PROJECT DELIVERABLE – PUBLIC

O1: A LEARNML PEDAGOGICAL FRAMEWORK DEVELOPMENT

18 June 2020

This project has received funding from the European Union's Erasmus + Programme Key Action 2: Cooperation for Innovation and the Exchange of Good Practices KA201: Strategic Partnerships for School Education Under Grant Agreement Number 2019-1-MT01-KA201-051220. This document reflects only the authors' view. The Research Executive Agency (REA) and the European Commission are not responsible for any use that may be made of the information it contains.

PROJECT FACT SHEET

Acronym
LearnML
Full Title
Key Action 2: Cooperation for Innovation and the Exchange of Good Practices KA201: Strategic Partnerships for School Education
Programme
Erasmus+
Type of Action
Key Action 2: Cooperation for Innovation and the Exchange of Good Practices KA201: Strategic Partnerships for School Education
Grant Agreement
No 2019-1-MT01-KA201-051220
Duration
36 months (1/9/2019 – 31/8/2022)
Grant Amount
€ 449.070
Overview
LearnML project transfers the notion of AI literacy to primary and secondary education and aims to introduce students to the core principles of AI and ML through a uniquely designed game-based educational toolbox. Students will also learn how disinformation and biases may be intertwined with training ML algorithms and how the response of machine learning may be interpreted in real life problems. Specifically, the core objectives of the project are to:

i) Design an Artificial Intelligence (AI) and Machine Learning (ML) framework within the primary and secondary educational context in Malta, Greece and Norway.

ii) Implement a game-based learning toolbox that realises Machine Learning training scenarios (games and game authoring tools).

iii) Produce relevant and effective material for course development based on gameful machine learning activities.

iv) Educate teachers through games and game authoring tools in an engaging manner to train students to reflect creatively on AI ethics, data biases and societal implications.

v) Widely involve students in machine learning training courses that include playful game-based learning activities so that they become AI literate but most importantly responsible citizens of Europe with regards to the ethics and threats of Artificial Intelligence

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DOCUMENT IDENTITY

Deliverable code number	O1
Deliverable title	A LearnML pedagogical framework development
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Submission date	18.06.2020
Dissemination level	Public

DOCUMENT HISTORY

Version	Date	Handling partners	Description
0.1	11.05.2020	NTNU	Initial draft
1.0	19.05.2020	NTNU	Revised draft with input from partners
2.0	10.06.2020	NTNU	Advanced draft
3.0	16.06.2020	NTNU	Revised draft with input from partners
Final	18.06.2020	UM	Final draft

Executive Summary

The key objective of IO1 is to examine existing educational practices, needs, requirements, beliefs and attitudes, potential impact regarding computational thinking, digital literacy, game-based learning, AI, ML, and relevant ethics concerns and values, gender and culture bias, in primary and secondary education.

Specifically, the LearnML framework will:

- Define guidelines for teaching and learning activities with references to existing and newly created teaching opportunities, that are going to be implemented in O2 (Educational Toolbox) and O3 (Teacher Guidebook).
- Specify requirements for the games to be developed in O2.
- Identify specific learning outcomes to be implemented in O2 and O3. Identify educational scenarios and educational objectives in relation to ethics, culture, social issues, etc. (for O2 and O3)
- Define an evaluation method for testing game-based learning, AI, and ML concepts (for O5) (e.g. learning objectives, skills and competences).
- Examine existing formal and non-formal education practices across Europe for supporting computational thinking, digital literacy, AI and ML concepts for students particularly in relation to game-based learning (but limited to game-based learning, e.g. through coding)

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1. Introduction

During the last few years, digital games have become increasingly popular in Computer Science (CS) and Information Technology (IT) education (Harteveld et al., 2014; Kordaki & Gousiou, 2016). Digital games have been a popular approach of several endeavors to enhance CS education. At the K-12 schools, there are programs that engage students to play games that include tasks and problems that must be solved in order to progress (Vahldick et al., 2014), or encourage students to develop games using visual and block-based programming environments such as Alice (Cooper, 2010) or Scratch (Resnick et al., 2009). However, most of the game-based learning efforts focus on the craft and practice of programming, rather than higher-level CS concepts (Garneli et al., 2015).

In general, students are positive in game-related projects or game-based learning in course curriculum or informal learning (Vahldick et al., 2014; Wallace et al., 2010). Moreover, such approaches have a positive impact on students' learning and motivation (Papastergiou, 2009). Leutenegger (2006) demonstrates how students regularly exceed project requirements in his game-base course, while the norm is that students just meet the specified requirements. Thus, in CS education literature, game-based approach seems to provide inherent benefits and justifies the intense utilization of such practices in the CS education discipline (Vihavainen et al., 2014).

Our motivation for this work lies on the natural connection between games and AI methods. In particular, the emphasis of the introduction of game elements in CS education has focused on dedicated game design and development courses as well as on introductory courses (e.g., CS0, CS1, CS2), with a great success (Vahldick et al., 2014; Wallace et al., 2010). In addition, games and puzzles have a long history as interesting problem domains for AI research (Wallace et al., 2010). Moreover, games have long been seen as the perfect test-bed for AI methods (Yannakakis, & Togelius, 2018), therefore the confluence of game-elements and the AI domain is meaningful and helpful for students to develop an interest and competence in the increasingly important field of AI.

