge of AI (its power and implications) triggered teachers’ thinking and questioning of ethical and moral issues as 21st-century citizens.

As claimed in the “AI4People—An Ethical Framework for a Good AI Society” supporting education in school to promote awareness plays a key role in developing an ethical AI future for our society (Floridi *et al.*, 2018). The findings from PHASE 3 and 6 with teachers resonate with the importance of promoting awareness in order to cultivate the ethical use of AI in society. As the teachers developed their knowledge of AI they found themselves reflecting and questioning their **role as educators** in the era of AI. Teachers began to understand how paramount their role as educators is in the development of students' understandings and use of these emerging technologies [F6.7]. Consequently, they could see clearly how paramount their role is in positively and ethically influencing younger generations [F3.9].

6.5 EPE on emerging technologies through and with teachers

Emerging technologies like AI are playing an important role in different aspects of our lives. There is therefore an urgency to provide opportunities to promote awareness and understanding of these technologies and how they impact our lives and society (Floridi et al., 2018). EPE actions from research groups working on these technologies should reach out to children collaborating with teachers as they have a multiplier effect (Dolan, 2008). Findings from this research study can represent an example of best practice in engaging with teachers in a participatory way focusing on teacher learning which will in turn enhance children learning.

While there is an increasing interest and growing availability of learning programmes and Massive Open Online Courses (MOOC) on AI for teachers (European Schoolnet, 2021 and ISTE, 2021), how to collaborate effectively with teachers to design programmes related to these emerging technologies still remains to be studied in-depth. Zhou et al. (2020) challenged researchers to consider teachers not only as learners or instructors but also as designers of AI curriculum for children. Results from PHASE 3 and 4 highlighted the potential of engaging with teachers in designing activities for children, and results from

PHASE 5 demonstrate how it is possible to create a flourishing environment to collaborate with teachers in designing teacher training programmes.

Previous studies have not examined in much detail how to engage with teachers with different backgrounds and competencies (Vazhayil et al., 2019 , Brummelen and Lin, 2020, and Williams et al., 2022). Findings from PHASE 2 and 3 of this study demonstrated how a teacher-centred learning programme on AI could be very effective for both preservice teachers and primary school teachers, with and without a background in computer science. The research to date has focused on training and co-designing with teachers rather than theoretically framing EPE or teacher learning of emerging technologies. This Ph.D. study argues the importance of communicating findings to research groups working on emerging technologies in order to guide them in effectively engaging with teachers when developing their public engagement programmes.

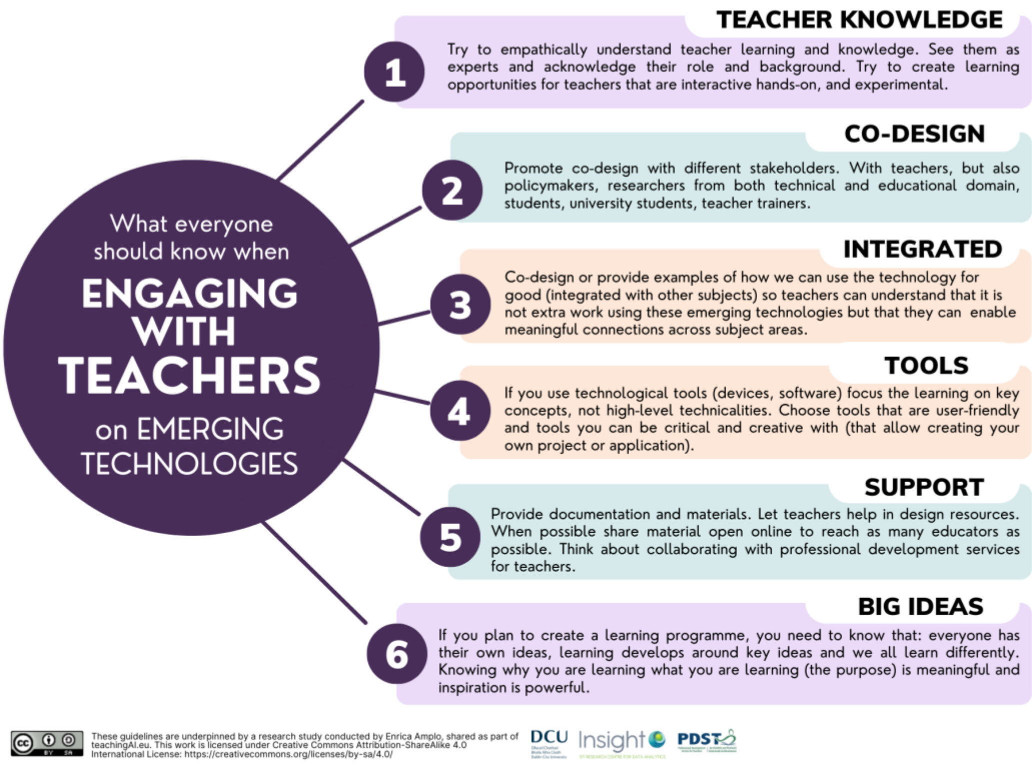


Fig. 83 EPE guidelines

Building on the learning from engaging with this research and the development of the teacher programme, I have developed guidelines (Fig. 83) that could support research groups working not only on AI but any emerging technologies to address the need and responsibility of building a bridge between research and the public, through participatory and creative teacher engagement. I have distilled the main findings from this study into 6 key concepts those involved in designing EPE initiatives, particularly researchers in emerging technologies should know when engaging with teachers.

Specifically, how teachers learn, and the complexity of **teacher knowledge (1)** should be introduced to experts from different domains outside education who are working on emerging technologies that are interested in co-creating with teachers and promoting teacher learning. As discussed in the previous section (Section 6.4) it is imperative to acknowledge the complexity of teacher knowledge. EPE action should provide learning opportunities for teachers based on effective learning methods and approaches i.e., interactive and practical activities underpinned by constructionism and design, as opposed to lectures (Bransford, Brown and Cocking, 2000). Teachers who took part in this study expressed particular appreciation for the hands-on and practical approach used to enable them to develop their knowledge of AI [F3.3] [F6.3]. Furthermore, the literature suggests engaging with teachers as experts leveraging their expertise, skills, and background (Twining *et al.*, 2020).

Co-design (2) as an effective EPE action in promoting AI literacy is encouraged by the literature (Brummelen and Lin, 2020) and also emerged from

PHASE 3 [F3.1]. Teachers' help in the co-design of resources is crucial. Rather than research groups engaged with emerging technologies trying to do this alone they should follow the strategy of this PhD study and reach out to those agencies responsible for the design and development of teacher professional learning programmes. PHASES 5 of this study constituted a positive example of co-design between academia and teachers both for teachers and children [F5.15, F5.16]. The role the researcher played with teachers and partners (e.g., PDST, AI experts) was important for the realisation of the project. The positive feedback from PHASE 2 [F2.2, F2.3, F2.4] participants on the programme highlighted the importance of researcher role. Researchers who conduct research at the intersection of technology and education are key as they can mediate the collaborations among experts from technical domains and schools, teachers, and children. Moreover, co-designing with teachers is key to develop learning opportunities for children **integrated (3)** with standard curriculum subjects (Zhou, Van Brummelen and Lin, 2020) as the teachers understand the curriculum and the children they are working with so are best placed to input on how best to integrate the big ideas of AI with curriculum subjects. Consequently, as illustrated by the Advisor's feedback in Phase 5[F5.8] there is no extra layer of work for teachers as in their normal professional practice they have to develop learning experiences for the children they interact but now they will do so with an AI informed lens.

When engaging with teachers, **tools (4)** used should be constructionist in nature offering space to create and design, as a means to build new knowledge around the **big ideas (6)** related to a new technology (Bransford, Brown and Cocking, 2000).

Lastly, findings from the survey conducted in PHASE 6 resonated with Marques et al.'s study (Marques et al., 2020) pointing out the need for **support (5)** for teachers also in terms of materials and resources. In addition, from the implementation in the school trial emerged the need for more support in terms of templates [F4.8, F4.10] and materials (e.g., the handbook and a website with online resources) [F5.6, F5.11, F6.9].

6.6 Contribution to knowledge

This research is the first comprehensive investigation of EPE on emerging technologies through and with teachers in Ireland, if not further afield. This study contributes to our understanding of EPE focused on teachers, as learners, designers, and experts, to create learning opportunities for children that leverage new emerging technologies. Although, I worked mainly with primary school teachers, the experiences with secondary school teachers and policymakers outside of the Irish context (Chapter 5) evidenced that this study's outcomes could be relevant not only with groups engaging with primary school teachers but could resonate with teachers and educators in general. Lastly, findings from the collaboration with teachers resulted in the development of a set of EPE guidelines for researchers and policymakers.

It was when trying to design a programme for teachers about the big ideas in AI that I really understood the complexity of developing teacher knowledge and how it was intrinsically linked to many interconnected factors. Therefore, what has emerged from this work has been a number of connected but different contributions. Firstly, is a framework for the design and development of an effective learning programme for teachers focused on the big ideas of AI (Fig. 81) and a summary of the main ideas teachers should know about AI (Appendix P, Fig. 87). Secondly and perhaps more significant, it is the understanding of the complexity of teacher knowledge which lead to the development of a framework that captures what is necessary for the development of teachers understanding of emerging technologies (Fig. 82). Finally, building on the findings of this research a set of guidelines have been developed (Fig. 83) to support research groups working not only on AI but any emerging technologies to address the need and responsibility of building a bridge between research and the public, through participatory and creative teacher engagement.

I created a series of graphics (Figures 89-92) with the intention that they could be easily understood and used by different stakeholders (researchers, policymakers, educators) so that the field of emerging technologies and in particular AI can be understood by all. Non-experts in teacher learning or education are the target audience for these guidelines, therefore, the language style is intentionally not academic.

This set of graphical resources is published online using a dedicated website that I developed as part of my PhD work (teachingAI.eu). Publishing online was a purposeful decision in order to reach as many educators, policymakers, and research groups working in emerging technologies as possible. In addition, these resources are open for all to use as they are shared with creative commons rights so that policy makers, researchers, and other experts can use them and keep developing them into the future.

6.7 Limitations

The scope of this study was limited in terms of mainstream school/student perspectives. There was a small attempt with a special school class, as one of the teachers in the group did try out some of the programme with her children who had a diverse range of special needs. However, developing an AI curriculum for special needs students would require dedicated attention. Moreover, the small sample size of teachers involved did not allow for the creation of activities integrated with all curricular subjects. Being limited to time and participants, this study lacks an extensive implementation with a range of different schools with students of varying ages and backgrounds. However, the approach taken in this study could be iterated and expanded to gather more feedback to keep developing materials and the scope of the programme.

Due to the timing of this research which took place during a global pandemic, there were as a result a series of different challenges, and it was unfortunate that most of the work was conducted online or by the teachers with their own students and that I did not get an opportunity to work directly with primary school students. In addition, the digital tools used had to be compatible for use online e.g., Scratch and web-based scenarios. It would be interesting to see how AI understanding develops with the introduction of robots or other devices/agents (e.g., smart watches or voice assistants).

6.8 Recommendations

6.8.1 Research

The question raised by this study was how we can better collaborate with teachers to reach the general public, in particular children and create learning opportunities around emerging technology, in an awareness raising, critical and creative way. Future works should investigate further how the EPE guidelines (Fig. 83) that resulted from this study could support STEM research groups in collaborating with primary school teachers.

As this study was focused on engaging teachers and children to promote AI literacy and awareness, AI in education (applications of AI in the education domain, e.g., monitor performance or generative AI) was beyond the scope of this study. However, acknowledging the raising interest around them, I would recommend further investigation on how to better engage teachers in these emerging technologies for teaching, learning and assessment. Furthermore, if the debate is to be moved forward, a better understanding of the impact of AI on teacher role needs to be developed both in theory and practice.

Lastly, the tools. I would recommend multidisciplinary research groups (from the education and technology domain) working on co-designing new tools and devices with teachers. Software or devices that could support the learning about AI and data while fostering creative and critical thinking (i.e. a moral machine for children or a more user-friendly version of machine learning for kids, or a robot with which AI models can be easily implemented).

6.8.2 Policy

Considerably more work will need to be done to determine policies that encourage and frame meaningful EPE with and through teachers and students of all ages. There is, therefore, a definite need for policies that could lead to changes to higher education curricula, that enable preservice teachers engaging in a diverse range of learning opportunities leveraging emerging technologies. Technologies should be introduced in a way that can promote awareness of in tandem with creative, and critical use of these technologies for good in society.

Greater efforts are also needed to ensure research groups working on developing cutting-edge technologies commit to bridging the gap between research and the public. So, I hope the guidelines underpinned by the findings from this study can represent a basepoint to inspire discussion and further work to support the development of more extensive guidance for STEM research groups and organisation (e.g., museums, maker spaces, AI research centres) on how to engage with teachers, students, and schools. For this reason, the outputs of my research are posted open online on the website I developed as part of my PhD study (teachingAI.eu), and will be shared with partners and experts met during the Ph.D.

6.8.3 Practice

Part of this study was focused on designing an AI programme for children with the hope that more and more teachers start to introduce some of AI key ideas in primary school classes through the other subjects. The AI programme co-created could also represent an example of how to use technology (i.e., AI tools) as a means through which to engage children in creative and design-based learning activities. The handbook for teachers designed and developed can represent a support for primary school teachers in introducing AI into the classroom. Hopefully, it will inspire the design of new activities and learning opportunity for children on AI and data. Lastly, the open access website underpinned by this research study can help teachers introducing AI into the classroom offering resources, videos and links.

6.9 Conclusion

I hope this research can encourage research groups working on emerging technologies to prioritise effective and meaningful public engagement focusing on teachers, as they have a multiplier effect and deserve to be acknowledged as experts in their fields and partners in a public engagement initiative. I hope this study inspires more interdisciplinary research opportunities and design-based research projects with the aim of developing practical outputs that will be useful for educators. Lastly, I hope that other Ph.D. students can benefit from this thesis.

Recently, I came across this quote by Amit Ray, 2017, Ph.D. in AI and computational neuroscience, who wrote: *"As more and more artificial intelligence is entering into the world, more and more emotional intelligence must enter into leadership".* I would like to conclude my thesis with a slightly different and provocative version of that quote:

As more and more Artificial Intelligence is entering into the world,
we will need more and more Emotional Intelligence in making informed
decisions that impact our lives e.g., how we spend our time, how we let others
use our data, how we blow the filter bubble, but most importantly,
on how we Educate and how we Learn.

