Not only ChatGPT: educational approaches for Embodied Artificial Intelligence

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Abstract

The increasing interest in Artificial Intelligence has been translated in a growing number of educational proposals on machine learning and large language models. These proposals have addressed different targets, ranging from students to professionals, and adopted different approaches that cover both the theoretical foundations and practical applications of the technology. In the field of AI, robotics applications are gaining more and more appeal and a need for education in this specific field is emerging.

In the present contribution, we outline some challenges in teaching Embodied Artificial Intelligence and report three experiences of its teaching to children and kids, post-graduate students and professionals.

Keywords [1]

Embodied Artificial Intelligence, Education for AI

1. Introduction

The rapid rise of Artificial Intelligence (AI) has captured the attention of both academia and industry, sparking a surge in educational initiatives aimed at understanding the field. Among the most prominent areas of focus are Machine Learning (ML) and Large Language Models (LLMs), two key technologies driving advances in AI. As the demand for AI expertise grows, educational institutions and online platforms have responded with an increasing array of courses, workshops, and specialized programs [1, 2, 3]. These initiatives aim to equip learners with the skills and knowledge required to understand and develop cutting-edge AI applications. Consequently, the intersection of AI education and real-world innovation has never been more crucial or more dynamic.

There are several key methods and strategies to effectively teach AI, for example Hands-On Projects and Practical Applications where students are invited to contribute to practical projects, following a project-Based Learning approach [4, 5, 6]. Collaborative Learning through AI Competitions and Hackathons is effective as well; platforms like Kaggle [7] provide AI challenges where students can apply their skills in a competitive, collaborative environment. During hackathons, students are encouraged in creative problem-solving, allowing learners to tackle real-world AI problems in a short period of time [8, 9].

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By combining these approaches, educators can offer a well-rounded AI curriculum that is both theoretically sound and practically applicable. In the next section we will introduce some educational pathways on AI.

2. LLMs educational pathway

In current educational proposal on LLMs, represented graphically in fig.1, the starting point is often the foundational knowledge in mathematics and programming.

AI relies heavily on linear algebra, calculus, probability, and statistics. Building a strong mathematical foundation helps students understand algorithms, optimization techniques, and data analysis [10]. At the same time, it is important to provide students with programming tools, for example in languages like Python, R, and frameworks like TensorFlow and PyTorch. Teaching programming skills is essential for implementing AI models.

The next step is to provide tools to understanding Machine Learning (ML) algorithms, particularly Supervised Learning (algorithms like linear regression, decision trees, and support vector machines, which rely on labeled data to make predictions) and Unsupervised Learning (techniques like clustering and dimensionality reduction enable to find patterns in unlabeled data).

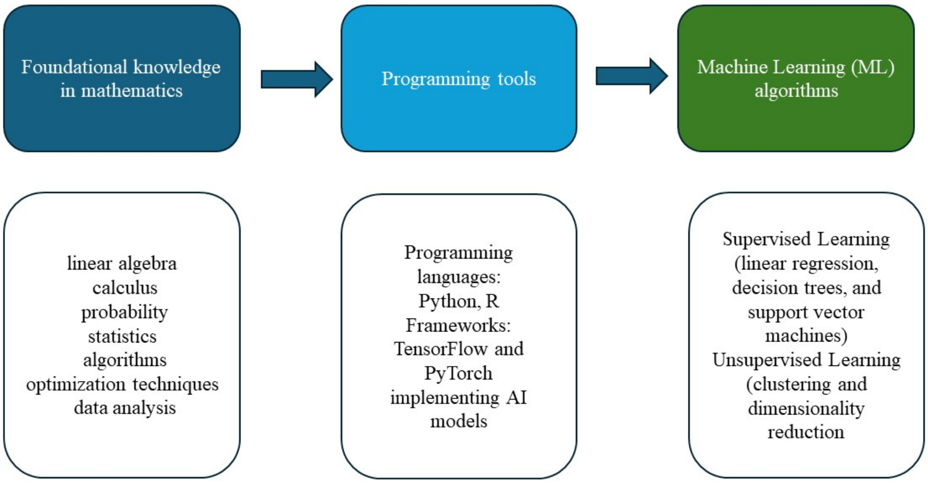

Figure 1: Steps for AI education addressed to LLMs

These steps prepare the exploration of Large Language Models (LLMs) which represent a highly advanced frontiers of AI applications. In this case, it is important to introduce Natural Language Processing (NLP), such as tokenization, sentiment analysis, and text generation, which are key in training and fine-tuning LLMs like GPT and BERT [11].