Keeping the aforementioned benefits and challenges in mind, the goal is to present an overview of recent research into games to support AI and ML education. AI is expected to play an even more pervasive and critical role in education. In 2018, UNICEF launched the “Generation AI” initiative (https://www.unicef.org/innovation/GenerationAI) aiming to address and discuss the challenges and opportunities emerging in the face of AI advancements while limiting the risks and safeguarding the rights of children. A recent working paper by UNESCO (Division for Policies and Lifelong Learning Systems, UNESCO’s Education, 2019) discusses the design of learning environments and learning management systems integrating AI, and the potential and challenges of AI for all education stakeholders such as students, teachers, administrators, and policy makers. Social and ethical concerns are raised, and the importance of the involvement of all stakeholders at the early stages of design rather than as mere beneficiaries or users is proposed. This deliverable is situated in this field, the provision of tools for empowering students and educators to understand and become active participants in the design of AI and ML systems, and presents a general review of what and how game elements have been used to support AI and ML pre-college education. Although the confluence of game elements and AI/ML pre-college education is a relatively young area, enough work has already been done to conduct a review and provide insights.

2. Background

AI and ML is a rapidly developing field, attracting an increasing number of researchers and learners in the past few years. In response to this need, efforts in the USA, China, and many other countries are developed to support AI education in K–12 schools (Touretzky et al., 2019a). In addition, during the last years new curricula and online resources have been developed, focusing on pre-college students, and professional development for K–12 teachers to learn the basics of AI (Touretzky et al., 2019a). In 2018, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) announced a joint initiative to develop national guidelines for supporting AI education in K-12 students. Moreover, initiatives such as AI for K-12 working group (AI4K12) and AI4All (http://ai-4-all.org/) were established to define what students should know and be able to do with AI, as well as develop national guidelines and collect resources (e.g., videos, demos, software, and activity descriptions) for AI education in the USA (Touretzky et al., 2019b).
During the last years, several software and hardware tools have been created to allow young students to engage with AI and ML. For example, Cognimates (http://cognimates.me/) offers a set of Scratch extensions to provide access to speech generation, speech recognition, text categorization, object recognition, and robot control Application Programming Interfaces (APIs). Kahn and Winters (2017) develop a similar set of extensions called eCraft2Learn (https://ecraft2learn.github.io/ai/). ML for Kids portal (https://machinelearningforkids.co.uk/) provides online demos for students to train classifiers using web apps or Scratch extensions. Google has also developed several software tools to support students to engage with AI concepts. For example, Google has developed the concept of "online AI experiment" (https://experiments.withgoogle.com/collection/ai), that allows young students to train visual classifiers (i.e., Teachable Machine) or see how a neural network tries to guess what you're drawing (i.e., QuickDraw). Another example is Google's "AI and You" kits that offer affordable Raspberry Pi Zero-based image and speech recognition (uses a neural network classifier). Another example that allows K-12 students to explore neural networks and backpropagation learning via an interactive graphical tool is TensorFlow Playground (https://playground.tensorflow.org). Therefore, during the last few years we have seen several initiatives resulting in software and hardware tools to support K-12 students to engage with AI and ML.

Despite the rapid development of AI/ML education, novices find it hard and obscure to learn the fundamentals, such as game theory, machine learning, decision trees, etc. During the 2014 Educational Advances in Artificial Intelligence (EAAI) conference, the 68% of the participants indicated games and puzzles as a topic they teach in their AI courses (Wollowski et al., 2016). In addition, Eaton et al., (2018) indicate that the introduction of agent-based models through games and puzzles allows instructors to introduce concepts for later exploration such as search, string-replacement-iteration, planning, machine learning, etc. It is therefore agreeable that games have long been seen as an ideal test-bed for understanding AI methods (Yannakakis, & Togelius, 2018).

Games (and game-based curricula) provide a widespread medium to support teaching and learning CS and IT (Vihavainen et al., 2014). Games have been used to improve several aspects in CS and IT education, for example the lack of diversity in STEM fields, including CS at both the university and K-12 levels (Horn et al., 2016). Games have also been used as a means to enhance student engagement and motivation (Wallace et al., 2010). Another example comes from Clarke and Noriega (2003) who developed a war strategy game with hooks for the addition of AI modules. Their results indicate that

students find AI much more interesting and accessible with examples and projects based on this game. Besides efforts to develop novel game-based curricula to enhance teaching and learning CS in the context of formal education, many efforts to reach younger students are done in informal contexts such as classroom visits, summer camps, and after-school programs (Vahldick et al., 2014).