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Appendices

Appendix A – Video resources on AI

“Coded bias”, Netflix
“CODED BIAS explores the fallout of MIT Media Lab researcher Joy Buolamwini’s discovery that facial recognition does not see dark-skinned faces accurately, and her journey to push for the first-ever legislation in the U.S. to govern against bias in the algorithms that impact us all.”
(https://www.codedbias.com/)

“Social dilemma”, Netflix
“This documentary-drama hybrid explores the dangerous human impact of social networking, with tech experts sounding the alarm on their own creations.”
(https://www.netflix.com/ie/title/81254224)

“The great hack”, Netflix,
“Explore how a data company named Cambridge Analytica came to symbolize the dark side of social media in the wake of the 2016 U.S. presidential election.”
(https://www.netflix.com/ie/title/80117542)

“*The Turing test: Can a computer pass for a human?*” YouTube, Short animated videos by Alex Gendler describing the Turing test with a short animated video.
(https://www.youtube.com/watch?v=3wLqsRLvV-c)

“*The danger of AI is weirder than you think*”, YouTube, Talk by Janelle Shane on demystifying AI and machine learning algorithms.
(https://www.youtube.com/watch?v=OhCzX0iLnOc)

“*Can robots be creative?*”, YouTube, Animated video by Gil Weinberg on creativity in artificial intelligence and “Ada Lovelace test”.
(https://www.youtube.com/watch?v=Rh9vBczqMk0)

“The ethical dilemma of self-driving cars”, YouTube
(https://www.youtube.com/watch?v=ixIoDYVfKA0)

“Machine learning and human bias”, Google, YouTube
(https://www.youtube.com/watch?v=59bMh59JQDo)

Appendix B – Resources on AI (K-12)

Activities and resources	
MIT raise https://raise.mit.edu/resources.html	It is a collection of many activities and tools related to coding, physical computing and AI.
An Ethics of Artificial Intelligence Curriculum for Middle School Students	By Blakeley H. Payne, MIT Media Lab It is a curriculum for teachers and middle school students on AI. https://docs.google.com/document/d/1e9wx9oBg7CR0s5O7YnYHVmX7H7pnITfoDxNdrSGkp60/edit#heading=h.1et5vs39qkyh
DAILy Workshop https://aieducation.mit.edu/daily/index.html	This curriculum is currently being piloted through NSF EAGER Grant 2022502. This is a joint venture between the Personal Robots Group at the MIT Media Lab, MIT STEP Lab, and Boston College.
AI unplugged. Unplugging Artificial Intelligence. https://ddi.cs.fau.de/schule/ai-unplugged/ https://computingeducation.de/	Written by Annabel Lindner and Stefan Seegerer from Friedrich-Alexander-Universität Erlangen-Nürnberg for all aged learners. It is a collection of activities on key ideas about AI that learners can experiment without the need of screens or devices. https://www.aiunplugged.org/
AI4K12 https://github.com/touretzkyds/ai4k12/wiki	"Envisioning AI for K-12: What Should Every Child Know about AI?" David Touretzky, Christina Gardner-McCune, Fred Martin, Deborah Seehorn Tools and resources, guidelines and key concepts.
Data detox toolkit	Tactical tech with Save the children designed a toolkit for young people on data awareness and misinformation.

Teacher courses	
Schoolnet https://www.europeanschoolnetacademy.eu/courses/course-v1:CodeWeek+AI+2021/about	Basic elements of AI, learn how to define AI, look at the ways AI is already used in our everyday lives and explore the opportunities and challenges of AI for teaching and learning
ISTE https://www.iste.org/professional-development/iste-u/artificial-intelligence	In Artificial Intelligence Explorations and Their Practical Use in Schools, you'll learn to identify the various types of AI, hear about AI technologies on the horizon and build some of your own tools to make AI concrete and accessible for you and your students.

Software and games (Giannikos, 2020), (Kahn and Winters, 2021)	
AI for Ocean https://code.org/oceans	The aim of the project is to engage children in key ideas about AI and machine learning while simulating the training of a system that can detect pollution in the ocean.
Minecraft hour of code: AI for good https://education.minecraft.net/hour-of-code	Developed by Microsoft is a coding activity where the goal is to use AI to save the planet from fires.
Machine learning for kids https://machinelearningforkids.co.uk/	It is a platform developed by volunteers to engage children in the basics of machine learning. It is also possible to train a neural network to recognize words and images.
Cognimates **Snap!**	Both are platform where children can train models with “Scratch block-like” programming language.
Google AI experiments	Applications and tools that combine art and AI algorithms to make, among the others, drawing out of text or auto generated music from a drawing.
Teachable machine https://teachablemachine.withgoogle.com/	A trainable model that has also been used in this literature to better explain how machine learning works in Section 2.3.2
Thought Starter https://thought-starter.com/	It is a website similar to Google AI experiment with some applications of AI to ignite ideation and see how algorithms can help in the process or completely fail in it.

Children’s books and movies	
Can I build another me?	It is a picture book by a world award winning Japanese author Yoshitake Shinsuke. The book explores concepts like robot and data, while reflecting on humanity's peculiarities such as feelings and emotions and data (in Fig. 1.9.1 the book cover and an illustration).
The wild robot.	A novel by Peter Brown, on themes like engineering and artificial intelligence, beside collaboration and empathy, with a female robot as protagonist that will learn and live in an animals' environment.
The Mitchells vs the machines	Netflix, 2021 Humans are against intelligent machines that take over world control. There are references on AI and machine learning. Robots are defeated because the AI model for image recognition can be fooled.

Appendix C - Problem in context (Network)

Aoibheann Bird, Insight
Education and Public Engagement Manager for the Insight SFI Research Centre for Data Analytics at University College Dublin and Dublin City University, Ireland. Their EPE programme is mandated to raise public awareness of Insight research to various stakeholders, to inspire, excite and motivate an interest in Science and Technology and to help lay the foundations for a new generation of scientists.

Chrys Ngwa, Insight
Dr Chrys Ngwa is the External Relations & Business Development Manager for Insight in UCC, Tyndall and UL. He also acts as Public Engagement Manager for the sites and he is also a Project Manager.

Denise McGrath, Insight
Dr. Denise McGrath is an Assistant Professor at the School of Public Health, Physiotherapy and Sports Science, University College Dublin and an SFI Funded Investigator with the Insight Centre for Data Analytics.

Anthony Kilcoyne, Professional development service for teachers (PDST)
PDST Deputy Director, Digital Technologies. PDST Technology in Education provides a range of digital technology related support and advice services to schools.

Martyn Farrows, Soapbox
Dr. Farrows, CEO. SoapBox Labs wants to transform how kids interact with technology using their voices. Our privacy-first, low-code, proprietary technology delivers 95% accuracy for kids ages 2-12 of all accents and dialects. R&D driven company, with an ever expanding team of world-class AI and machine learning experts.

Amanda Jollife, DreamSpace Microsoft
With the Microsoft Ireland Education team. In Dream Space, we provide students and teachers with immersive learning experiences that are centred on key skills (problem-solving, collaborating, creative and computational thinking etc) and exposing young people to the power of combining these with STEAM.

Rob Brennan, ADAPT and DCU
He is programme chair of the new masters degree in Privacy and Data Protection Law that is jointly given with the School of Law and government. His research is on data value, quality and governance where he is a SFI Funded Investigator in the ADAPT Centre.

Marta Rocchi, DCU
Assistant Professor in Corporate Governance and Business Ethics at DCU Business School, and member of the Irish Institute of Digital Business. She previously worked as Research Fellow and Vice-Director of the Markets, Culture and Ethics Research Centre in Rome, Italy.

Samuele Buosi, Insight
Machine learning researcher, previously with National centre geocomputation (Maynooth University) now with University of Galway on AI for health projects.

Enric Moreu, Insight DCU
Insight, PhD researcher. His research lies in the intersection between AI and 3D animation, with a focus on generative adversarial networks.

David Azcona, Insight DCU
Before moving to Industry, he was a Postdoctoral Researcher in the Insight Centre for Data Analytics at Dublin City University working in Computer Vision projects with Industry partners. His research in Artificial Intelligence and Applied Machine Learning covered a variety of fields, among which Computer Science Education.

Georgiana Ifrim, UCD
Dr. Georgiana Ifrim is an Associate Professor at the School of Computer Science, University College Dublin, Co-Lead of the SFI Centre for Research Training in Machine Learning (ML-Labs) and SFI Funded

Investigator with the Insight Centre for Data Analytics. Her recent work is on time series and explainable AI.

Appendix D – Data collection instruments

D.1 - Pre-survey (Phase 2), Pilot with preservice teachers

1_Understanding of Artificial intelligence (AI) key ideas (technology)
1.1 Nowadays Artificial Intelligence (AI) is more intelligent than humans. Strongly disagree (We are very far from there). Strongly agree (We are nearly there) *[Likert question]*

1.2 *

Artificial Intelligence is a technology based on Mathematics.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

1.3 Artificial Intelligence is a technology based on Coding. *[Likert question]*
1.4 Can you mention one technique used for AI in computer science? *[Likert question]*

2_Understanding of Artificial intelligence key ideas (ethic and impact on our lives)
2.1 AI has a strong impact on our lives nowadays. *[Likert question]*
2.2 AI could have a strong impact on our lives in the future. *[Likert question]*
2.3 AI can influence human decision making. *[Likert question]*
2.4 Human mistakes can influence AI algorithms. *[Likert question]*

3_ Confidence
3.1 I am scared to know more about AI *[Likert question]*
3.2 I am curious to know more about AI *[Likert question]*
3.3 I am afraid AI can be too difficult for me *[Likert question]*
3.4 I think AI is relevant for my course of study *[Likert question]*

4_AI and children
4.1 AI is too difficult to be introduced to primary school children. *[Likert question]*
4.2 AI knowledge is only relevant for specialists and researchers. *[Likert question]*
4.3 How strong should your own knowledge on AI be before introducing it to primary school children? *[Likert question]*

D.2 - Post-survey (Phase 2), Pilot with preservice teachers

1_Understanding of Artificial intelligence (AI) key ideas (technology)

1.1 Nowadays Artificial Intelligence (AI) is more intelligent than humans. Strongly disagree (We are very far from there). Strongly agree (We are nearly there) *[Likert question]*

1.2 *

Artificial Intelligence is a technology based on Mathematics.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

1.3 Artificial Intelligence is a technology based on Coding. *[Likert question]*
1.4 Can you mention one technique used for AI in computer science? *[Likert question]*

2_Understanding of Artificial intelligence key ideas (ethic and impact on our lives)

2.1 AI has a strong impact on our lives nowadays. *[Likert question]*
2.2 AI could have a strong impact on our lives in the future. *[Likert question]*
2.3 AI can influence human decision making. *[Likert question]*
2.4 Human mistakes can influence AI algorithms. *[Likert question]*

3_ Confidence

3.1 I am scared to know more about AI *[Likert question]*
3.2 I am curious to know more about AI *[Likert question]*
3.3 I am afraid AI can be too difficult for me *[Likert question]*
3.4 I think AI is relevant for my course of study *[Likert question]*

4_AI and children

4.1 AI is too difficult to be introduced to primary school children. *[Likert question]*
4.2 AI knowledge is only relevant for specialists and researchers. *[Likert question]*
4.3 How strong should your own knowledge on AI be before introducing it to primary school children? *[Likert question]*

5_On the programme

5.1 Topics of the workshop were hard to follow *[Likert question]*
5.2 I enjoyed the workshop *[Likert question]*

5.3 What was the part you enjoyed the most and why? *[Open-ended question]*
5.4 What was the part you didn't enjoy and why? What would you change? *[Open-ended question]*

D.3 – Pre-survey (Phase 3), Teachers

1_Artificial Intelligence (AI) preconception and prior knowledge

1.1 What does Artificial Intelligence (AI) mean for you (in your daily life, at school…)? *[Open-ended question]*

1.2 Do you think nowadays Artificial Intelligence (AI) is more intelligent than humans? *[Open-ended question]*

1.3 *

Artificial Intelligence is a technology based on:

- [ ] Algorithms
- [ ] Probability
- [ ] Robotics
- [ ] Coding
- [ ] Data
- [ ] Humanoids
- [ ] Mathematics

1.4 Can you mention one technique used for AI in computer science? *[Open-ended question]*

1.5 Can you name one thing or more that you use in your daily life that uses some kind of AI system? *[Open-ended question]*

1.6 *

Rate the following sentences (1=strongly disagree, 5=strongly agree)

	Strongly disagree	Somewhat disagree	Not sure	Somewhat agree	Strongly agree
AI has already an impact on our lives nowadays	○	○	○	○	○
AI will have more and more impact on our lives in the future	○	○	○	○	○
AI can influence human decision-making	○	○	○	○	○
Human mistakes can influence AI algorithms	○	○	○	○	○
AI algorithms can be 100% confident of the wrong answer	○	○	○	○	○

2_AI and teaching perception

2.1

Rate the following sentences

	Strongly disagree	Somewhat disagree	Not sure	Somewhat agree	Strongly agree
I am scared to know more about AI	○	○	○	○	○
I am curious to know more about AI	○	○	○	○	○
I am afraid AI can be too difficult for me	○	○	○	○	○
I am afraid AI is too difficult to be introduced to primary school children	○	○	○	○	○
AI knowledge is only relevant for specialists and researchers	○	○	○	○	○
I am not sure I will be able to introduce AI to my class	○	○	○	○	○
I can build my knowledge on AI	○	○	○	○	○
My knowledge as a teacher is enough to teach AI to children (I don't need to be an expert)	○	○	○	○	○
Professionals and experts in AI are the only one who should teach AI in school	○	○	○	○	○
I can envision how AI could be integrated in my subject	○	○	○	○	○

2.3 Why do you think we should introduce AI to children? *[Open-ended question]*
2.4 If you imagine yourself teaching AI in class in a few months, how do you see yourself? Write your feelings (any feeling is right, don't feel judged) *[Open-ended question]*

3_Pedagogy

3.1

I am familiar with Constructionism

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
○	○	○	○	○

3.2

I am familiar of using a constructionist approach in teaching my subject

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
○	○	○	○	○

3.3

How often do I use Design-Based Learning in my class?

Every lesson	At least once a month	At least once a year	Never
○	○	○	○

3.4

What subject do you teach?