Along with this algorithmic approach, there are some fields of AI where the focus is put on the modelling meaning of AI, on how it represents a simulation of natural behaviors, natural nervous systems and adaptation: we will focus on these pathways in next section.

3. Embodied Artificial Intelligence educational pathway

Embodied Artificial Intelligence (E-AI) refers to a branch of AI that focuses on the development of intelligent systems or agents that interact with the physical world through a body, such as robots or virtual agents [12, 13]. Unlike traditional AI, which often exists solely in software environments and deals primarily with abstract data, embodied AI is concerned with integrating perception, movement, and decision-making to navigate and perform tasks in real-world environments [14, 15].

The concept of embodiment implies that intelligence arises not just from cognitive processing but from the interaction between the body and the environment. This idea draws from cognitive science theories that suggest intelligent behavior is shaped by the way an organism's body perceives and responds to its surroundings [16, 17, 18].

In the educational pathways on E-AI, the first step is to introduce perception and sensorimotor integration; indeed, Embodied AI systems use sensors (e.g., cameras, microphones, touch sensors) to perceive their environment and actuators (e.g., motors, robotic arms) to interact with it [14]. The integration of sensory input with motor control is crucial for these systems to learn and adapt to dynamic environments. The next point consists in determining the control system, that, following the metaphor of natural agents, mainly consists of artificial neural networks, with artificial nodes linked by weighted connections and specific activation functions, organized in layers and with possible recursive connections [13].

The third step is devoted to the learning via interaction. Embodied AI often employs learning techniques, such as reinforcement learning, where the agent improves its performance by interacting with the environment, receiving feedback, and refining its actions or evolutionary algorithms where the metaphor is once again derived from natural evolution [15].

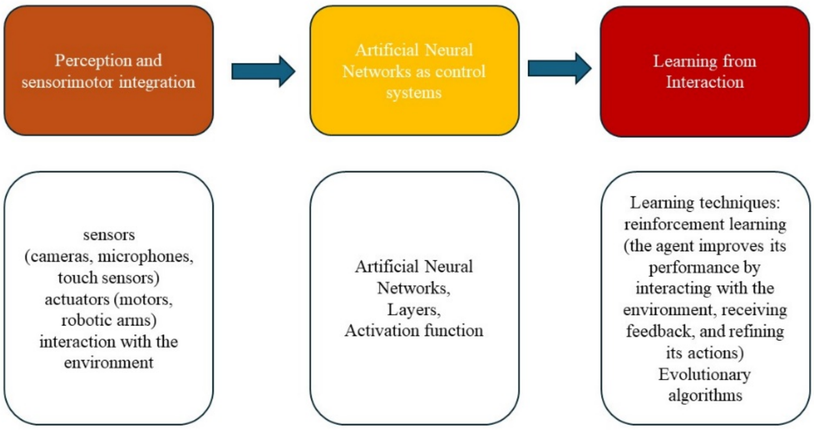

Figure 1: Steps for AI education addressed to E-AI

These steps lead to robotics, which represents a core element of E-AI and is widely used in the context of educational robotics. Autonomous robots and humanoids rely on Embodied AI to perform tasks such as moving through complex environments, manipulating objects, and interacting with humans [12, 13, 14].

Embodied AI aims to create autonomous and adaptive systems that can operate in the physical world much like humans and animals do. This field is particularly important for applications where real-world interaction is critical. By grounding AI in physical experiences, Embodied AI allows to bring us closer to creating machines that not only think in abstract but also act and learn in ways that are more natural and intuitive in human-centered environments.

4. Comparison between LLMs and E-AI teaching

Sketching the differences in these two pathways, we must start from the domain. LLMs like GPT, BERT, and others are designed to process and generate human language. The teaching of LLMs centers around Natural Language Processing (NLP), which includes tasks like text generation, translation, summarization, sentiment analysis, and more [19]. On the other hand, E-AI focuses on systems that interact with the physical world through bodies, such as robots. Teaching E-AI is about sensorimotor integration, physical interaction, and how agents learn from their environment. It deals with perception, navigation, manipulation, and physical tasks in the real or simulated world [13].