In addition to several beneficial qualities of games, such as engagement, competition, collaboration that lead to greater student interest (Horn et al., 2016; Papastergiou, 2009). AI and ML, as a content, certainly can benefit from games (e.g., game engine that can be easily used or modified; Hartness, 2004). Moreover, Cook and Holder (2001) used a simple game to teach students about the need for internal representations of the world, natural language processing, look-ahead search, plan generation, and machine learning; demonstrating the power of games to support AI/ML education. Their students managed to significantly improve and modify the game to handle different problems.
In our point of view, ML and AI education, can significantly benefit by introducing to students the state-of-the-art algorithms, concepts and methods related to game playing, for example, game tree based search, reinforcement learning and neural networks. Such an approach has a tremendous potential to successfully introduce those concepts to pre-college students. Looking in the literature we can find several studies that exploited the intersection between games and AI/ML to form the basis for a dedicated course or a module of a course (Zhou et al., 2018; Li et al., 2019; Konen, 2019). In this work we provide a general review of games and software tools that can be used to support AI and ML pre-college education.

Based on this collection from the literature and together with workshops and interviews with school teachers and practitioners conducted in the participants' countries, we will provide a springboard to define the existing formal and non-formal education practices and guidelines for teaching and learning activities and identify learning outcomes and requirements for the games to be implemented in O2 and O3 of the project.

3. Methods

3.1 Methodology for the overview of games and software tools

The aim is to collect and summarize the various games and software tools that can be used to support AI and ML pre-college education exists. The selection phase determines the overall validity of the work, and thus it is important to define specific criteria. Games were eligible for inclusion if they were focusing on AI/ML education. To find those games, we searched in various libraries and search engines (Google) as well as scientific publications (e.g., Google Search, ACM Digital Library, IEEE Xplore, Science Direct, Google Scholar). The search string used during the search covers three main terms content ("AI Education", "ML Education", "CS Education") and the medium ("Game-Based Learning", "Games for Learning"). The combination resulted in 6 different search strings. Due to the high number of irrelevant papers (i.e., false positives) returned back using the search string "CS Education", the authors decided to narrow the search by combining it with the terms "AI" or "ML".

3.2 Workshops with various stakeholders

Each participating country conducted half-day workshops and interviews with teachers and practitioners (figure 1). These events serve a threefold purpose for the LearnML project. First, they will identify problems and challenges that are strongly relevant to the target groups as well as

pedagogical scenarios and game-based educational methods that were proven state-of-the-art interventions. Second, they will consist the core of schools and practitioners who will form the 'lead' schools/practitioners of the project, and train them to the LearnML educational aims and learning objectives throughout the project. These 'flagship' stakeholders will be the core drive for further development, analysis, validation and refinement on the remaining IOs. Third, they will assemble the key stakeholders for developing and implementing the research and assessment methodology.

Below (table 1) presents the main structure of the workshops followed in each country.

Table 1: Workshops' phases

Workshops' phases:	Topics for discussions among the participants
Phase 1	Introduction to the topic AL and ML, presentation of the tools to learn ML, AL, Coding and examples
Phase 2	*Current state, challenges, requirements, learning objectives*
Phase 3	*How can a leaning scenario be implemented?*

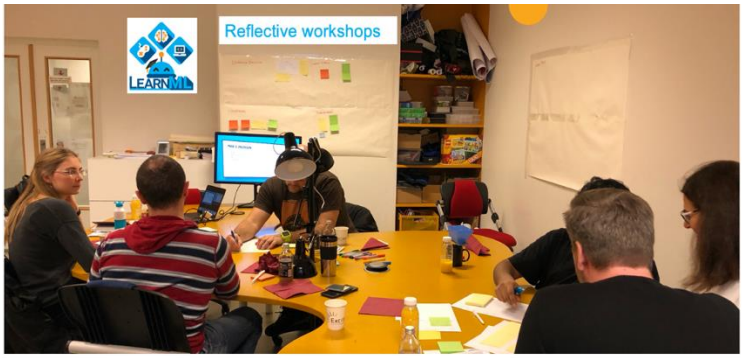
Workshops in Greece: The workshops were held with teachers, practitioners and students. Participation at the workshops was voluntary and took place after their school programme. Teachers were both primary and secondary level and they were mathematicians, philologists, IT teacher and physicists. Four workshops conducted in total, two with 22 teachers, one with 14 practitioners and one with 18 students.

Workshops in Malta (Science Center): The participants were 4 students 11 years old the Assistant Director Science Centre, the EO ICT, the EO Computing, the HoD Digital Literacy and HoD Computing.

Workshops in Malta (UM): There were 9 participants with various backgrounds (i.e. educators, students, academics, policy makers). Among the participants there were university students (mainly computer science), teachers, a student with his parent who was working in marketing, and a person working in health care

Workshops in Norway: 6 participants with various backgrounds in the workshop (i.e teachers, undergraduate and graduate students, researchers).

Figure 1: Reflective workshops in Norway (left) and Greece (right)



Results from the review of the literature:

Finally, after implementing the aforementioned search strategy, we reviewed the outcomes of the search and identified 17 games/projects. Then, we reviewed those games and projects and summarized their essential elements and focus below (table 2). These summaries allow us to consolidate the essence and the main focus of the games/projects and their connection with the AI/ML concepts.