D.4 – Mid-survey (Phase 3), Teachers after the first three online sessions

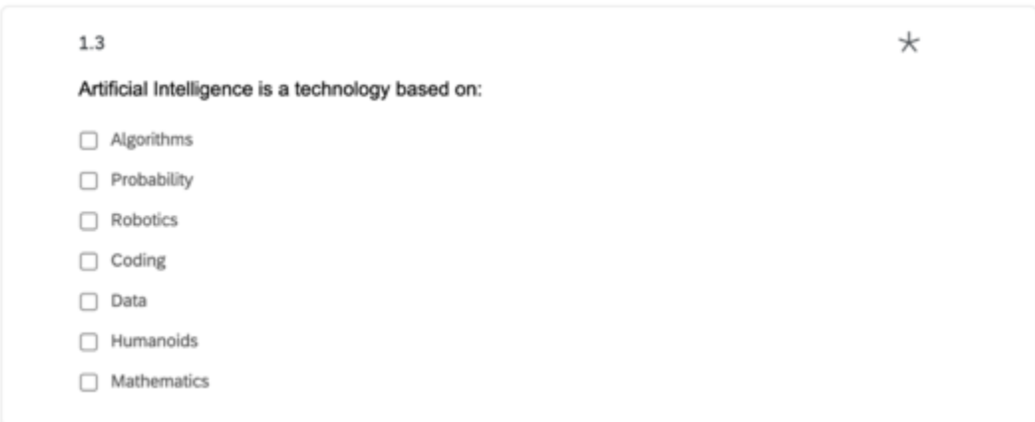
1_Content
One thing you learned about AI from the online sessions: *[Open-ended question]*
One thing you learned about Data from the online sessions: *[Open-ended question]*
Describe machine learning workflow in your words: *[Open-ended question]*
Where data come from? (in your words): *[Open-ended question]*

2_Online sessions
One thing you liked/enjoyed of these three sessions online: *[Open-ended question]*
One thing you would have done differently: *[Open-ended question]*
Was there a good balance between lectures and hands-on activities? *[Yes/No/Not sure]*
Do you think these sessions were useful to learn more about AI? *[Yes/No/Not sure]*
Do you think these sessions were useful to learn more about Data? *[Yes/No/Not sure]*
Do you think our three online sessions are enough as an introduction to AI/Data? *[Yes/No/Not sure]*
Do you think our three online sessions are enough to enable you to design activities on AI / Data? *[Yes/No/Not sure]*
Do you think three online sessions are enough to enable you to design activities that integrate AI into curricular subjects? *[Yes/No/Not sure]*
Are you happy to have one more session face to face focused on designing together activities for children on AI? *[Yes/No/Not sure]*

Anything you want to add: *[Open-ended question]*

D.5 – Post-survey (Phase 3), Teachers

1_Artificial Intelligence (AI) preconception and prior knowledge
1.1 What does Artificial Intelligence (AI) mean for you (in your daily life, at school…)? *[Open-ended question]*
1.2 Do you think nowadays Artificial Intelligence (AI) is more intelligent than humans? *[Open-ended question]*


1.3 *

Artificial Intelligence is a technology based on:

- ☐ Algorithms
- ☐ Probability
- ☐ Robotics
- ☐ Coding
- ☐ Data
- ☐ Humanoids
- ☐ Mathematics

1.4 Can you mention one technique used for AI in computer science? *[Open-ended question]*
1.5 Can you name one thing or more that you use in your daily life that uses some kind of AI system? *[Open-ended question]*

1.6

Rate the following sentences (1=strongly disagree, 5=strongly agree)

	Strongly disagree	Somewhat disagree	Not sure	Somewhat agree	Strongly agree
AI has already an impact on our lives nowadays	○	○	○	○	○
AI will have more and more impact on our lives in the future	○	○	○	○	○
AI can influence human decision-making	○	○	○	○	○
Human mistakes can influence AI algorithms	○	○	○	○	○
AI algorithms can be 100% confident of the wrong answer	○	○	○	○	○

2_AI and teaching perception

2.1

Rate the following sentences

	Strongly disagree	Somewhat disagree	Not sure	Somewhat agree	Strongly agree
I am scared to know more about AI	○	○	○	○	○
I am curious to know more about AI	○	○	○	○	○
I am afraid AI can be too difficult for me	○	○	○	○	○
I am afraid AI is too difficult to be introduced to primary school children	○	○	○	○	○
AI knowledge is only relevant for specialists and researchers	○	○	○	○	○
I am not sure I will be able to introduce AI to my class	○	○	○	○	○
I can build my knowledge on AI	○	○	○	○	○
My knowledge as a teacher is enough to teach AI to children (I don't need to be an expert)	○	○	○	○	○
Professionals and experts in AI are the only one who should teach AI in school	○	○	○	○	○
I can envision how AI could be integrated in my subject	○	○	○	○	○

2.3 Why do you think we should introduce AI to children? *[Open-ended question]*
2.4 If you imagine yourself teaching AI in class in a few months, how do you see yourself? Write your feelings (any feeling is right, don't feel judged) *[Open-ended question]*

3_On the programme
3.1 One thing you really enjoyed of this course: *[Open-ended question]*
3.2 Anything you would have done differently: *[Open-ended question]*
3.3 Anything you want to add... *[Open-ended question]*

D.6 - Focus group (Phase 3), Teachers

Prompt questions prepared upfront
1. Did you find that the design process of designing the activities helped you to understand better AI key ideas?
2. In which way the design process help you learn more about AI?
3. Did this design session help you to see how AI can be integrated into subjects?

4. What was the challenge in designing activities that integrate AI into standard subjects?
5. Did you appreciate your role as expert?
6. Did you enjoy being part of the design process and not receive something prepared by others?

D.7 - Observation framework (Phase 4)

1_Observation framework for Teachers

IMPORTANT: While writing notes please do NOT at any time write the names, surnames or initials of students. It is important NOT to use any kind of identifier.

TO BE FILLED IN **BEFORE** STARTING EACH WORKSHOP

Date______________ Class / Age of students ___________________________

Activity of the programme that will be children will be engaging with today

____

TO BE FILLED **DURING** THE WORKSHOP

Example of children's **questions/reflections/ideas shared** during the activity on the TOOLS used	
Example of children's **questions/reflections/ideas shared** on Artificial Intelligence BIG IDEAS	

TO BE FILLED **AFTER** THE END OF THE WORKSHOP

Any insights / aspect you find **important to highlight** (Including feedback on the activity, anything that needs to be changed):	
One thing your children really **enjoyed** of this activity:	
What did your children **learn**?	
Any other thoughts	

D.8 - Semi-structured interview (Phase 4), Teachers after their trial in school

IN SCHOOL
1. Is there anything you really enjoyed when implementing it with children?
2. Which activities did you try?
3. Is there anything that was very challenging and difficult?

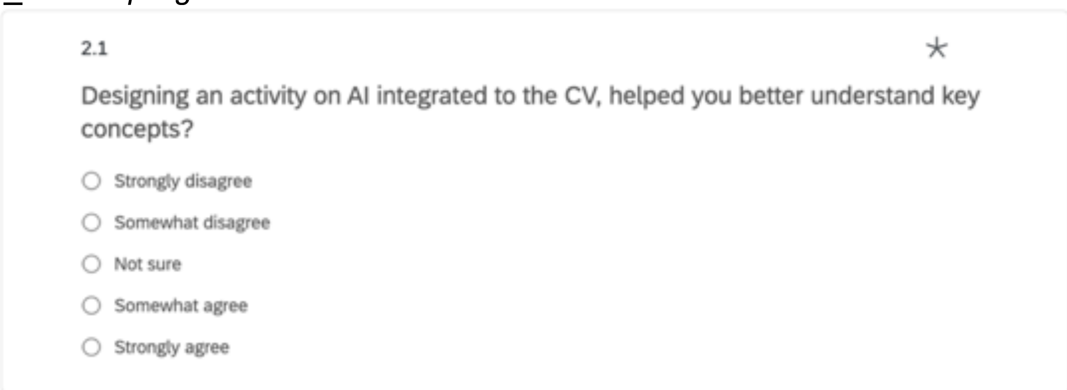
CHILDREN
1. Can you point to any particular examples that you think developed the children's understanding of Machine Learning / AI?
2. Can you point to / describe a significant learning moment you or your students had?

CONFIDENCE/LEARNING/CREATING
1. Did the experience of co-designing the programme influence your implementation with the class?
2. Do you feel confident in designing new opportunities for your children to better understand AI integrated with your subjects?
3. Would you feel confident describing some of the big ideas underpinning AI to another colleague in your school? Would you be able to support them if they wanted to use the AI programme with the children in their classroom?

D.9 - Post-survey (Phase 6), new teachers

1_Lesson learnt
1.1 Do you think nowadays Artificial Intelligence (AI) is more intelligent than humans? *[Open-ended question]*
1.2 Can you mention one technique used for AI in computer science?Articulate. *[Open-ended question]*
1.3 Why do you think we should introduce AI to children? *[Open-ended question]*

2_On the programme


2.1 *

Designing an activity on AI integrated to the CV, helped you better understand key concepts?

- Strongly disagree
- Somewhat disagree
- Not sure
- Somewhat agree
- Strongly agree

2.2 I learnt something on AI and Data today *[Likert question]*
2.3 Did you enjoy the workshop? *[Likert question]*
2.4 Are you curious to know more about AI? *[Likert question]*

2.5 Are you interested in trying to introduce AI key ideas to your students? *[Likert question]*

3_Resources
3.1 Having a Handbook with key ideas and activities could help you in introducing AI in class? *[Likert question]*
3.2 Having a Website as a collector of resources on AI could help you in introducing AI in class? *[Likert question]*

4_General and personal feedback
4.1 One thing you really enjoyed today *[Open-ended question]*
4.2 One thing you would have done differently *[Open-ended question]*
4.3 Anything you want to add... *[Open-ended question]*

D.10 – Focus group (Phase 5) teachers

1)Do you think the learning approach used in the workshops helped in building your understanding of Machine Learning AI?

If not, can you elaborate on what type of learning approach / learning experiences would have helped you.

2) Can you point to any examples that did develop your understanding of Machine Learning?

3) Can you point to / describe a significant learning moment you had?

4) Would you feel confident describing some of the big ideas underpinning AI to a colleague?
5) What examples in real life do you think would be appropriate to relate them to?

6) Do you think the combination between an introduction focus on the developing your own understanding of the big ideas of AI and a hands-on experience with the tools and methods help to enable you to design an effective learning environment on AI for children?

7) Did you enjoy the co-design session? Which aspect do you appreciate the most?

8) What did you find challenging?

9) Did your confidence in developing learning opportunity for children on AI develop during the workshops / co-design sessions? Can you elaborate?

10) Co-design teachers

D.11 – Focus group (Phase 6), Advisors

HOW DID THE DAY STARTED?
Who led and who observed?

How many participants?
Participants background?

Experience with coding/computational thinking?

Tell me about yesterday from the start: what time did you start and where?
All the phases from start till the end of the day, time frame

Pick a picture and tell me

How was your experience leading?
Your preparation

TEMPLATES:
Did they work? Challenges
Handbook and website? Slides?

DESIGN:
Tell me more about it
One example of activity

Appendix E – PLS and Consent for adults

Plain language statement: Teachers (PDST Advisors / Associates)

Research study title:
Co-designing with teachers a programme for primary school children (9-12 years) to develop an effective Education and Public Engagement (EPE) framework that can be used by research groups to raise awareness on emerging technologies (Artificial Intelligence).

University: Institute of Education, Dublin City University (DCU)
Primary Investigator and Supervisors: Enrica Amplo, PhD student, enrica.amplo2@mail.dcu.ie
Professor Deirdre Butler, main supervisor (DCU) and Dr. Tara Cusack, supervisor (UCD)

Dear Teacher,

The purpose of the research is to co-design with teachers, like you, a programme to engage primary school children in hands-on learning opportunities to develop their own understanding of Artificial Intelligence (AI), its impact and implication for our lives and our society.

If you decide to take part in this research project:

1) You will participate in **a learning program on AI** (no particular skills are required) focused on key ideas both related to coding and ethics. You will then experiment with the *machinelearningforkids.co.uk* platform combined with *Scratch* to learn how to "teach" your computer to solve problems.

2) You will participate in **co-design sessions with colleagues form the PDST** and the primary investigator of the research to design and **develop a programme on AI for children** (9-12 years) focused on the health.

3) You will receive **support** at any stage from the researcher.

4) You will have support at any stage with materials and resources, and through a web community developed for peer-support.

Participation in the research is voluntary and participants have the right to withdraw at any time without penalty.
If you agree to take part and then decide that you have changed you mind, you can withdraw at any stage.

Data collection and analysis

<u>Survey:</u>
You will be asked to fill in, anonymously and on a voluntary basis, a digital pre- and post-survey. No personal information such as names and surnames or other identifiable information will be asked at any time. There is no way to track who has submitted the responses. The

purpose of the survey is to understand if the intervention is effective to enable participants to build their knowledge on AI from content and pedagogy point of view.

Researcher's observation (as a participant):
The researcher will take hand-written notes during workshops. These notes will be digitalised and stored on a password protected folder on the researcher's DCU account. Only the researcher can access it. Physical hand-written notes will be destroyed in a safe manner (confidential shredding bin in the secretary's office of the School of STEM Education, Innovation & Global Studies).
No personal data will be included in the notes. The purpose of the notes is to collect data to re-design and improve the programme and the format of co-design sessions for teachers.

Interviews:
If you agree to participate in the research, you may be asked to participate in a focus-group or personal interview. Your participation is completely voluntary. Digital audio recordings of interviews will be made to password protected storage on a digital recording device. Once transcribed and checked for accuracy, the digital recordings will be deleted from the DCU PC hard drive. Any personal identifying information will be replaced with pseudo names (e.g. PDST_A1) so your identity will be protected.
Transcripts will be stored in DCU Google drive folder that is password protected, and only accessible by the researcher.

The purpose of the interviews is to collect your views and opinions about the workshop content and design, the AI programme for children and EPE frameworks.
No personally identifiable information will be used in any publication that results from the project as all identifying information will be anonymised. Pseudonyms will be used throughout and any identifying information removed (e.g. in transcripts saved on the NVivo database and any use of transcripts in the project documentation).

You will not be identified in any notes or in any write up of the research. Data will be deleted within three years after the end of the research project. However, it must be noted that the confidentiality of information provided can only be protected within the limitations of the law. Only the researcher and the supervisors will have access to the data gathered, which will be password protected and safely stored on DCU cloud storage.

As benefits from this project, you will have the opportunity to develop your own understanding of the big ideas that underpin AI both form a coding and ethic perspective. To be part of a growing community of teachers engaged in developing learning opportunity for children on emerging technologies.

Findings of this research will be part of PhD research thesis and can be presented at education conferences and in journal articles.

If you have any further queries, please do not hesitate to contact the researcher listed above.

If participants have concerns about this study and wish to contact an independent person, please contact: The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Consent Form: Teachers (PDST Advisors / Associates)

Research study title:
Co-designing with teachers a programme for primary school children (9-12 years) to develop an effective Education and Public Engagement framework that can be used by research groups to raise awareness on emerging technologies (Artificial Intelligence).

University: Institute of Education, Dublin City University (DCU)
Primary Investigator and Supervisors: Enrica Amplo, PhD student**,**
enrica.amplo2@mail.dcu.ie
Professor Deirdre Butler, main supervisor (DCU) and Dr. Tara Cusack, supervisor (UCD)

Clarification of the purpose of the research:
The purpose of the research is to co-design with teachers, like you, a programme to engage primary school children in hands-on learning opportunities to develop their own understanding of Artificial Intelligence, its impact and implication for our lives and our society.

Confirmation of particular requirements as highlighted in the Plain Language Statement:
Participant – please complete the following (Circle Yes or No for each question)

I have read the Plain Language Statement (or had it read to me).	Yes / No
I understand the information provided.	Yes / No
I understand the information provided in relation to data protection.	Yes / No
I have received satisfactory answers to all my questions.	Yes / No

Confirmation that involvement in the Research Study is voluntary:
I may withdraw from the Research Study at any point without penalty. Yes / No

Advice as to arrangements to be made to protect confidentiality of data, including that
confidentiality of information provided is subject to legal limitations:
I am aware that I will not be identified in any notes or in any write up of the research. Data will be deleted within three years after the end of the research project. However, it must be noted that the confidentiality of information provided can only be protected within the limitations of the law. Only, the researcher and the supervisors will have access to the data gathered, which will be password protected and safely stored on DCU cloud storage.

Signature:
I have read and understood the information in this form. My questions and concerns have been
answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project.

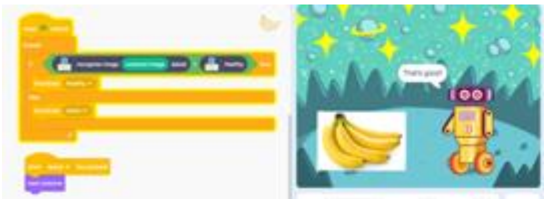
Teacher's Signature: ______________________________
Name in Block Capitals: ________________________________
Date: ______________________

Appendix F – PLS and Consent for children

Plain language statement: Children (9-12 years)

Project title: Exploring the development of creative and critical thinking related to Artificial Intelligence
University: Institute of Education, Dublin City University (DCU)
Primary Investigator and Supervisors: Enrica Amplo, PhD student, enrica.amplo2@mail.dcu.ie. Professor Deirdre Butler, main supervisor (DCU) and Dr. Tara Cusack, supervisor (UCD)

Dear Student,
I would like to invite you to take part in a project with your class in which you will learn about Artificial Intelligence. You will discover what Artificial Intelligence (AI) is and how to creatively use AI for Good. You will learn how to teach a computer to help people to improve their health habits.
With your teacher you will train a model and code your program using building blocks (Scratch). Teachers will take some notes during the activities to help the researcher understand if you enjoy it and how it can be improved.