Teaching LLMs emphasizes text-based data processing, including tokenization and embeddings (transforming words into vectors), language model architectures (e.g., transformers), pre-training and fine-tuning on large text corpora, attention mechanisms, sequence modeling, and text generation [11].

Learning Environments are also different, as LLMs typically learn in virtual environments with large text datasets. The focus is on how models process and predict language patterns using labeled and unlabeled data, whereas E-AI happens in real-world environments or simulations, where the agent physically interacts with objects, learns through sensory feedback, and adapts to its surroundings. This could include robotic experiments or simulations where agents perform tasks like walking, grasping, or navigating [14].

Moreover, LLMs are trained primarily using supervised learning and self-supervised learning techniques [20]. The models are trained on massive datasets of text to predict the next word or sentence, with no direct physical interaction. Feedback is often provided through loss functions (e.g., cross-entropy) that measure the difference between predicted and actual outputs and E-AI systems typically learn through Reinforcement Learning (RL) or Evolutionary Algorithms, where feedback comes from interactions with the environment [13, 14]. The agent receives rewards or penalties based on how well it performs a task (e.g., reaching a goal or manipulating an object), learning through trial and error.

In summary, LLMs focus on language, dealing with text-based data and algorithms to understand, generate, or manipulate human language. Teaching LLMs revolves around NLP tasks, large-scale data, and model architectures like transformers.

Embodied AI deals with intelligent agents interacting with the physical world. Teaching Embodied AI involves robotics, sensorimotor systems, and algorithms like Reinforcement Learning, focusing on how systems learn to navigate, manipulate, and perform tasks in dynamic environments [12, 13, 14].

These distinct approaches reflect the different challenges and goals in creating intelligent systems that either understand and generate language or physically interact with their environment.

Whereas there are nowadays many proposals of educational pathways on Artificial Intelligence, there is still less attempts to build educational pathways on E-AI. We propose here some examples of how E-AI can be introduced to different target groups.

5. Some examples of E-AI educational pathways

Embodied Artificial Intelligence (E-AI) represents a transformative approach in AI, emphasizing the integration of physical bodies or agents with cognitive capabilities. By embedding AI systems within physical forms, E-AI aims to achieve more robust interactions with real-world environments, supporting advanced learning, adaptation, and responsiveness. Understanding the diverse pathways through which E-AI is realized is crucial for advancing applications in robotics, autonomous systems, and human-robot interaction. In the following subsections, we introduce some key examples of these pathways, each illustrating distinctive strategies for introducing and teaching the fundaments of E-AI, including artificial neural networks, learning algorithms, and evolutionary strategies.

5.1. Introducing Embodied Artificial Intelligence to post-graduate students of humanities

In the last years, in the field of AI, we have witnessed the overcoming and solution of many technical challenges, including the possibility to rely on stronger and stronger computational resources, but, at the same time, many challenges raised concerning the human factor in AI [21, 22].

For this reason, there is a growing tendence to widen the interdisciplinary AI teams to include specialists in human disciplines, thus recovering the foundational approach [23]. Teaching AI to people in humanistic fields enables them to bring a human-centered perspective to AI development and use, especially in ethical awareness [24], and informed critique and policy influence [25].

Moreover, this trend allows to improve communication between disciplines: AI is increasingly interdisciplinary, requiring collaboration between technical and non-technical experts. Humanists who understand AI can bridge communication gaps between technical developers and broader society, translating complex technological concepts into language that non-experts can understand and ensuring public discourse around AI is accessible [26]. On the other hand, humanists contribute to creativity and innovative thinking that can lead to new, imaginative applications of AI. When AI is taught in the humanistic context, it opens possibilities for its use in fields beyond traditional tech spaces.

At the University of Naples "Federico II", under the supervision of Laboratory for Natural and Artificial Cognition "Orazio Miglino", there have been two editions of an innovative post-graduation course devoted to Artificial Intelligence.

The key distinguishing features of these educational pathways lie in their ability to merge the humanistic backgrounds of participants with a strong and comprehensive technical foundation in Artificial Intelligence (AI) tools and methodologies. This interdisciplinary approach ensures that learners not only understand the theoretical and ethical dimensions of AI but also gain the technical proficiency needed to apply AI in real-world contexts. Programming languages, such as Python, serve as the critical instruments through which participants can create complex simulations, develop sophisticated models, and build artificial environments, with the goal of modeling and replicating aspects of reality in a controlled, computational setting [27].