Table 2: Summary of digital games for AI and ML education

Name of the Game	**Short Description**	**Reference**
Bug Brain	Bug Brain is a game where children can experiment with the neurons and nodes that make up a brain. They build a brain for a Lady Bug to help it feed and survive. Not specifically aiming at learning AI and ML, Bug Brain features rendered graphics, challenging puzzles and the opportunity to learn about neural networks (free).	http://www.biologic.com.au/bugbrain/
Human Resource Machine	Human Resource Machine is a puzzle game. Players are required to solve problems through programming. Concepts	http://tomorrowcorporation.com/humanresourcemachine

	relevant to AI such as automation and optimisation are introduced. In each level, players have to automate work by programming the employees of an office environment. (purchase required)	
7 Billion Humans	Following up on the "Human Resource Machine" game and developed by the same studio, players are required to solve puzzles by programming multiple agents (workers). Concepts such as parallel computing, debugging, and optimization. (purchase required)	https://tomorrowcorporation.com/7billionhumans
Machine Learning for Kids	Machine Learning for Kids introduces machine learning by providing hands-on experiences for training machine learning systems and building things with them. It provides an easy-to-use guided environment for training machine learning models to recognise text, numbers, images, or sounds. Machine Learning for Kids adds models to educational coding platforms Scratch and App Inventor, and helps children to create	https://machinelearningforkids.co.uk/

	projects and build games with the machine learning models they train (free).	
AI Machine Learning Education Tools	The platform (currently in beta) offers tools for teaching students the basic concepts of Machine Learning. It incorporates a number of Scratch extensions as a coding medium for the children, such as a chatobot extension, home automation, image recognition, classification, and teaching the computer how to play the Flappy Bird game, accompanied with lesson plans and materials for educators (free registration required).	https://www.ai4children.org/
While True: Learn()	This game aims to familiarise players with concepts and processes of Machine Learning. Players take up the role of a machine learning specialist who uses visual programming to complete the clients' projects. It includes elements such as neural networks, actual machine learning techniques, and machine learning related problems such as self driving cars. (purchase required)	https://luden.io/wtl/

ViPER	ViPER aims to teach concepts in machine learning to middle school students. By programming a robot to solve pathfinding problems, players learn how machines learn, and engage with concepts such as algorithms, testing and training phase, and identifying patterns in the data (for assessment of game design issues see also Parker & Becker, 2014) (purchase required)	https://wonderville.org/asset/ViPER
Minecraft. Hour of Code: AI for Good	The game integrates a coding interface with Minecraft. Players, by programming a robot to predict forest fires, are introduced to basic coding concepts and learn about artificial intelligence (AI) and its potential for protecting the environment. A lesson plan and supporting material for educators are also provided (free).	https://education.minecraft.net/hour-of-code
The Moral Machine	The players are asked to choose the lesser evil when facing an impending car crash. This platform is mainly situated in the field of ethical decision making. It aims to address the diversity of human perspectives in face of a	http://moralmachine.mit.edu/

	moral dilemma and the implications on machine intelligence designed to make similar moral decisions (e.g. self-driving cars) (free)	
PopBots (Preschool-Oriented Programming Platform)	The applications included in this platform aim to familiarise young children with main concepts and processes of AI such as programming, classification, training and testing datasets, through simple activities such as the training of models to recognise healthy and unhealthy food or different types of music. It also includes supporting material (e.g. lesson plans) for teachers (for more details and related study see also Williams et al., 2019).	https://www.media.mit.edu/projects/pop-kit/overview/
Universal Papersclips	Not quite a game for teaching AI concepts but rather for triggering discussion on the role and potential of AI in society. Based on the philosophical thought experiment "paperclip maximiser" about artificial intelligence design and machine ethics, this is a clicker game where the player takes up the role of an AI machine making	https://www.decisionproblem.com/paperclips/

	paperclips. After several upgrades such as the possibility to "interpret and understand human language" or buy "autonomous aerial brand ambassadors" the game ends when 100% of the universe is explored and all matter is turned to paperclips (web version free).	
Gladiabots: AI combat arena	A game not specifically aiming to teach AI to students but, as the designers describe, the players have to assemble a "perfect team of robots and set their AI strategy with the simple to use but satisfyingly deep visual AI editor". Players are introduced to the logic and structure of AI programming (purchase required).	https://gladiabots.com/
Tynker: Coding for Kids	Platform including applications and games, separated by age group, for children as young as 5. Children can create games through block programming, and share their artifacts (subscription required)	https://www.tynker.com/
Scratch Jr.	The younger version of Scratch, aiming at children ages 5-7. Children through a simple, visual, drag-and-	https://www.scratchjr.org/

	drop interface, create code, programme and share their own projects with the community (free, available for Android and iOS devices).	
Code.org	The platform aiming at children and educators, includes applications, games and courses for learning coding, creating new projects, sharing them with the community, as well as a curriculum and lesson plans for computer science education. Code.org also organizes the annual Hour of Code campaign engaging students in coding around the world (free).	https://code.org/
LightBot	LightBot is a puzzle game based on coding; aiming to teach programming logic to children as young as 4 and above. It is translated to multiple languages. Web (free), iOS and Android devices (purchase required) versions.	
Codespark Academy	A platform aiming at children 5-9 which includes games, puzzles and applications for learning coding and creating new games, as well as resources for	https://codespark.com/

	parents and educators. (subscription required)	

In the table above we summarize games or platforms for supporting AI/ML pre-college education. Many of them were focusing in the wider area of CS education with applications in AI/ML education as well. In particular, we identified only a small number of games, applications, and platforms specifically aiming at explicitly supporting AI and ML education to children and young people. Coding seems to be the main goal of most of the existing environments. However, environments aiming to enhance AI and ML pre-college education mainly address concepts such as training a model for image, text, or audio recognition (e.g. “Machine Learning for Kids” and “AI Machine Learning Education Tools”) and programming logic (e.g. “Minecraft. Hour of Code: AI for Good”, while games not aiming at formal children’s education address more abstract, ethical and social implications (e.g. “The Moral Machine”, “Universal Papersclips”).