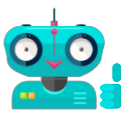


If you have any further queries, please do not hesitate to contact us.
If you have worries about this project, tell your teacher and the teacher can contact the University: The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Children's Informed Consent Form

I know what the project is for. I had a chance to ask questions. I know I can ask questions at any time. I know it is my decision to take part in the project. I know that I can leave the project at any time.

Please circle thumbs up if you want to take part and thumbs down if you do not want to take part.




Child's Name___________________________ Date ______________________

Parent's /Guardian's Signature______________________________

Appendix G – Pilot workshop worksheet

SMART TOY – Worksheet

Imagine…We are trying to design a smart AI toy for kids who are not able or capable to speak. So that they can interact with it using written plain language instead of vocal commands (as usual instead with voice assistants). You are going to create a Sprite in Scratch that will move and chat through written commands. To do so you will learn to train a model (using machine learning) to recognise your written speech.

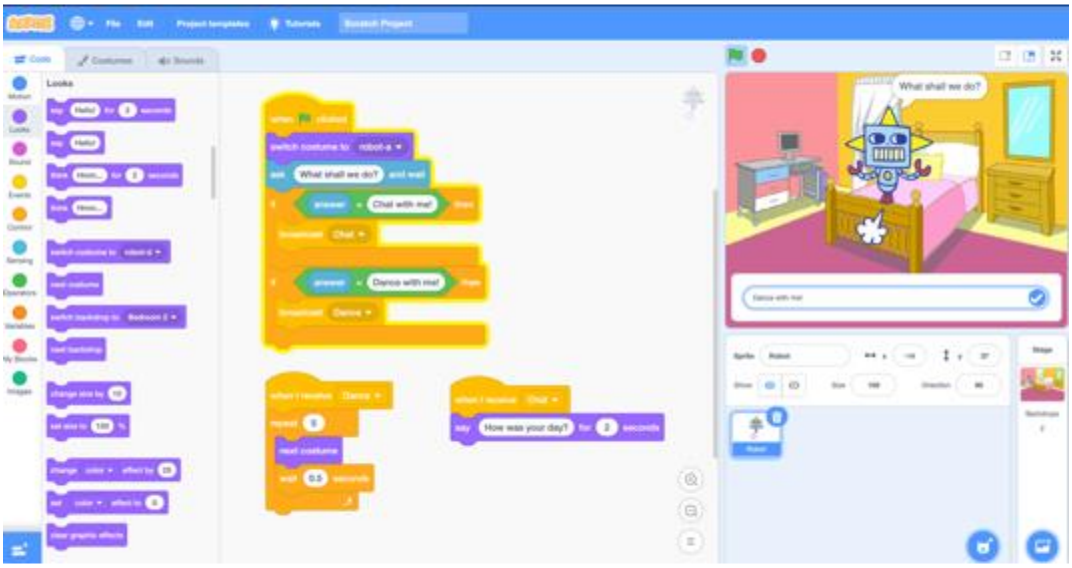
STEP 1 – Set up your scene in Scratch

GO TO Scratch at the link: https://scratch.mit.edu/
Choose CREATE

Start to add a background you'd like.
Add a sprite you'd like, be sure to choose one with different costumes so it can move!

Code your sprite so you can command it to move with a simple written command like "Dance with me!" and chat with a simple command like "Chat with me"
Use the "ASK … AND WAIT" block and "ANSWER" (both are under sensing).

SAVE YOUR PROJECT: File / Save to your computer



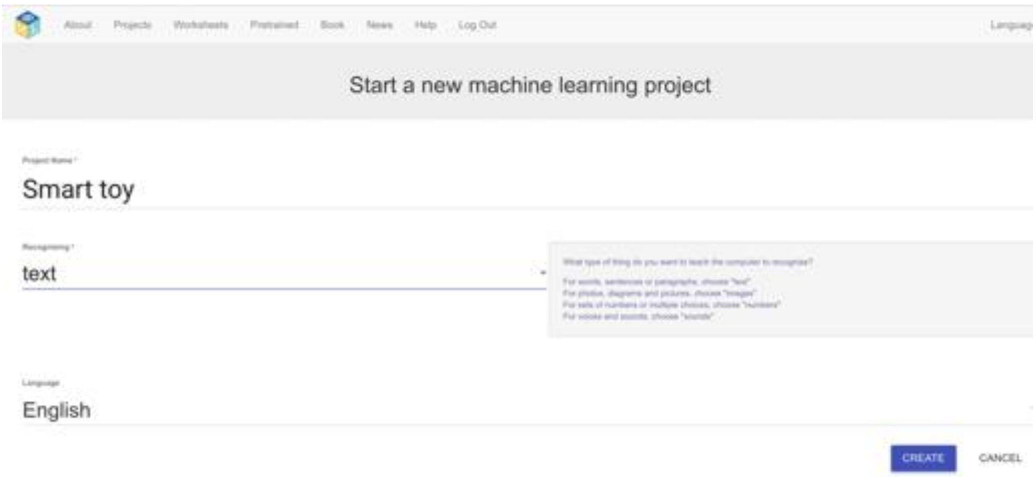
Reflect:
1.1 What happens if you type slightly different commands? (i.e. "Dance with me" or "Dance")

1.2 Can you explain why?

STEP 2 – Train a model to recognise written commands

You will teach the model to recognise commands to make your sprite move.
GO TO link (you do NOT need to sign in): https://machinelearningforkids.co.uk/
Get started / Try WITHOUT registering / Try it now

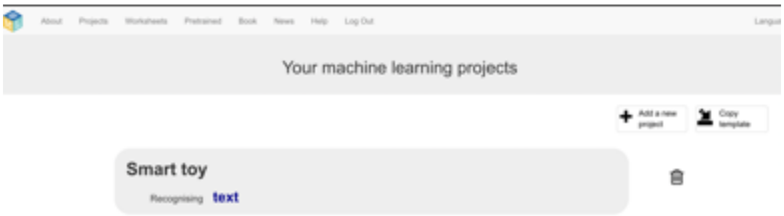
Click ADD A NEW PROJECT, give your project a name and choose **Recognising: Text.** Then **CREATE.**



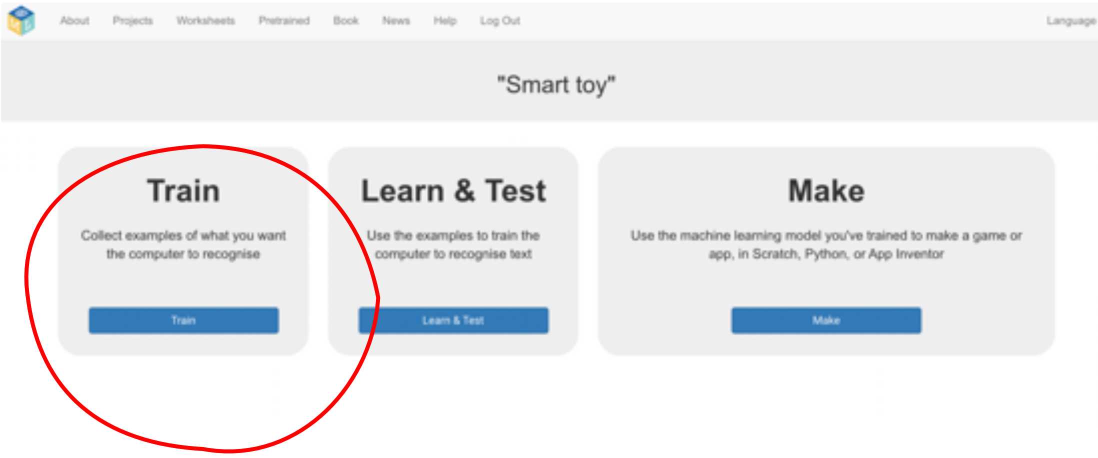
Main steps in Machine learning workflow: DATA - TRAINING - TEST
To implement a Machine Learning model and design with it:
Build a dataset/Label (Data and train) - **Train** (Learn and test) – **Implement** (Make)

So now it's time to create your **DATA SET**.
Think of many ways of saying "Dance with me!" as you can and write them down on paper.
At least 10, but the more the better! (Consider also spelling errors, and different words/ways.)

Think of many ways of saying "Chat with me!" as you can and write them down on paper.
At least 10, but the more the better! (Consider also spelling errors, and different words/ways.) Select your project by clicking it.



Let's start the TRAINING now.

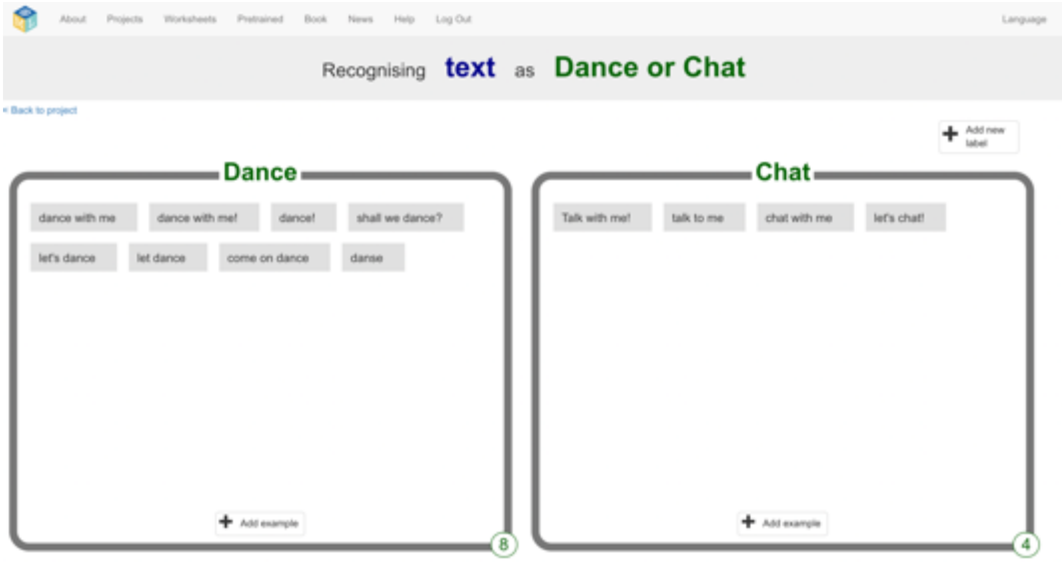


To do so click **Train**.

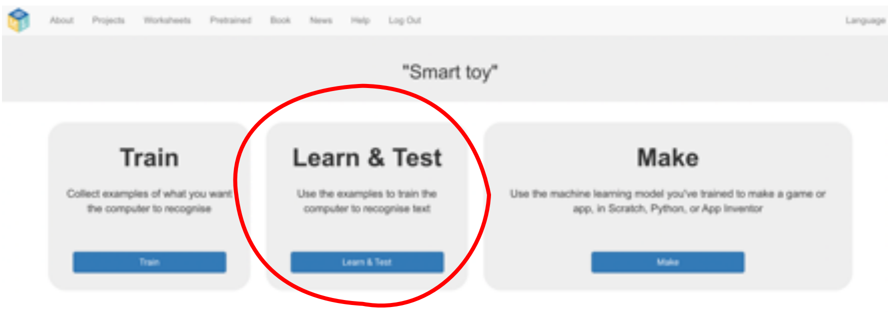
We would like to teach the toy to category of commands: dance and chat.
So let's add a new **label**: "Dance".
And a new **label**: "Chat".

Add examples to create your data set. Add most of the words and expressions you wrote before.

! BUT keep 3 expressions a side (3 for Dance and 3 for Chat).
You will use them later on to test the model.



When you are ready click “back to project” now it is time to let the model LEARN from the data set.



To do so, click **Learn & Test**.

Then click: **TRAIN NEW MACHINE LEARNING MODEL**.
It can take a while, be patient, it requires a huge number of calculations to learn from the dataset.

Once the training is finished, you can test your Machine Learning Model:

1) Type in an expression added by you before, as an example for “Dance” in the training.
Click Test and see what happen.

2) Type in an expression added by you before, as an example for “Chat” in the training.
Click Test and see what happen.

3) Type in an expression you have kept a side and did not trained the model with. Click Test and see what happen.

Reflect:

2.1 Did the model work properly in recognizing your data?

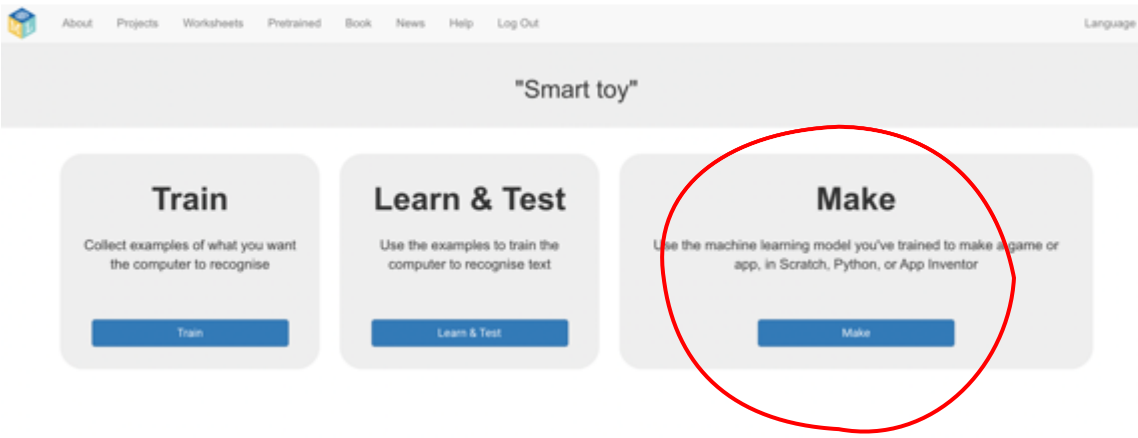
2.2 Have you noticed the word "confidence"?