Furthermore, delving deeply into the study of AI models and their practical applications, as well as exploring various systems and methods in Machine Learning (also referred to as artificial learning), computational linguistics, and advanced data analysis, lays the groundwork for more specialized fields such as Evolutionary Robotics and neurorobotics [12, 13, 14]. These emerging areas of research and application are particularly significant in the realm of machine autonomy, where robots and artificial agents are endowed with the ability to adapt, evolve, and make independent decisions based on their interactions with the environment.

Integrating Embodied AI education into academic and professional training is essential for addressing emerging challenges at the intersection of cognitive science, robotics, and human-machine interaction. As artificial intelligence systems increasingly operate in dynamic, real-world environments, the need for embodied intelligence—wherein agents perceive, reason, and interact through physical or simulated bodies—has grown substantially [28]. Unlike traditional AI, which often relies on static data or limited environmental feedback, Embodied AI leverages sensory-motor capabilities and real-time environmental responses to foster adaptive and context-sensitive interactions [29, 30]. Teaching Embodied AI in educational settings has therefore become essential for equipping the next generation of AI researchers and practitioners with the knowledge and skills necessary to design, evaluate, and ethically implement these systems.

Moreover, incorporating Embodied AI into advanced curricula enriches students' understanding of not only computational algorithms but also the biological, psychological, and sociocultural dimensions of intelligence. Students trained in Embodied AI can better understand concepts such as perception, proprioception, and motor skills that are foundational to both human cognition and robotic functionality. This interdisciplinary approach encourages innovative research, bridging fields that traditionally operate in silos, thus fostering a comprehensive view of intelligence in natural and artificial systems.

The integration of Embodied AI into educational frameworks, also exploiting on-line collaboration (for an example, see https://www.moowcode.eu/) represents a promising evolution in AI education, preparing post-graduate students to address complex challenges in interdisciplinary and human-centered ways. As AI systems increasingly interact with the physical world and affect human lives, the importance of Embodied AI education becomes evident.

5.2. ADA (All Digital Academy): an educational pathway for adult training on AI

The All Digital Academy (ADA) project serves as a comprehensive educational platform aimed at upskilling adult educators in key areas of Artificial Intelligence (AI) and digital technologies. By aligning with the European Commission's Digital Education Action Plan (DEAP) [31], ADA targets the growing demand for digital literacy in a society where only 56% of individuals aged 16-74 currently possess basic digital skills [32, 33]. The project recognizes the critical role educators play in shaping a digitally competent citizenry and addresses this through structured learning experiences designed to foster understanding, application, and ethical consideration of AI.

The ADA initiative utilizes a blended learning approach, incorporating various resources such as MOOCs, webinars, and an extensive repository of educational materials. Designed around the ADDIE instructional model (Analysis, Design, Development, Implementation, and Evaluation), ADA ensures that its courses are both adaptable and responsive to the evolving needs of educators [34, 35]. Moreover, ADA's curriculum is built upon the Digital Competence Framework for Citizens (DigComp 2.1) [36], which serves as the foundation for developing AI-related skills across different facets, including Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Security, and Problem Solving.

The ADA curriculum emphasizes a holistic and hands-on approach to AI education. This approach encompasses foundational concepts, technical know-how, practical experimentation, and ethical considerations—elements crucial to the responsible integration of AI into everyday practice. In the introduction, the importance of understanding AI's history, mechanics, applications, and ethical implications was highlighted. ADA addresses these aspects through its structured educational pathways, providing educators with a deep dive into AI topics and competences.

For example, the ADA curriculum stresses the importance of understanding what AI systems can and cannot do. This includes recognizing that AI systems, despite their autonomous appearance, are fundamentally products of human intelligence and decision-making. Educators are guided to explore how AI systems process data, make predictions, and influence both real and virtual environments. Additionally, ADA underscores the relevance of understanding the mechanics behind AI systems, such as the use of statistics and algorithms, as well as the principles of machine learning, to provide educators with a solid technical grounding in AI concepts.