When it comes to the age those environments are focusing, we found that they address all the range from kindergarten to high-school (K–12), with some of them addressing even younger ages (appropriate for 4 years old). In addition, there are also environments supporting parents and teachers to teach AI and ML to children (e.g., lesson plans such as the “Minecraft. Hour of Code: AI for Good”). Although most of the materials have been implemented primarily in the English language, we also see environments and materials supporting multiple languages (e.g., a good example is the case of Code.org).

Looking at the types of platforms utilized from the identified environments, we noticed that there is a wide variety such as proper applications, applications running on the web as well as applications that are developed for mobile devices such as mobile phones and tablets. As with any applications, the ones requiring installation (e.g. While True: Learn(), Human Resource Machine) are more robust and don’t necessarily rely on internet connection, compared to the ones that run online and don’t require installation (e.g. The Moral Machine). Another important dimension of the AI/ML learning environments is the cost. Looking the identified environments, we note that many of them are free, or have a free version, (e.g. The Moral Machine, Code.org), however, there is also a sustainable part of games that purchase is required or a paid subscription (e.g. Codespark Academy, Gladiabots: AI combat arena); in most of the cases the teacher/parent can have a free trial with the game.

In order for pre-college students, instructors and parents to understand the fundamental ideas of AI and ML, they also need to be able to practically engage with them. Most of the identified games have been developed during the last few years and schools and teachers have just started to adopt them. In the near future, we expect further development on the available environments, but also more environments to be accessible. Moreover, besides games, we have also seen an increasing number of daily products and tools that demonstrate AI's capabilities (Google Assistant, Apple’s Siri, Microsoft’s Cortana), and there are a number of home appliances with similar functionality (Google Home, Amazon Echo, Apple HomePod). Most of them are used from young children and will help them to familiarize themselves with AI technologies. Going a step further, a variety of new software and hardware tools are providing AI components to young programmers who can incorporate them into their own creations.

Results from the workshops and interviews with the participants:

Based on the results from the workshops and interviews conducted in each country, here we present the most prominent results, in a form of categories, as revealed from the collected materials from the workshops (figure 2). The categories are relevant to the research that will be followed in the rest of the project.

Perceptions about AI:

In this category the results vary. For example, in Greece, the teachers' perceptions about AI were initially around the use of robots and on how they will affect our lives. Also, they expressed that AI is something about the smart devices and gadgets, but all teachers were focused on how all these "smarts things" will change dramatically our habits and lives, expressing also fear for that change. However, after the presentation from the facilitator, they had a better view of what is AL and ML, and they gradually developed their thoughts during a reflective discussion on how important is for them, first to understand, and then to communicate to students what AI is. One of the several things to discuss, and what is shown to be the most urgent for teachers, is ethics around it. Compared to teachers, practitioners in Greece seemed to be more knowledgeable about AI and ML. They also believe that AI will have a crucial role in near future, and it will change our contemporary life, so it is important for children to be introduced to it. In Malta (workshop at UM), most of the participants were aware of AI and familiar with its applications in everyday life. They identified AI applications in various fields such as social media, games, recommender systems (e.g. Netflix, Google Maps), self-driving cars, weather predictions, advertising, marketing, and health care systems. On the other hand, in Norway and Malta (science centre) there were no specific discussions about AI and ML at the beginning among the participants. Especially for Norway, it was shown that there is a general lack of teacher's training and competence to support students.

Learning objectives

In this category, the ideas emerged from the participants were almost the same in all the three countries. All the participants mentioned how important is the development of students' digital skills in general. Especially they highlighted the huge challenge of our contemporary's societies: "how students will react in an environment without critical thinking". "Machines", as the participants called them, may present disinformation or biased information. So, the critical presentation of the idea of AI is significant and students have to obtain a critical notion of AI and ML. Maybe democracy will be under danger in near future. The interplay between human and the "machines" is a discussion that students should know about, early, due to the limits and restrictions that these can cause to human life. They described for example that students in Greece, learn about informatics and technology, as there are relevant subjects in schools, but the case is that students are not informed about the social impact of AI.

They highlighted the importance of teaching students about what is AI, recognize AI applications in the real world, be familiar with how it works, and areas of application. Specifically, for understanding how AI works, participants commented on the use of practical examples, coding and robotics (e.g. Lego Mindstorms), learning about the structures of algorithms, and how AI systems are developed. They further discussed the importance of teaching the students that AI has pros and cons, it can provide valuable help, and with the appropriate actions we could embrace it for our benefit. Also, it is

important to understand the difference between AI and ML. Perceive a functional understanding of ML; for example, understand what "training" the data means, learn basic ML concepts, and then even apply them to a new context. In addition, discover the creation of an algorithm, learn algorithmic thinking and problem solving were evident in the discussions during the workshops, as learning objectives. It is important for students to engage in problem solving and overcome challenges. In simple words the teachers expressed that students should learn to give instructions to a computer to conduct actions and transfer patterns they think and observe in real life, in a digital form.