2.3 What is the percentage? What do you think this means?

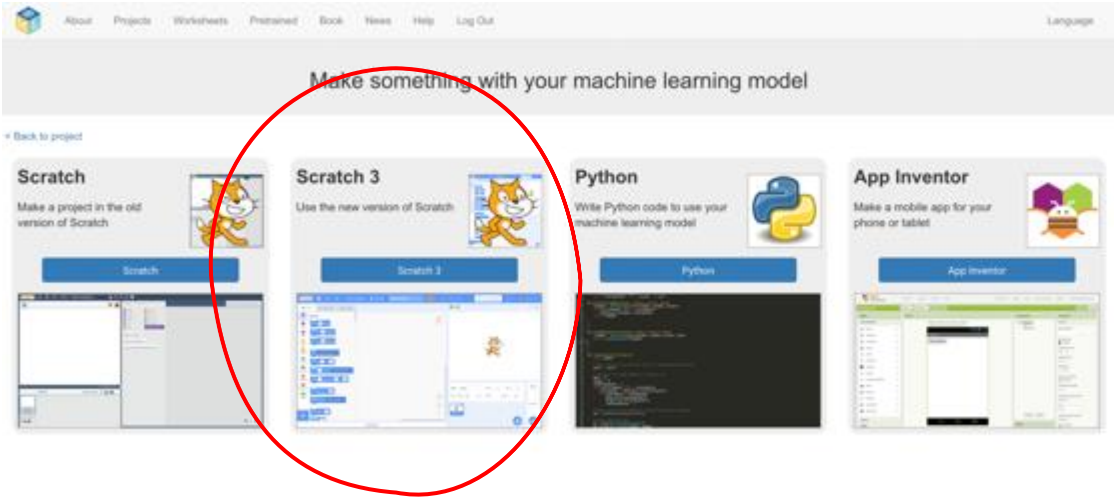
STEP 3 – Implementation

GOOD JOB! You are doing great so far…
Now it's time to implement your Machine Learning model in your programme and test it.

In Machine Learning for Kids click "Back to project" and "MAKE"



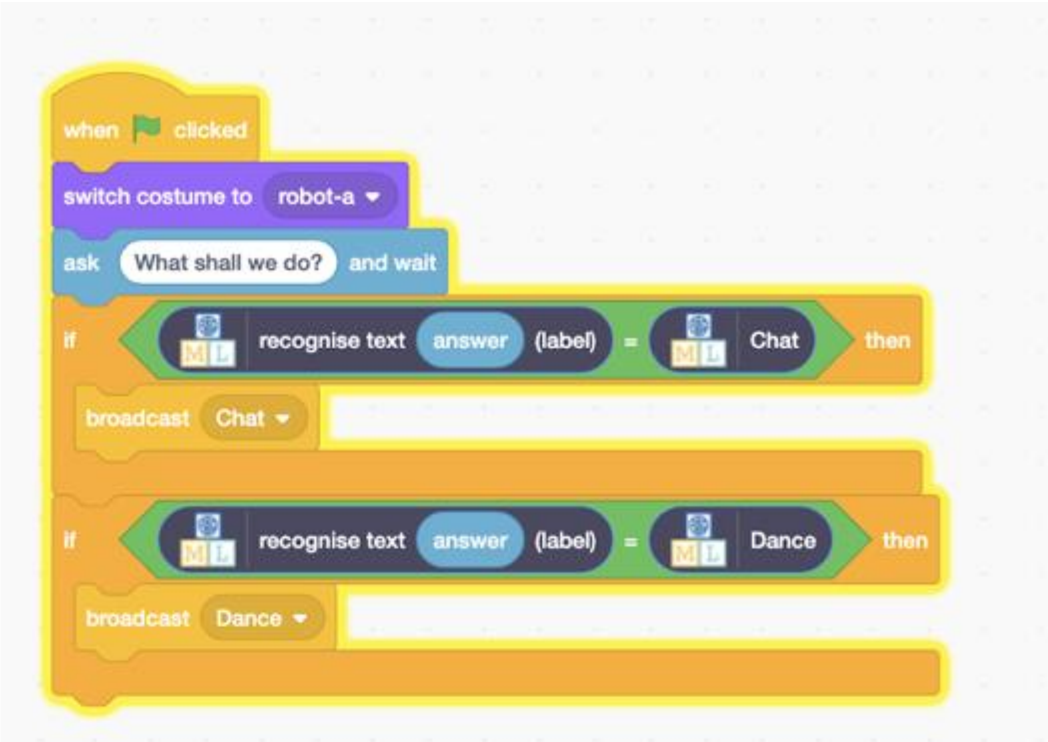
Choose **Scratch 3** and then **Open in Scratch 3**.



Load your programme you created and saved in step 1: **File / Load from your computer**.

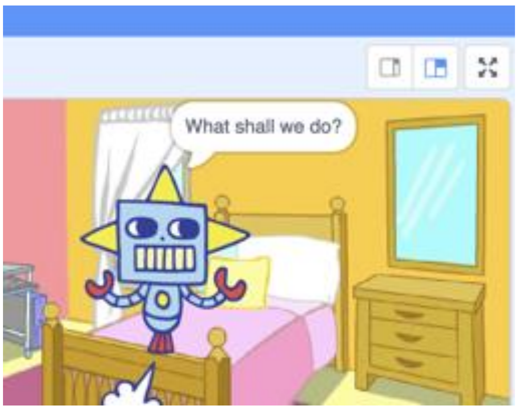
You will find a new category of blocks on the left called "**Smart toy**". This is the model you trained.

Now you can implement your trained model in your programme, see diagram below.



You are now asking the model to recognise your typed text (answer).
Then if the prediction from the model is correct you will see your toy dance or chat with you.

TEST all your work.
Click the button "Full screen control", and interact with your smart toy, using also never before used expressions.



Reflect:

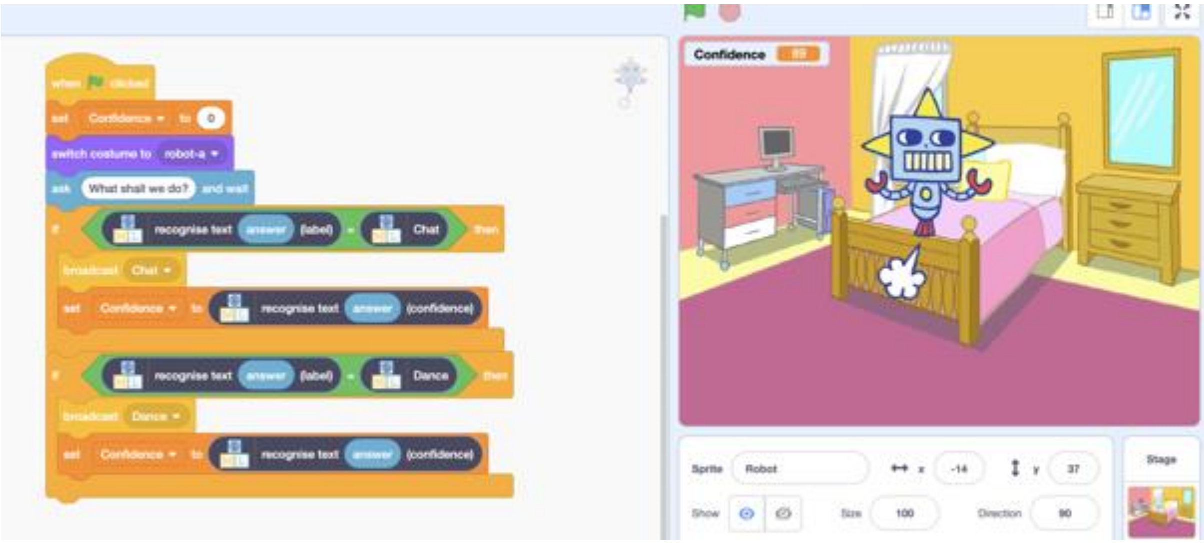
3.1 Is your programme working?

3.2 Is it always working?

3.3 Does it work with new expressions?

ADD HERE a screengrab of your programme:

EXTENSION:
Are you curious to understand how your toy is "confident" in understanding what you are saying to it? You can try to play around with the block related to **confidence** and **variables**.
Can you imagine a way to improve the model?



ADD HERE a screengrab of your programme:

Appendix H – Website

Website
https://teachingai.eu/

Appendix I – Handbook

Link to view the handbook as pdf:
https://teachingai.eu/wp-content/uploads/2023/05/Handbook-V4.pdf

Appendix J – Ethical approval

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

DCU

Enrica Amplo
School of STEM Education, Innovation & Global Studies

Prof. Deirdre Butler
School of STEM Education, Innovation & Global Studies

Dr. Tara Cusack
UCD School of Public Health, Physiotherapy and Sports Science

12th March 2021

REC Reference:	**DCUREC/2021/043**
Proposal Title:	**Co-designing with teachers a programme for primary school children (9-12 years) to develop an effective Education and Public Engagement framework that can be used by research groups to raise awareness on emerging technologies (Artificial Intelligence).**
Applicant(s):	**Enrica Amplo, Prof. Deirdre Butler, Dr. Tara Cusack**

Dear Colleagues,

Further to expedited review, the DCU Research Ethics Committee approves this research proposal.

Materials used to recruit participants should note that ethical approval for this project has been obtained from the Dublin City University Research Ethics Committee.

Should substantial modifications to the research protocol be required at a later stage, a further amendment submission should be made to the REC.

Yours sincerely,

Geraldine Scanlon

Dr Geraldine Scanlon
Chairperson
DCU Research Ethics Committee

DCU Research & Innovation

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Appendix K - Conference presentations and publications

Amplo, E. (2023), *“Artificial Intelligence Education and Public Engagement through Teacher Learning and Co-Creation.”*
AIET Artificial Intelligence in Education Technology
[Conference presentation, 1st July 2023]

Amplo E., & Butler D. (2023) *“Design-Based Learning and Constructionist Learning Principles to Promote Artificial Intelligence Literacy and Awareness in K-12, a Pilot Study”*
The IAFOR International Conference on Education – Hawaii 2023 Official Conference Proceedings.

Amplo, E. and Butler, D. (2023) *“A learning programme framed by TPCK (Technological Pedagogical Content Knowledge) and based on Constructionism and Design to enhance Teacher learning and development of Artificial Intelligence (AI) key ideas and competencies.”*
In Society for Information Technology & Teacher Education International Conference (pp. 1914-1923). Association for the Advancement of Computing in Education (AACE).

Amplo, E., Butler, D., and Cusack, T., *“Developing AI (Artificial Intelligence) literacy through an online programme for Preservice Teachers underpinned by TPCK (Technological Pedagogical Content Knowledge) and Constructionist learning principles.”*
Computers and Education: Artificial Intelligence, Elsevier Journal.
[Reviewed and comments addressed, awaiting final decision of the editor.]

Appendix L - Phase 2 pilot programme design

The design of this programme was grounded in the Technological Pedagogical Content Knowledge (TPCK) framework (Koehler and Mishra, 2006). As preservice teachers were the learners in this programme, activities were underpinned by constructionist principles to improve the quality of the learning experience for them and to demonstrate approaches that can be used with their future classes (i.e. teaching preservice teachers as if they were their future students (Bransford, Brown and Cocking, 2000)).

The programme was focused on the AI literacy principles and key ideas from Long and Magerko, (2020) and Touretzky et al., (2019) previously outlined to engage preservice teachers in an interactive and active way using constructionist tools and approaches. Due to restrictions as a result of the Covid 19 pandemic the programme was facilitated online through the Zoom platform. The main room and breakout rooms in Zoom were used to create a safe environment for the participants to peer learn and support each other in groups as they engaged with each learning activity. For this study two cohorts of preservice teachers were identified. One group consisted of final year preservice primary school teachers from Dublin City University (DCU), who engaged with the workshops as part of an undergraduate module. The second cohort were preservice students form Università Cattolica in Milan who participated in the workshops in addition to their regular coursework. The programme consisted of two online workshops (2x 2 hours), see Fig. 84.The first workshop was focused on the content **[CK]** and designed as an opportunity for the participants to develop their own understanding of AI. Starting with participants' pre-conception and perception on AI and building from there (Bransford, Brown and Cocking, 2000). Throughout the workshop the participants were involved in hands-on active learning experiences to foster critical thinking and to stimulate discussion. The second workshop was focused on the pedagogical approach **[PK]** that these preservice teachers could use in their future classroom practice. Informed by design thinking and constructionist learning principles the approach adopted was to model the process of how these preservice teachers could in turn design and facilitate learning opportunities for their future students to develop the big ideas of AI (Bransford, Brown and Cocking, 2000). In both workshops, different AI tools were used as a means to enable the preservice teachers to understand AI key ideas while developing their AI literacy and competencies **[TK]**.

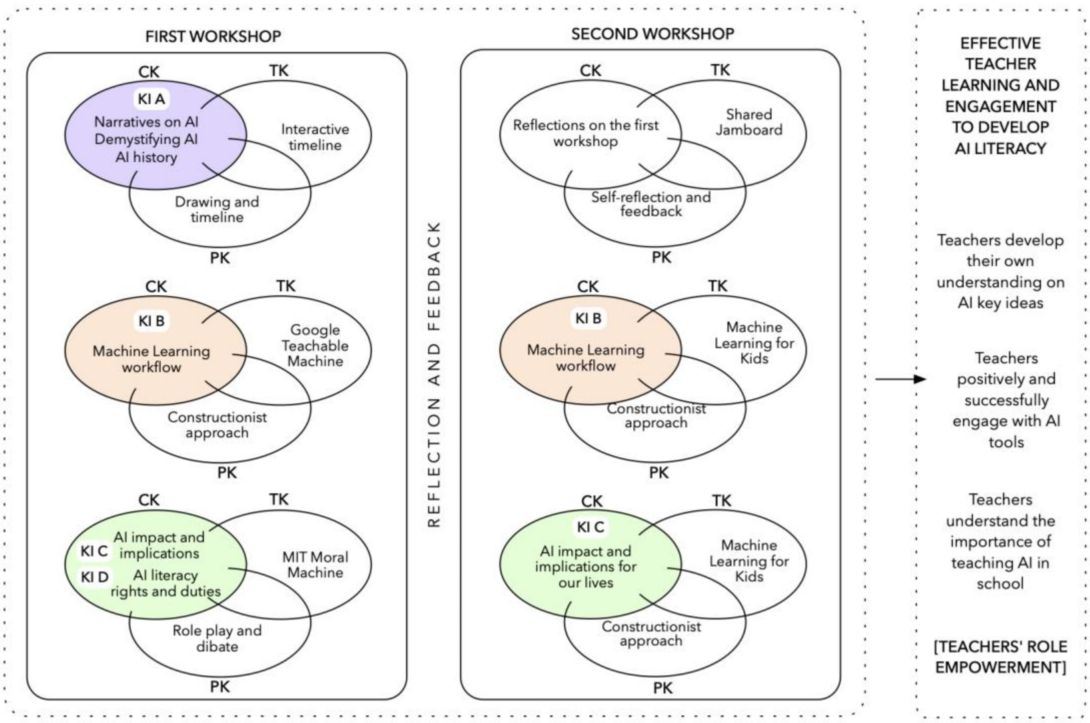


Fig. 84 Programme design

In line with constructionist principles, the tools used within the workshops were selected to enable the learner (in this case preservice teachers) to build their own understandings of the key ideas as they engaged with designing and constructing “an object to think with” (Papert, 1980). The tools used were:

1. Machine learning for kids: A web-based platform where children can train a machine learning model to recognise text, images or sound and then implement the model in Scratch (Lane, 2022)
2. Scratch (version 3): A web-based platform where children are introduced to coding and computational thinking through a block-based visual programming language (MIT Media Lab, 2022)
3. Google Teachable Machine (Google, 2022)
4. MIT moral machine web app (MIT, 2022)

Due to the time commitments of their undergraduate coursework, it was only possible to design 2 workshops in which the preservice teachers could engage. Consequently, a decision had to be made about which ideas and competencies were appropriate to focus on. Drawing on the research literature, four main ideas were selected as a possibly effective way to start a conversation on AI:

KI A. Demystifying AI and AI people history: AI is not new, it is based on mathematics and coded by humans (Long and Magerko, 2020)

KI B. How computers learn from data, machine learning workflow (Touretzky et al., 2019)

KI C. AI applications can impact society in both positive and negative ways (Touretzky et al., 2019)

KI D. AI literacy relevance for everyone for now and for the future, rights, and duties as citizens in the era of AI (Floridi *et al.*, 2018)

A detailed breakdown of the sessions is summarised in Table 27, with a list of activities, tools used and pedagogical approaches suggested. The researcher conducted the workshops using presentation slides as support. The first workshop started with a drawing exercise to investigate pre-conceptions followed by a brief introduction with presentation slides on AI facts and history. History of AI was then presented in an interactive way by sharing a link to a multimedia timeline developed for the participants. Presentations were alternated with hands-on activities and opportunities for discussion. Participants generally engaged in activities individually due to the online nature of the learning programme. However, it was encouraged that students also could work in breakout rooms for peer support. The activity with Moral Machine was deliberately designed to be engaged in as a group activity. Students in groups, with different ideas and backgrounds, could discuss ethical decisions that had to be made. Moral Machine software represented an engaging way for students to start to reflect on ethical issues related to AI. However, it is important to acknowledge the ambiguity of the “black and white” structure often used to introduce AI ethical dilemmas, which does not include the shades of reasons and choices in between (Sommaggio and Marchiori, 2020).