Furthermore, ADA places a strong emphasis on the application of AI across various domains, supporting educators in identifying where AI can bring benefits to everyday life. By linking theoretical knowledge with practical experimentation, ADA equips educators to implement AI-based tools in their teaching practices. The program encourages hands-on experiences with model building and training, helping educators gain confidence in applying AI to solve real-world problems, thus mirroring the project-based and collaborative learning methods mentioned in the introduction.

To further support its mission, ADA fosters a Community of Practice (CoP) [37, 38] where educators can engage, share knowledge, and collaborate on AI-related topics. This community-driven approach aligns with the introduction's mention of collaborative learning and hackathons, providing an avenue for continuous learning and professional development. Through this digital environment, educators are encouraged to exchange best practices, troubleshoot challenges, and stay updated with advancements in the field of AI, enhancing both their own skills and those of their learners.

The ADA project, through its focus on a comprehensive AI curriculum, hands-on experimentation, and an ethical framework, aligns with the key elements introduced in AI education. It not only equips educators with the necessary technical skills but also fosters an understanding of AI's broader implications.

5.3. TEACH E-AI 2C (Teaching Embodied Artificial Intelligence to Children): an educational proposal for young learners on E-AI

The Teach E-AI 2C (Teaching Embodied Artificial Intelligence to Children) project [39] was born with the objective of filling the gap between AI growing progress and the users' knowledge of even basic principles [40]. It aims to create tailored educational resources that enable children, aged 9-13, to learn about AI by using AI itself. It is in an ongoing phase of development and assessment. Future evaluations are essential to ensure its applicability and educational potential.

The project follows an Embodied AI approach [41] and is grounded in the instructional design principles of the 4C/ ID model [42]. This educational model is designed to cope with complex learning tasks. Also, it emphasizes the importance of practice in realistic context where learners can integrate both knowledge and skills [42].

These features, together with E-AI approach, will make it possible to: (i) moving beyond a strictly algorithm-driven approach; (ii) understanding biological systems to replicate their functions in artificial systems; (iii) clarifying principles for intelligent behavior; (iv) enforcing these principles to artificial systems that interact with the physical world; (v) encouraging hands-on learning methods.

To achieve the educational aims, the project comprises three Learning Units (LUs), which introduce E-AI concepts to children and early adolescents. Consistent with the 4C/ ID model, Supportive Information for these LUs provides permanent source material on core AI topics, including Artificial Neural Networks, Genetic Algorithms, E-AI, Robotics, and Evolutionary Robotics, alongside foundational concepts such as Learning processes, Evolution, and Darwin's Theory. The LUs consist mainly of text written in a simplified form, to make complex AI topics accessible to young learners. Hyperlinks direct learners to additional content from sources like the Treccani Vocabulary and Encyclopedia, allowing for deeper exploration of fundamental concepts. Visual aids, links to educational videos, games, activities, and audio-pills are incorporated to enhance engagement and meet diverse learning preferences.

For Learning Tasks, the project incorporates case studies, mini-projects, and problem-solving activities based on real-world scenarios. These tasks lead learners to play with unplugged practice and creativity, allowing them to master individual concepts progressively, and improve knowledge retention. In addition, children are supported with Procedural Information, in the form of ‘how to’ or ‘step-by-step’ instructions on using E-AI.

Finally, the Part-task Practice has been filled with the development of the Teach E-AI 2C robotic farm, in order to provide hands-on activity on E-AI. It is an integrated hardware-sofware platform developed for Thymio [43] and AlphAI [44] robots. This software simulates artificial evolution, enabling users to breed and evolve a population of robots, even without technical expertise [45]. Starting with a given first generation, users can observe robot performance and select some of them to produce subsequent offspring. The selection for reproduction can either be made by the system, selecting the "best robots", or made by the users. Human users, however, simply choose the robots they believe performed best.

Once the selection process is complete, the system creates clones of the selected robots, introducing random mutations into their control systems. This selection/cloning/mutation cycle can be repeated until the "breeder" finds a particularly capable robot. At this point, the brain of the simulated robot can be uploaded to a real robot, allowing the user to observe its performance in the real world. The system also tracks population fitness over generations and offers various customization options through its interface, making it accessible and user-friendly for young learners experimenting with artificial evolution. With the Teach E-AI 2C robotic farm, children can conduct their own artificial evolution experiments firsthand, observe theory in action, play in competitive groups, and foster collaborative learning.

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