The participants raised also the ethical aspect of AI: the ethical dilemmas involved, the advertising, and the disinformation. They highlighted the importance of students becoming responsible consumers, learn to compare and make their own choices, be critical about information distributed over the internet, and they should learn to recognise how algorithms work behind applications of AI and come to their own conclusions.

Challenges

Teachers, and all the other participants highlighted many challenges in terms of how AI and ML should be introduced to students. The main issues discussed by the participants were:

- How it would fit in the curriculum and maybe in the subjects that already exist at schools.
- The need for well-defined learning goals, and the limited time at school settings. Most of the participants agreed that this would be an important issue.
- The teacher-centred culture which they have to overcome. To introduce AL and ML concepts, more student-centred approaches are required so that students can experiment and construct their knowledge.
- The teachers' lack of knowledge and sometimes even on basic programming knowledge. For example, in Malta, teachers expressed their fear of teaching coding (this is particularly true of primary school teachers)
- Lack of schools' equipment (Particularly in Malta and Greece).
- Game-based learning (GBL) can provide a competitive context that challenges students.
- The overflow of information for students and teachers. There shouldn't be too much information available for teachers and students so that the topic does not become too overwhelming for them.
- They also mentioned that is important students understand how game-based learning will help them to know deeply the ML and AI.
- A multidisciplinary approach, through various school subjects, was also mentioned by the participants.
- How to assess the knowledge gained.
- The concerned teachers and parents should encourage and motivate female students to choose technology subjects such as Computing.
- The need to include education programmes to strengthen the element of innovation across all curricular areas. This necessitates the need to engage students in thinking up new problems as well as new ways to solve old and already existing problems with the use of technology.

Students' insights

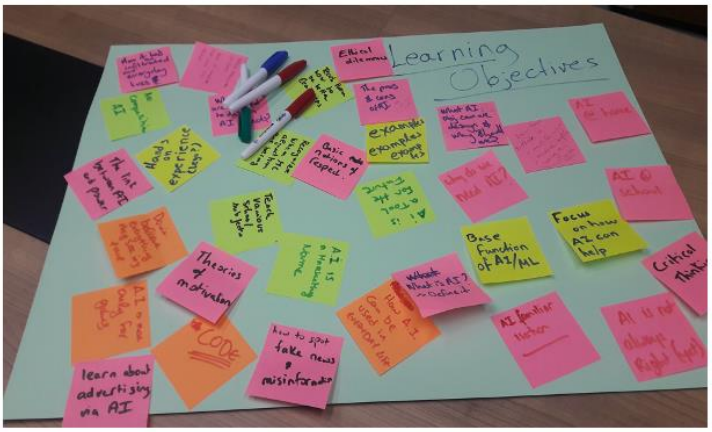
Based on a workshop conducted only with students in Greece, below are some of their perceptions about AI and ML. First, students expressed mostly that AI is related to smart robots. They mentioned that the robots have algorithms behind their functionality. Also, they are concerned that robots will replace humans at some point. But, using them in a smart way, robots can help our lives. Second, students were skeptical and stressed because they realized that they do not know how AI works. The workshop was a first step for them to come in touch with the operations of AI and ML and their potential impact on societies. Third, regarding their opinion about how they would like to be taught about AL and ML at school, they said that they would prefer to be engaged in real societal challenges and not only to see general ideas of technology and informatics.

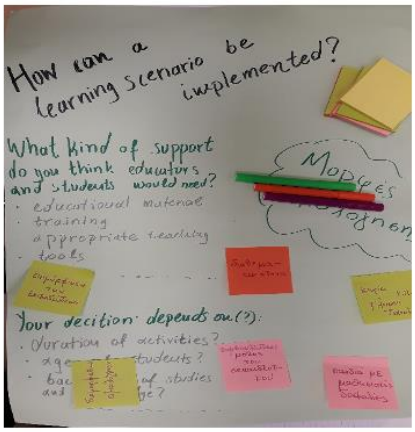
Learning scenarios

The development of potential learning scenarios was one of the tasks the participants in our workshops had to do. The description of two scenarios can be found in detail in the Appendix. Here we present the main characteristics of the scenarios created.