First session (2 hours workshop online)		
KI [CK]	**Materials/ tools used [TK]**	**Activity - Approach [PK]**
KI A	Pen and paper Jamboard	"If I say ARTIFICIAL INTELLIGENCE, you draw?" ("draw-and-write" technique) allows us to see participants' preconceptions and existing ideas on AI. Participants share on a Jamboard Narratives on AI they are familiar with.
KI A	Slides/ videos/ interactive timeline	Brief introduction to build on preconceptions leading to key principles that underpin AI and machine learning workflow. History of AI explored with an interactive timeline.
KI B	Google teachable machine	Students have two categories of objects (e.g. pens, books, markers) Take pictures of their own objects and train an image classifier to recognise them. Then analyse the performances of the machine learning model with objects used to build the dataset and also with objects the model has never seen before.
KI B **KI C**	Slides/videos/pen and paper	Brief overview on data and how we can interpret the world through data. Human role in AI and repercussions of human biases. The "draw-and-write" technique is very helpful in gathering data and allows participants to express themselves (Kara, 2012). Example: "Draw a shoe?" to illustrate how we are biassed in how we categorise / classify objects.
KI D	Slides/ news articles	Brief overview on the impact on our society and in decision making of AI. General introduction to GDPR and rights on autonomous machines for European citizens.
KI D	MIT Moral Machine	Through role play and hands-on activity using Moral Machine students engage in group discussion and critical debate trying to pick one decision for each scenario as a group. This allows students to simulate a round table of different stakeholders (policy makers, developers..etc.) and understand the criticality of such a dialogue.
KI C	Google Jamboard	Students are asked to search online for AI applications for good and imagine their impact, writing notes on a shared Jamboard.
Second part (2 hours workshop online)		
KI [CK]	**Materials/ tools used [TK]**	**Activity - Approach [PK]**
KI B **KI C**	Jamboard	Reflection and anonymous brainstorming allow no judging active environment to reflect on learning.
	Worksheet Scratch Machine Learning for Kids	"Smart toy" worksheet. Students work on it on their own machine but supported by peers in zoom rooms. The activity is based on constructionist learning theory and design-based learning. Students create a simulated toy/robot that can understand text language for children who are not able to speak.

Table 27 In-depth sessions overview

As highlighted in Fig. 84, a spiral learning approach was adopted to the key ideas KI B and KI C which were related to machine learning and AI impact. These key ideas were presented to the participants several times using different activities and approaches as an opportunity for them to develop their learning throughout the sessions. The second session activity on designing a machine learning model for a smart inclusive toy was purposefully designed as a wrap-up of all the key ideas the workshop had focused on.

Conscious that one of the major challenges to learning AI is not having a computer science background (Zhou, Van Brummelen and Lin, 2020), it was critical to be mindful of the backgrounds of the different participants and scaffolding the learning activities accordingly. The DCU students were engaging in a digital learning specialism as part of their undergraduate programme and so were familiar with a range of digital tools as week as coding and computational thinking. Consequently, this group engaged in a series of self-directed challenges they could follow at their own pace, Fig. 85, available entirely for reference in Appendix G.

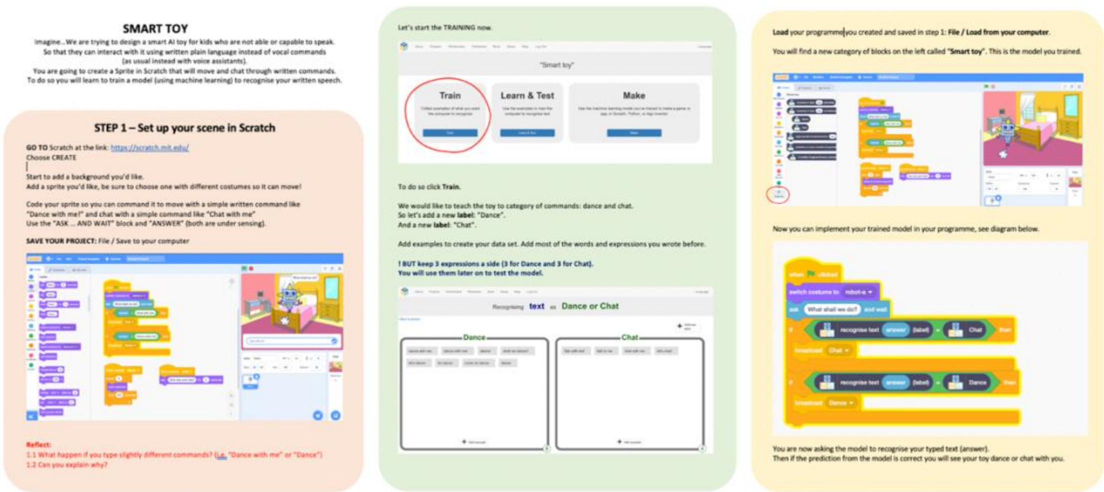


Fig. 85 Example of self-directed task worksheet

The challenges were developed as a sequence of small steps designed to scaffold participants' exploration and building of their own understanding, in line with the constructionist approach. Students were given space to customise their projects and they spontaneously and independently improved them as shown for example in Fig. 55, where a student chose a *sprite* (character in Scratch) of their choice and improved "dance" and "start" functions. In contrast, the students from Milan University had very little background in coding and computational thinking. Therefore, the researcher conducted a short interactive introduction to the key ideas of computational thinking using Scratch (CK and TK) and then led participants through the same challenge as DCU students. Both groups of preservice teachers had the opportunity to develop their confidence with the new tool, Machine learning for kids, which was used on its own platform and then incorporated with Scratch blocks. Participants were involved in creating their first project using machine learning to solve a hypothetical real-world problem. The problem identified for this purpose was: Designing an inclusive smart robot-toy for children who cannot use their voice to play with it. Preservice teachers at their own pace and with peer support created a programme choosing their own sprite (character in Scratch) and background and then programmed it to "dance" or "chat" following text command. Each participant built a dataset for the two classes: "dance" and "chat" and then trained a machine learning model to classify them. They tested, deployed, and integrated it with Scratch blocks (Fig. 54).

Appendix M - Phase 3 teacher programme design

Teachers are expected to keep growing as digital creative leaders throughout their careers in order to be ready to prepare students to develop the skills and competencies they need as citizens in the 21st century (Vuorikari, Kluzer and Punie, 2022). However, teacher learning is a multifaceted ecosystem and according to Asli Zgün-Koca and Ilhan En (2006), they require time and opportunities to develop their own content-based understanding as well as their own awareness of the most effective ways to engage children in that particular content.

The Technological Pedagogical Content Knowledge (TPCK) framework offers a model that outlines teachers' learning complexity. Teaching with and about new technologies, in fact, requires content, pedagogy, and technology knowledge (Koehler and Mishra, 2006). Moreover, teachers' knowledge encompasses not only the content but also the capacity to elaborate on that content in order to share it with the students (Schulman, 1986). Consequently, the objective of an effective professional learning programme is not to tell teachers what to do, but rather enable them to develop the knowledge and the confidence needed to create learning opportunities for their students (Schulman, 1986, as quoted by Koehler and Mishra, 2006), as their role is fundamental. This is because being an expert in the field of AI does not necessarily mean having the skills to educate students (Bransford, Brown and Cocking, 2000). Recent examples of learning programmes for teachers on AI can be drawn from both academic (Vazhayil *et al.*, 2019) and non-academic sources (European Schoolnet, 2021). On one side, teachers are the learners with their own prior knowledge, ideas and beliefs on the subject (Asli Özgün-Koca and Ilhan Şen, 2006). On the other hand, they need equal support and guidance in exploring the pedagogy of teaching AI (Tedre *et al.*, 2021). Therefore, research claims approaches, methods, and frameworks to guide educators when it comes to teaching AI to students (Kahn and Winters, 2021).

Constructionist pedagogy in AI is promoted by research and could be beneficial both for teachers and students as both are learners (Kahn and Winters, 2021). Constructionism sees learners as active creators of their knowledge and illustrates the importance of constructing and creating "objects to think with" (physical and digital) (Papert, 1980). Therefore, teacher learning programmes should engage teachers in activities that use technology as a tool to develop learning and understanding, while also exploring the potentialities and limitations of the technology itself (Butler and Leahy, 2021). Furthermore, the research describes how hands-on teacher professional learning programmes on AI could positively engage teachers, empowering them to introduce AI literacy in school (Vazhayil et al., 2019). More recent research states that designing an AI curriculum with teachers which can then be integrated into K-12 subjects, is considered to be more effective when compared to just delivering pre-made resources designed by others i.e. researchers or experts (Brummelen and Lin, 2020). Therefore, teachers should be involved in co-creating learning opportunities for students (Dolan, 2008) to promote a form of more inclusive and impactful STEM (Science Technology Engineering Mathematics) engagement (Severance *et al.*, 2016).

The literature has highlighted how Design-Based Learning could successfully lead learners to develop their knowledge of AI thanks to its iterative, creative, and collaborative process (Tedre *et al.*, 2021). Creativity is an expression of learning and understanding, as represented in Bloom's Taxonomy where researchers added creativity at the top of the learning pyramid in 2001 (Krathwohl, 2002). For that reason, designing with teachers should also represent a method that enables them to develop their own skills and competencies in AI.

This phase of the research is PHASE 3. In this iteration, I designed and led a learning programme for teachers underpinned by TPCK and based on constructionist learning principles and design. It was ideated as an opportunity for teachers to develop their own knowledge on AI and as an opportunity for the researcher to co-create with teachers' resources for children on AI integrated with other subjects. The programme consisted of an online introduction and a face-to-face design session on DCU Campus.

The design of the learning programme was underpinned by the guidelines on AI for K-12 by Zhou et al. (2020). As stated by Bransford et al. in 2019, *"Successful programs involve teachers in learning activities that are similar to ones that they will use with their students"*. The guidelines I implemented to improve the teachers' programme on AI are listed in Table 28, together with a brief overview of how I addressed them.

The professional learning programme developed consisted of three introductory 2 hours-long online sessions, and one day-long face-to-face design session at our university. The participants were a small group of 6 teachers from the Irish context with different backgrounds and education.

Guidelines (Zhou, Van Brummelen and Lin, 2020)	**Implementation**
Introduce comprehensive definitions of AI, be more explicit about AI's capabilities and limitations, multidisciplinary, and embed ethical discussion [6.1]	I added a space to talk about AI for good and Minecraft Education activity on Ai for good related to fire prevention, to balance the negative impact of the technology deeply covered through activities like Moral Machine
Data science skills: Collect and use concrete data [6.2.1]	I added an introduction on the data cycle
Learning through teaching an agent [6.2.2]	I kept the activity on the simulated smart robot
Gamification [6.2.3]	With teachers we tried face-to-face bingo and games on machine reasoning
The need to scaffold if there is no background in computer science [6.3]	Self-directed challenges on the design of a smart robot were written for teachers with no need of coding or computational thinking skills
Support iteration, trial, and error providing feedback [6.3.2]	Introducing AI and data key ideas multiple times during different sessions
Involve teachers as designers [6.4.1]	During the face-to-face design sessions teachers participate as designers
Equitable, diverse and inclusive AI education [6.5]	The activity on the smart robot is an example of an inclusive application of AI. Moreover, one of the teachers was a special education class teacher and one was a learning support teacher so there was a discussion on how AI activities could be inclusive.
Integrate AI to other curriculum subjects [6.6]	The whole design session was focused on creating AI activities integrated with the standard curriculum

Table 28 Guidelines and their implementation in the learning programme developed

There were 4 associates and 2 advisors from PDST (Professional Development Service for teachers) who voluntary took part in the programme. The PDST associates are full time classroom teachers who are released for a designated number of days per year to support other teachers in nominated schools to embed the use of digital technologies into their classroom practice. PDST advisors are teachers who contribute to the planning, designing, scheduling, facilitating, monitoring, and reviewing professional development programmes. Of the 4 teachers, one was a 6th class teacher, one was a special education class teacher, one was a learning support teacher, and one was a home liaison teacher. From a pedagogical point of view this programme is based on Constructionist learning principles [PE1] and Design-Based Learning [PE2]. The overarching themes of the programme were AI and Data science. Therefore, the content was organised into 5 macro topics: Artificial Intelligence (AI), Machine Learning (ML), Data, Ethics, Pedagogy, as shown in Fig. 86. The macro themes were introduced slowly as they were interconnected and were revisited multiple times as teachers built their knowledge.

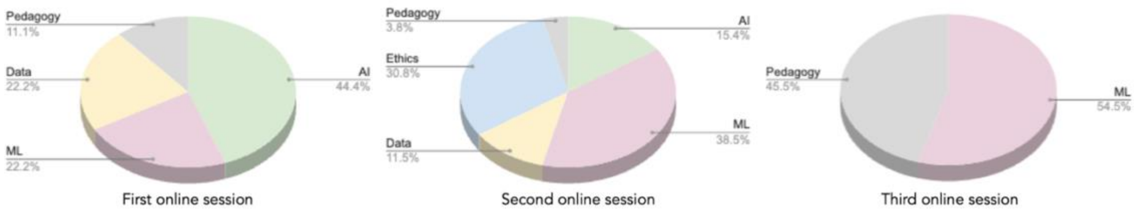


Fig. 86 Macro-topic coverage, in synchronous online sessions, in terms of the duration of the activities

In particular, the AI4K12 framework was acknowledged (Touretzky et al., 2019) [BI 1-5]. While it is considered to be a framework for student-learning it is thought to be a valid reference point for teacher learning, empowering teachers to learn as students (Bransford, Brown and Cocking, 2000). I found it appropriate to expand AI key ideas referencing AI competencies (Long and Magerko, 2020) [C1-17]. These are listed in Table 29 AI key ideas and concepts covered over the three online sessions. Finally, it was paramount to highlight to teachers the importance of developing AI knowledge first of all as citizens themselves (Floridi *et al.*, 2018) [P1] and in their role in promoting AI awareness among students both from a technical perspective but most importantly from an ethical perspective (UNICEF, 2020) [P2].

KEY IDEAS AND COMPETENCIES			1st session	2nd session	3rd session
AI big ideas for K-12	BI1	Perception	X	X	
	BI2	Representation and reasoning	X		
	BI3	Learning	X		X
	BI4	Natural interaction			X
	BI5	Societal impact	X	X	X
AI literacy and competencies	C1	Recognizing AI	X	X	
	C2	Understanding Intelligence	X		
	C3	Interdisciplinarity		X	X
	C4	General vs. Narrow	X		
	C5	AI's Strengths & Weaknesses	X	X	
	C6	Imagine Future AI		X	
	C7	Representations	X		
	C8	Decision-Making	X		
	C9	ML Steps	X		
	C10	Human Role in AI	X		X
	C11	Data Literacy	X		
	C12	Learning from Data		X	X
	C13	Critically Interpreting Data	X		
	C14	Action & Reaction		X	
	C15	Sensors	X		
	C16	Ethics		X	
	C17	Programmability			X
Pedagogy	PE1	Constructionist learning principles	X		
	PE2	Design-Based Learning			X
Purpose	P1	AI awareness	X	X	X
	P2	Teacher role	X	X	X

Table 29 AI key ideas and concepts covered over the three online sessions

The technology chosen for this programme was in line with constructionist principles (Kahn and Winters, 2021) allowing "*tinkering with machine learning*" (Vartiainen, Tedre and Valtonen, 2020). Machine learning for kids (Lane, 2022), Teachable machine (Google, 2022) enable teachers to design simple machine learning models. Scratch platform (MIT media lab, 2022) was used to enhance the coding with AI. Lastly, Minecraft Education was useful to engage teachers in an interactive activity of an application of AI for good (bush fire prevention) and

Moral Machine (MIT, 2022) to encourage discussion and reflection on one of the ethical dilemmas related to AI.

First online session

FIRST ONLINE SESSION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
Pedagogy	Introduction: what, how, why of the programme	Lecture with slides	P1, P2
AI	Introduction on AI as a technology	Video and slides	BI5, C1, C2, C4, C5
AI	Machine reasoning and decision tree	Interactive activity	BI2, C2, C7, C8, PE1
ML	Machine Learning and Teachable Machine	Interactive activity	BI1, BI3, C9, C10, C15, PE1
Data	Data science introduction	Video and slides	C11, C13

Table 30 First online session macro topic mapping

In our first online session the overall purpose of the programme was explained. The first activity of the session was an ice-breaker. Teachers were asked to start drawing a mind map titled “Artificial Intelligence”. This activity revealed the participants’ existing preconceptions, ideas and reflections on AI. The “draw-and-write” technique is very helpful in gathering data and allows participants to express themselves (Kara, 2012). AI was introduced as a technology (i.e., what AI is right now and what it could be in the future). Both slides and explanatory videos were used.

To encourage reflection on AI systems in our daily lives, teachers were engaged in an “AI or not AI” game inspired by an MIT programme for middle school (Lee *et al.*, 2021). The game allowed participants to discuss the current uses of AI. The researcher then introduced both the concepts of machine learning and machine reasoning. In particular, teachers tried out an unplugged exercise on a decision tree to correctly classify monkeys in a natural park (Lindner, Seegerer and R Romeike, 2019).

After the unplugged activity teachers were led to tinker with Teachable Machine. Teachers had time to try the autonomous software and familiarise themselves with the machine learning workflow. The activity was strategically chosen also to demonstrate the relationship between AI and data as a hook to introduce the macro topic – data science. Specifically, what data is, what is the data detective cycle (Leavy, Hourigan and MacMahon, 2012), and what data can capture.

Second online session

SECOND ONLINE SESSION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
AI	Expert on AI application for school History of AI and its dependence on data	Lecture with slides, interactive timeline, and video	C1, C5
Data	Data clustering and privacy	Lecture with slides	BI5, C12
Ethics	BIAS implication and GDPR	Video	BI5, C6, C16
Ethics	Moral dilemmas related to autonomous machines with Moral Machine	Interactive activity	C14, C16
Pedagogy	Teacher role and critical thinking	Lecture with slides	P1, P2
ML	AI for good: Minecraft Education module on AI and drones for bush fire prevention	Interactive activity (coding)	B1, C3

Table 31 Second online session macro topic mapping

The second online session was mainly focused on data and ethics. After a warmup and a brief exchange of thoughts around takeaways from previous sessions, teachers played with an interactive AI timeline to learn more about AI history (Table 31). Discussing why even though AI is not a new technology, there is currently such an increasing interest in it. This led to a discussion on the strong relationship between AI and data and how the availability of data and computing power to handle these big datasets has changed over time. The session then continued on data. Teachers were involved in an interactive digital work of art on data related to emotions (Levenson, 2019). Bias concept and implication was then introduced with an explanatory video. Finally, teachers were asked to try Moral Machine and reflect on ethical dilemmas related to intelligent machines. The researcher then gave a brief introduction to our rights in terms of data privacy as European Citizens. After the break, the session continued with One Hour of Code Activity in Minecraft Education. It is a module that consists of self-directed challenges with building blocks in Minecraft world. Teachers had to code a robot to help prevent bushfires and collaborate with firefighters. It represented an example of AI for good, an opportunity to re-think machine learning workflow and see where AI technology stands in complex problem solutions.

Third online session

THIRD ONLINE SESSION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
Pedagogy	Design cycle	Lecture with slides	PE2
ML	Design of an inclusive smart toy (with Machine Learning for Kids and Scratch)	Practical activity	BI3, BI4, BI5, C10, C12, C17, C3
Pedagogy	Design based learning	Lecture with slides	PE2
Pedagogy	Teachers' role as experts of their class	Discussion	P1, P2

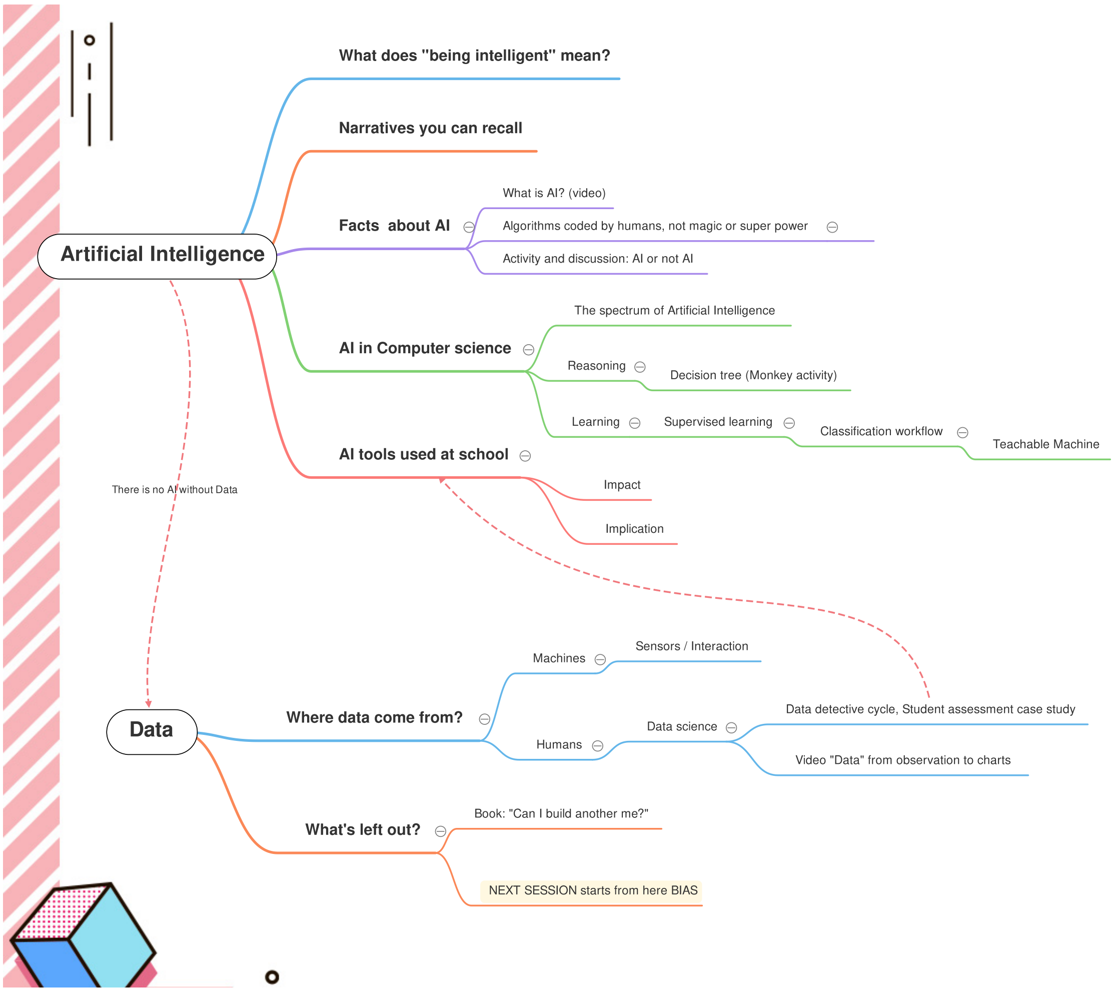
Table 32 Third online session macro topic mapping

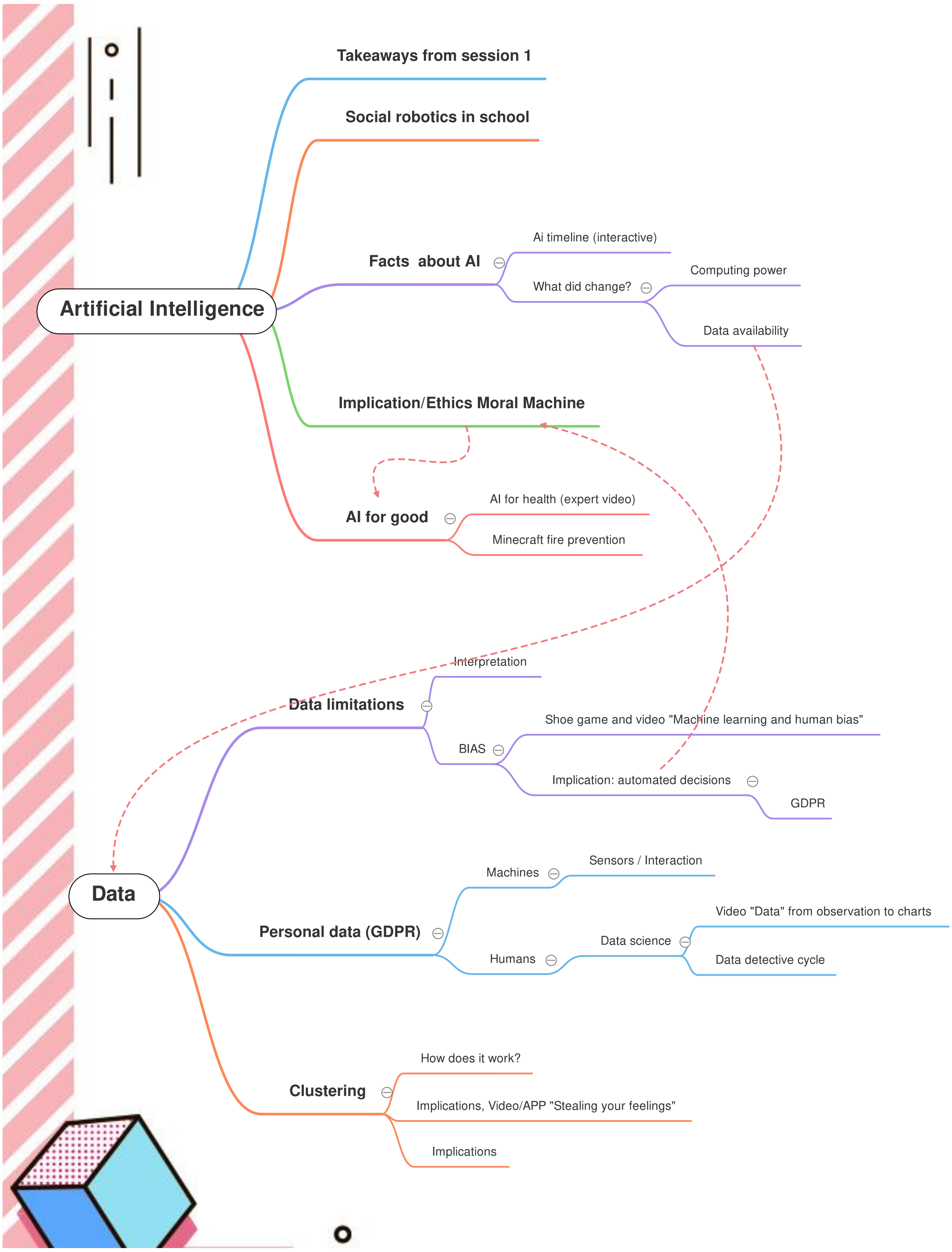
The third online session was mainly focused on a design challenge to enable teachers to become familiar with Machine Learning for Kids and its integration with Scratch (see Table 32). Teachers followed a series of self-directed challenges to create a smart inclusive toy. They first worked in Scratch and then with Machine Learning for Kids. The aim was to design a toy that could respond to text commands, and which was inclusive for children with speech-related disabilities. In Scratch, teachers created a character that represented the simulation of the toy/robot. However, with Scratch blocks, the toy could be commanded only with specific words, and typing errors or synonyms do not work. Therefore, teachers could train a model in Machine Learning for kids to overcome the limitation of the programme. Once back in Scratch teachers integrated the machine learning model in their programme to enhance their coding. In his way they created a smart inclusive toy that can respond to typed commands. With this activity, participants were involved in a constructionist approach to learning about AI big ideas 3, 4, and 5: how machines learn, how AI can have a positive impact on our society, and how we could programme artificial systems to better interact with humans.

Face-to-face session

After the three synchronous online sessions, the group of teachers came for a one day-long face-to-face session in university where they were asked to co-design AI activities for their students which could be integrated with other subjects. The day started with a brief introductory video on Explainable AI. The teachers then engaged with two unplugged activities that worked as ice breakers and as a way to review key ideas learnt so far. In particular, all together we tried the dataset-prediction Bingo (Hao, 2020). I read a list of data sets and teachers tried to fill tiles, linking datasets with predictions of specific AI systems. Then in pairs teachers experimented with the classification unplugged game (Lindner, Seegerer and R Romeike, 2019) where one participant studied a set of images, represented them on paper with simple shapes, and created a table with characteristics. For example, a cat is drawn as two triangles and one circle. Using a small table then the second teacher should classify a new image checking the main characteristics. For this second game, printed images of cats, cars, houses, and a small table were prepared in advance. The second part of the day was dedicated to designing activities together on AI and integrating them with other subjects. As the reference age group, students aged 9-12 years were addressed. The ideation process started with a brainstorming of possible topics that could be taught with AI. To promote creativity, I asked participants to stand up and use sticky notes on a desk. I tried to encourage free thinking with no constraints. I asked for a second run of ideas to enable teachers to think about other subjects that were not already covered. Together we grouped similar topics to have a better view of the ideas. Teachers, in pairs, chose three topics to develop in-depth. I tried to ask each pair for three activities: one unplugged, one with a Teachable machine, and one suitable with Machine learning for a kids platform. I provided teachers with a simple template as support asking for the title of the activity, duration, link to curriculum topics of a standard subject, link to AI4K12 big ideas, and the description of the activity (i.e. warm-up, main activity, wrap-up). Finally, at the end of the afternoon, teachers shared their ideas and reflections, and we discussed the whole professional learning programme in a focus-group to conclude the day and the programme.