- All the activities included collaboration with children working in teams of 2 or 3. Also, they suggested comparisons and discussions after the end of the tasks and among the groups of the students.
- Game and Project-based learning
- The targeted age group of students is from the age of 9 years old; from late primary to secondary education. As a precondition, students should have basic coding skills.
- The scenarios included:
    - Simple examples for students. The idea is that students will learn through the simulation of a system and its subcategories (import, export, reaction, decision, result). The simulations should be photographs, cars, animals etc.
    - Ethical dilemmas and the results of the decisions taken, with further discussion on the ethics involved in each decision and the potential integration of such dilemmas in AI systems.
    - Students create a simple recommendation system and then compare the recommendations given to them by the AI systems with their actual choices. The relation between input (e.g. a personality test) and output (i.e. recommendation) are discussed, as well as potential implications on real life (e.g. health insurance fees).
    - Hack the system: students should learn how AI systems work and be able to "hack the system", through cooperation with others, by manipulating the input so as to get their optimal results.
- Required materials:
    - Smart phones, computers, tablets,
    - Tangible objects pre-made objects, use other materials to create)
    - Leaflets/worksheets, use paper-based materials
- Learning Objectives: Creativity, collaboration, problem solving, computational thinking, design thinking, critical thinking.
- Students' assessment based on the functionality and the properties of the created projects. Reflections on each step of the learning procedure and discussion at the end of the subject (how do they feel, what changed for the procedure).

Figure 2: Example of reflective notes from the participants during the workshops





Requirements of games to be developed for O2

Based on the input from the stakeholders during the workshops and also the literature review, for selecting and customising the games to be implemented for AI/ML education, in the framework of O2, the following should be considered:

- Games should address learning objectives relevant to AI and ML (e.g. what is AI, how AI works, core principles of architecture of Neural Networks, imitation learning, supervised learning, reinforcement learning), as well as learning objectives relevant to social and ethical issues and implications of AI and ML in our everyday lives (e.g. social impact, ethical dilemmas, bias, disinformation, prejudice).
- The games should support multiple languages, also for non-English speaking students and teachers, or be language-independent
- The games should be low-cost or free for addressing concerns educators' concerns about the cost and licencing fees
- The games should actively engage students so that the students can have practical experience with AI and ML
- Through the games and the learning scenarios students should be empowered to be critical and analytical towards the decisions and recommendations made by AI systems. Their own decision-making skills should also be leveraged.
- There is a need to move the conception of AI as a robot beyond this stereotype. Students should become aware that AI and ML may be implemented in various tools, platforms, and objects ubiquitous in their everyday lives.
- Try to address the multidisciplinary aspect of AI and ML by including various school subjects (e.g. history, environmental education, art).
- Infrastructure referring to access to computers or other devices (tablets, smartphones) in schools is limited. The computers available are usually of limited capacity and have low specifications.
- In primary education superficially, students and teachers will probably have limited knowledge of coding and programming.
- Time available will be limited. The typical school hour is approximately 40-50 minutes.

- The school curriculum is fixed and not all countries prioritise computer science education. In the current stage, AI and ML education should therefore be implemented in existing school subjects.
- The possibility for students and teachers to create their own games or customise existing games is desirable. Students will be able to create their own artefacts or projects, and educators would be able to apply the games to multiple subjects and adapt to students' requirements.
- Students and teachers may have different levels of knowledge on games, coding, and AI/ML.

Discussion

AI and ML despite their increasing role in everyday life and society are not being fully explored in schools. Opportunities for teaching relevant skills and competences through novel approaches have the capacity to revolutionize the contemporary teaching of computational and algorithmic thinking and CS overall. Skills and competences relevant to AI and ML, such as abstract thinking, problem solving, and management of data and information, will empower students to adopt a more critical and inquisitive approach towards existing systems (e.g. recognise bias, disinformation, biased search rankings, filter bubbles) and to participate in the design of new (Turchi, Fogli, & Malizia, 2019).

Although games that support AI and ML seem to be in their infancy, we identified a good number of games and applications, for various ages, school-levels and learner expertise, aiming to teach AI and ML concepts to young children, either by providing guided environments for practice or more open ended environments where children can create their own projects and creatively express their ideas. The number, though, of environments specifically aiming to teach AI, ML, and related concepts to young children is still limited, however, it is steadily increasing, following the general interest (UNESCO's Education, 2019). For instance, games such as PopBots, Minecraft. Hour of Code: AI for Good, and While True: Learn(), and environments incorporating game elements such as the Teachable Machine, AI Machine Learning Education Tools, and Machine Learning for Kids are indicative examples that have particular focus on AI and ML concepts.

Both guided and open-ended environments have been identified in the literature. Both types can be used to support different learning designs and scaffold AI and ML concepts. For instance, guided environments can help students by directing them master concrete concepts, practices and processes, while the open-ended environments empower students to utilize and further their understanding on AI and Ml concepts by deeply engaging in active learning and even by constructing artefacts.

Supporting material for students and educators is an extremely useful resource that can enhance the attainment of the learning objectives. AI and ML are still a new topic in pre-college education; therefore, students and teachers require more than an educational game to approach, understand and be able to discuss the relevant concepts. Learning about the subject matter by only playing the game may be challenging for both the student and the teacher, and insufficient for deep conceptual understanding, and might therefore lead students to develop misconceptions (Muehrer et al., 2012; Parker & Becker, 2014). Environments such as "Minecraft. Hour of Code: AI for Good" and "AI Machine Learning Education Tools" provide good practices by offering lesson plans, additional activities, and other resources for the teachers. In this framework, Camilleri et al. (2019), recently published a

practical guide, financed by the Ministry for Education of Malta, with lesson plans and resources for teachers aiming to teach AI to young people. It is important for both the student and the teacher to have proper learning designs and materials around these games and support AI and ML holistically.