See below mind maps to review and scaffold programme leading.





Artificial Intelligence
Takeaways from session 1
Social robotics in school
Facts about AI
Ai timeline (interactive)
What did change?
Computing power
Data availability
Implication/Ethics Moral Machine
AI for good
AI for health (expert video)
Minecraft fire prevention
Data
Data limitations
Interpretation
BIAS
Shoe game and video "Machine learning and human bias"
Implication: automated decisions
GDPR
Personal data (GDPR)
Machines
Sensors / Interaction
Humans
Data science
Video "Data" from observation to charts
Data detective cycle
Clustering
How does it work?
Implications, Video/APP "Stealing your feelings"
Implications

Appendix N - Phase 4 children programme design

Guidelines on how to better design learning programme for young students on AI suggest introducing both AI power and limitations, from a technical and ethical perspective, supporting trail-and-error and reflections (Zhou, Van Brummelen and Lin, 2020). It is also recommended to focus programmes on active learning, to include unplugged activities and projects students can work on and share (Williams *et al.*, 2022). Furthermore, learning situations and activities should be designed and developed connected to/with a meaningful context for the learner i.e., possible real-world problems that students can resonate with (Butler, 2007). Engaging children to design AI models that could potentially help others, pedagogically represents a valuable opportunity to deepen their understanding. A Design-Based Learning (DBL) approach was introduced for the last part of the programme as thanks to its iterative and creative process facilitated children's AI understanding while at the same time, encouraging collaboration and critical thinking (often referred to as "21-st century skills") (Tedre *et al.*, 2021).

The programme for children on AI tested in school was in its first draft and was created from the lesson plans co-designed with teachers in PHASE 3, during their learning development programme. As research suggests teachers should be engaged as experts and designers (Zhou, Van Brummelen and Lin, 2020) of learning activities. Moreover, collaborating with teachers is an advantage to overcoming the challenge of integrating AI into the standard curriculum (Tedre *et al.*, 2021).

After the co-design session with teachers, I worked on creating a prototype of a learning programme for children on AI, described in Table 33. The programme is based on constructionist learning principles and DBL as a way to actively engage children (9-12 years old students) while supporting them in their AI learning journey. The first three sessions consisted of activities on AI integrated with other subjects underpinned by constructionist learning principles. The aim of these activities was to introduce AI and machine learning to children step by step with low threshold, acknowledging students' different backgrounds and competencies, minding the digital gap (Williams *et al.*, 2022). The last three sessions were focused on designing AI for good in the health context. Vartiainen et al., 2021 suggested that the pedagogy of designing machine learning projects with young students includes contextualising machine learning (sessions 1, 2, 3), building ideas and skills (sessions 4 and 5), prototyping (session 5), sharing and reflecting (session 6). The duration of each session was one hour.

n.	SESSION	TOOL	APPROACH
1	Unplugged introduction "Farmer robot"	Pen and paper	Constructionism
2	Let's train an AI model	Teachable machine	Constructionism
3	Machine Learning with blocks	Machine Learning for	Constructionism
4	Let's design with AI: RESEARCH Define the problem to solve	Web Pen and paper	Design Based Learning
5	Concept PROTOTYPE	Machine Learning for Kids	Design Based Learning
6	TEST/Improve SHARE	Machine Learning for Kids	Design Based Learning

Table 33 Learning programme outline

The first session was designed to be an unplugged introduction to AI, titled "Farmer robot". For this activity children should create a decision tree to classify vegetables. Specifically, children received cards representing different-looking carrots and other vegetables and had to design using pen and paper a decision tree that could discern "carrots" from "not carrots". The second activity was designed to be a hands-on introduction to the machine learning workflow using Google Teachable Machine (Google, 2022). Children trained different models to classify 2D shapes i.e., circles and squares. During the third session children used Machine Learning for Kids (Lane, 2022). With this platform it was possible to train a machine learning model and then implement it in a Scratch-like platform with coding building blocks (MIT media lab, 2022). Children trained models using different datasets e.g., animal sounds.

The following three learning experiences aim to engage students in designing a prototype in groups focusing on AI for good to help to solve potential real problems. It was decided to focus on problems related to health and well-being. Children went through the entire design process from research to finding a problem to solve and from brainstorming ideas to prototyping their solutions using Machine Learning for Kids, Fig. 59. Web and video links were provided by teachers to prompt the research phase. Design journal templates were provided to each group of students to guide them through the design process.

Appendix O - Phase 6 teacher programme design

This professional learning programme was a one day face-to-face course, teacher-centred programme framed by TPCK and underpinned by constructionist learning principles and design. It represented a condensed and improved version of the learning programme piloted with pre-service teachers in PHASE 2 and iterated with teachers in PHASE 3. Therefore, the course was based, from a content point of view, on AI4K12 framework (Touretzky et al., 2019) [BI 1-5] that was expanded with AI competencies (Long and Magerko, 2020) [C1-17]. The course aimed to highlight to teachers, the importance of developing AI knowledge first of all as citizens themselves (Floridi et al., 2018) [P1] and secondly, in their role in promoting AI awareness among students from a technical perspective but most importantly from an ethical perspective (UNICEF, 2020) [P2]. From a pedagogical point of view this programme was based on Constructionist learning principles [PE1] and Design-Based Learning [PE2]. The overarching themes of the programme were AI and Data science. The content was organised into 5 macro topics: Artificial Intelligence (AI), Machine Learning (ML), Data, Ethics, Pedagogy. Ideas and competencies are listed in Table 34.

The programme was divided into three sections: introduction, middle and final. During each section, the advisors engaged with teachers using slides, video, and hands-on activities. The tools and activities used are the same tested in PHASE 2 and PHASE 3. Macro topics and key ideas/competencies covered are detailed in Table 35. As support, the advisors used the pre-print version of the handbook and the mock-up of the website with links to videos. Both Advisors

A and B led the course. They organised the parts they would each cover and when one advisor was leading the course, the other facilitated the work in the room supporting participants.

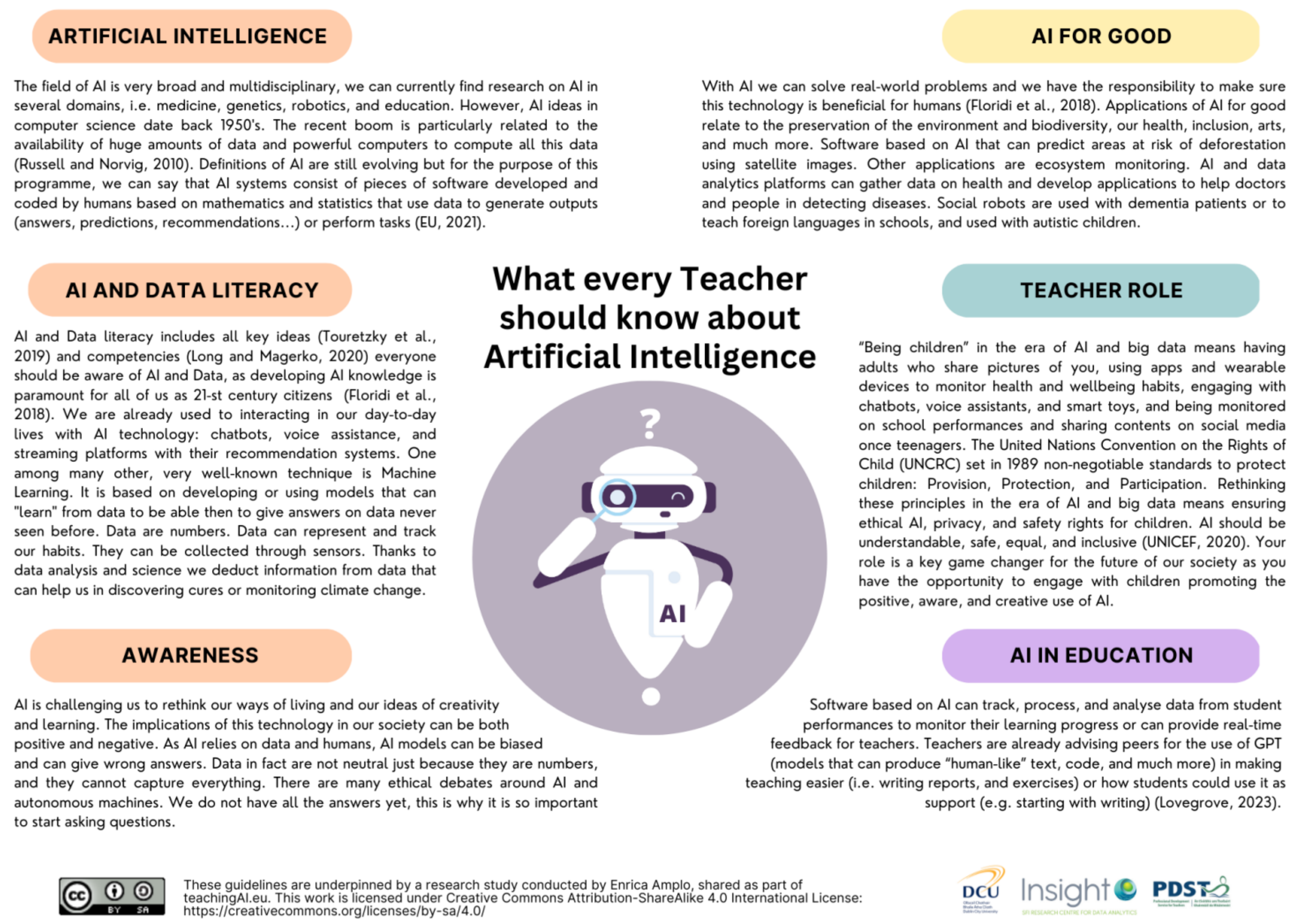
KEY IDEAS AND COMPETENCIES			Introduction	Middle section	Final section
AI big ideas for K-12	BI1	Perception	X		
	BI2	Representation	X		
	BI3	Learning	X		X
	BI4	Natural interaction			X
	BI5	Societal impact	X	X	X
AI literacy and competencies	C1	Recognizing AI	X		
	C2	Understanding	X		
	C3	Interdisciplinarity			X
	C4	General vs.	X		
	C5	AI's Strengths &	X	X	
	C6	Imagine Future AI		X	
	C7	Representations	X		
	C8	Decision-Making	X		
	C9	ML Steps	X		
	C10	Human Role in AI	X		X
	C11	Data Literacy		X	
	C12	Learning from		X	X
	C13	Critically		X	
	C14	Action & Reaction			
	C15	Sensors	X		
	C16	Ethics		X	
	C17	Programmability			X
Pedagogy	PE1	Constructionist learning principles	X		X
	PE2	Design-Based			X
Purpose	P1	AI awareness	X	X	X
	P2	Teacher role	X	X	X

Table 34 Programme framework

INTRODUCTION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
Pedagogy	Introduction: what, how, why of the programme	Lecture with slides	P1, P2
AI	Introduction on AI as a technology “draw AI” and Moral machine activities	Video and slides Discussion Interactive activity	BI5, C1, C2, C4, C5
AI	Machine reasoning and decision tree activity from the handbook	Interactive activity	BI2, C2, C7, C8, PE1
ML	Machine Learning and Teachable Machine activity	Interactive activity	BI1, BI3, C9, C10, C15, PE1
MIDDLE SECTION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
Data	Data science introduction	Video and slides Discussion	C11, C13
Data	Data clustering and privacy	Video and slides	BI5, C12
Ethics	BIAS implication and GDPR	Video	BI5, C6, C16
Pedagogy	Teacher role and critical thinking AI in education	Video and slides	P1, P2, C5, C6
FINAL SECTION			
Macro topics	**Activity**	**Approach**	**Key ideas/competencies**
ML	Design of an inclusive smart toy (with Machine Learning for Kids and Scratch) from the handbook	Practical activity	BI3, BI4, BI5, C3, C10, C12, C14, C17
Pedagogy	Design a new activity with the experimented tools related to a curricular subject topic *[not covered as expected – there was ideation and brainstorming]*	Practical activity	PE1, PE2, P1, P2

Table 35 Programme content outline

Appendix P – What every teacher should know about AI



What every Teacher should know about Artificial Intelligence

ARTIFICIAL INTELLIGENCE

The field of AI is very broad and multidisciplinary, we can currently find research on AI in several domains, i.e. medicine, genetics, robotics, and education. However, AI ideas in computer science date back 1950's. The recent boom is particularly related to the availability of huge amounts of data and powerful computers to compute all this data (Russell and Norvig, 2010). Definitions of AI are still evolving but for the purpose of this programme, we can say that AI systems consist of pieces of software developed and coded by humans based on mathematics and statistics that use data to generate outputs (answers, predictions, recommendations…) or perform tasks (EU, 2021).

AI FOR GOOD

With AI we can solve real-world problems and we have the responsibility to make sure this technology is beneficial for humans (Floridi et al., 2018). Applications of AI for good relate to the preservation of the environment and biodiversity, our health, inclusion, arts, and much more. Software based on AI that can predict areas at risk of deforestation using satellite images. Other applications are ecosystem monitoring. AI and data analytics platforms can gather data on health and develop applications to help doctors and people in detecting diseases. Social robots are used with dementia patients or to teach foreign languages in schools, and used with autistic children.

AI AND DATA LITERACY

AI and Data literacy includes all key ideas (Touretzky et al., 2019) and competencies (Long and Magerko, 2020) everyone should be aware of AI and Data, as developing AI knowledge is paramount for all of us as 21-st century citizens (Floridi et al., 2018). We are already used to interacting in our day-to-day lives with AI technology: chatbots, voice assistance, and streaming platforms with their recommendation systems. One among many other, very well-known technique is Machine Learning. It is based on developing or using models that can "learn" from data to be able then to give answers on data never seen before. Data are numbers. Data can represent and track our habits. They can be collected through sensors. Thanks to data analysis and science we deduct information from data that can help us in discovering cures or monitoring climate change.

TEACHER ROLE

"Being children" in the era of AI and big data means having adults who share pictures of you, using apps and wearable devices to monitor health and wellbeing habits, engaging with chatbots, voice assistants, and smart toys, and being monitored on school performances and sharing contents on social media once teenagers. The United Nations Convention on the Rights of Child (UNCRC) set in 1989 non-negotiable standards to protect children: Provision, Protection, and Participation. Rethinking these principles in the era of AI and big data means ensuring ethical AI, privacy, and safety rights for children. AI should be understandable, safe, equal, and inclusive (UNICEF, 2020). Your role is a key game changer for the future of our society as you have the opportunity to engage with children promoting the positive, aware, and creative use of AI.

AWARENESS

AI is challenging us to rethink our ways of living and our ideas of creativity and learning. The implications of this technology in our society can be both positive and negative. As AI relies on data and humans, AI models can be biased and can give wrong answers. Data in fact are not neutral just because they are numbers, and they cannot capture everything. There are many ethical debates around AI and autonomous machines. We do not have all the answers yet, this is why it is so important to start asking questions.

AI IN EDUCATION

Software based on AI can track, process, and analyse data from student performances to monitor their learning progress or can provide real-time feedback for teachers. Teachers are already advising peers for the use of GPT (models that can produce "human-like" text, code, and much more) in making teaching easier (i.e. writing reports, and exercises) or how students could use it as support (e.g. starting with writing) (Lovegrove, 2023).

Fig. 87 What every teacher should know about AI