Easy access, price, and technical requirements constitute further critical factors for the effectiveness, adoption, and impact of the learning environments. Not all pre-college education schools and families have the budget or the technological infrastructure and competence to access sophisticated games or platforms (Marklund & Taylor, 2016). The effectiveness of a game-based curriculum in schools relies upon multiple context-related factors such as game literacy of the students, technological skills of the teachers, class schedule restrictions, the computers available and their specifications, and the available bandwidth. Games with low technical demands and requiring less technical skills, such as "Minecraft. Hour of Code: AI for Good" and "Code.org" which require no installation, student accounts, or cutting-edge technology computers, seem more appropriate for the formal school settings.

Teachers, and anyone involved in the learning activities to introduce AL and ML to students, should receive a proper training. Also, the goal is for students to enjoy the process of discovering their own knowledge through the game-based learning experience. When students are engaged in a game-based learning, they gain much better sense of the idea of AI. Critical thinking, computational thinking and other learning objectives, should be met through hands-on experience from the students that design their own AI systems, and make other practical examples. There is also a need for different assessment of students' performance compared to the classical classroom experiences. This should happen, based on students' game results, their thoughtful discussions during the creation of their projects and how they apply the knowledge gained. A multidisciplinary approach, through various school subjects such as history, civics, language, mathematics, physics and so on) is also needed to empower students to take active role in creating their own ideas.

Conclusions

General game playing is an exciting, still young but on the verge of maturing topic, which touches upon a broad range of aspects of AI and ML. In this deliverable we created a general overview of games for pre-college AI/ML education in an attempt to show its many facets and highlight the fact that it provides a rich source of interesting and challenging qualities for pre-college students and instructors who want to introduce their students to AI/ML concepts. We also showed how different games provide a unique opportunity to teach a number of different concepts and topics in AI and ML.

Although research on the use of games or other applications teaching AI and ML to children and young people is still very limited, early results show a great potential for teaching even preschool children basic AI and ML concepts, as well as for engaging them in conversations about the role and implications of technology and AI in our everyday lives (Druga et al., 2017; Williams et al., 2019a; 2019b). Game design, though, for engaging the students and achieving an understanding of the concepts can be challenging requiring appropriate metaphors and easy to understand interactions (Parker et al. 2014). Children interact daily with applications and devices integrating AI (e.g. smart toys, smart home applications, video-sharing and streaming platforms) with potential privacy, safety and bias risks (McReynolds et al., 2017; Chu et al., 2019). Understanding of the processes and factors

involved in the design of such systems can help them develop a more accurate mental model of the limitations and potential of these systems.

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Appendix

Table 3: Example of a scenario developed during the workshop in Malta for implementation in primary school

	Learning Objective	Requirements	Duration	Challenges
Introduction Reflection on the fact that a service like YouTube/Netflix etc is coded by someone; Demonstration of how the system 'learns' a user's tastes depending on what one subscribes to, viewing history etc. and hence makes recommendations accordingly	Students appreciate the role of AI in such systems' recommendations	Internet connection	Term of 45-min lessons in Year 3	Finding the time in primary schooling
Reflection Questioning the intent of the code	Brainstorming: Students question the pros and cons of such recommendations	Internet connection	Term of 45-min lessons in Year 5	Finding the time in primary schooling
Simple coding Students create a simple system that asks the user three key questions (hence building a user-profile) and then makes recommendations. Students are left free to choose a scenario (e.g. tv series, books etc). A more advanced system should make recommendations based on the user's choice of series/books, ratings he gives etc. Students add further 'AI' features to their application.	- Creativity - Brainstorming - Problem-solving - Innovation - Computational thinking	- Coding skills - Ready-made Neural Network modules such as TensorFlow/Keras	Term of 1½ hour lessons between Year 9 and 10	Can this be done across the academic spectrum?

Table 4: Example of a scenario developed during the workshop in Malta for implementation in AI clubs

Sections of the activity	Learning Objective	Requirements	Challenge	Duration
Introduction Students introduced to neural networks via readymade 'machines', such as Google Teachable Machine.	Students appreciate the outlining concept of how machines learn.	- Internet connection. - Google Teachable Machine. - Worksheet prepared by the teacher *(for brainstorming exercise at home)*	Finding the time in regular schooling. Blocked Websites Internet connection stability and reliability.	AI Clubs during school breaks; at least twice per week. Duration whole scholastic year, maybe utilising a context/project for every term. For example: first term, image recognition, second term speech recognition and third term posture/gesture recognition. Such an activity can also be further developed and accredited according to the level of the content achieved; such as MQF 3. This can be offered as an 'Introductory to ML' course during summer holidays.
Implementation Students need to work in groups and think of different applications of how AI/ML can be used *(limited to the functionalities of Google Teachable Machines).*	- Creativity - Brainstorming - Innovation - Computational thinking			
Extra Coding Infiltrating AI/ML into the programming of dedicated systems *(This is suited to years 9 – 11 students)*	- Design Thinking - Problem-solving - Programming Skills	- Single Board powered by a microcontroller/SoC, such as Arduino, Micro:Bits, Raspberry Pi etc.		

		- Internet Access - A readymade neural network, as a module, that students can integrate into their coding		