A report about Education, Training Teachers and Learning Artificial Intelligence: Overview of key issues.

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Abstract

As Artificial intelligence (AI) is taking an important part in our lives, the question of educating *towards* AI becomes increasingly relevant. We argue in this document that although it may be premature to teach AI, we recommend an education to five pillars or core questions which should be of great use in the future: data awareness or the capacity of building, manipulating, visualising large amounts of data; understanding randomness and accepting uncertainty or the ability to live in a world where models cease to be deterministic; coding and computational thinking or the skills allowing each to create with code and to solve problems through algorithms; critical thinking as adapted to the digital society and finally a series of questions amounting to understand our own humanity in view of the changes AI induces.

Introduction

Artificial intelligence has been described as the new electricity. As such, the belief that it will have a profound influence over many fields, of which Education, is widely shared. For instance, in its 2018 report on artificial intelligence, the French committee chaired by Cedric Villani [25] presented *Transforming Education* as the first "focus". In [12], hundreds of applications of AI have been scrutinised and mapped to the relevant technologies. More recently, the JRC report *The Impact of Artificial Intelligence on Learning, Teaching, and Education*, by Ikka Tuomi *et al.* [20], considered the different aspects of the questions relating artificial intelligence and learning. And more generally, the question of transforming education with the help of technology is addressed by the Sustainable Development Goal 4 adopted by the United Nations in September 2015, and also by the OECD [13].

In this report we study the different interactions between AI and Education with an emphasis on the following question: If we accept that artificial intelligence is an important element in tomorrow's landscape, what are the skills and competences which should appear in the future curricula and how can we help to train the teachers so that they can play the required role?

This report is one of the first addressing these questions: as such it is less built as a synthesis of existing reports with an increment from previous works than as an analysis based on the experience of teachers, researchers, academics and practitioners. A recent exception is the work by the UNESCO itself who has been exploring the links between AI and education [15].

1 What is AI? Why is the issue of general interest?

The history of artificial intelligence goes back to the history of computing. Alan Turing was interested very early in the topic of *machine intelligence* [21]: some of the ideas he introduced 70 years ago are still extremely relevant today; he argued in favour of randomness and discussed the implications of machine learning to society. Even if Turing didn't predict the importance of data, he did understand the machine's capacity of learning would be key to machine intelligence.

Another of Turing's contributions to artificial intelligence is what became known as the Turing test: in this test an external (human) examiner has the capacity of interaction with both a machine and a human, but the interface being mechanical, he will have to examine the answers to the interactions rather than their form. The examiner's goal is to distinguish man from machine; the goal of the artificial intelligence is to confuse the examiner. This leads to the very general definition of artificial intelligence still in use today where it is less about a machine being intelligent than about a machine being able to convince the humans that it is intelligent.

The *official* birth of artificial intelligence is usually associated with the *Dartmouth Summer Research Project on Artificial Intelligence*: in 1956 researchers met in Dartmouth College to address the difficult questions for which computing failed to contribute [11].

Today, because of the impact of Machine Learning, and most notably of Deep Learning[1], alternative definitions for artificial intelligence have been considered: a more business oriented view is that AI matches these deep learning techniques which have a strong impact on industry [12, 30].

Being able to pass the Turing test is no longer the shared goal of research and would not explain the impact of AI today. Today's successes of AI depend on several factors including machines tailored to the needs of the algorithms and the massive increase in quantity and quality of data. Machine learning techniques work today much better than 10 years ago. They build better models, make less errors in prediction, they can make good use of the huge volumes of data, are able to generate new realistic data, and are being tuned and adapted to an increasing variety of tasks. As such, these algorithms are no longer aiming at tricking the human in believing that they are intelligent; they are actually replacing (in part) the human in one of her more intelligent tasks: that of building algorithms.

If computing is about algorithms and data, modern AI is a data science: it relies on being able to handle and make the most from data. Whereas the natural trend for computing was to build algorithms to handle data, me may argue that artificial intelligence is about data building the algorithms that build algorithms.

1.1 Why understanding AI matters

Artificial intelligence is influencing all parts of society where data can be made available and where there is room for improvement, either by automatising or by inventing new challenges and needs. In substance, this means that every human activity is being impacted or can be impacted. For instance, all 17 United Nations sustainable development goals (SDG) are currently being scrutinised by AI experts [8]. The use of AI can lead to complex new situations, which can only be understood through an actual understanding of the technical and conceptual aspects underlying it. In many cases our physical understanding of the world is insufficient to gauge the impact or even the opportunity for AI.

When we read `for i= 1 to 1000000` intuition is of little use: no human does anything 1 000 000 times in a lifetime! The mathematical world and its full abstraction doesn't give an adequate answer either. People may imagine artificial intelligence as a process by which a machine does things the same way as we (humans) do, only faster and with more memory, storage space or computation power. But AI doesn't always work that way. The algorithms will not follow the patterns from our physical world and an understanding of what they do will not give us a realistic idea of why they work and why they don't.

When it comes to training teachers, that leaves us with two approaches: the first one supposes the teachers should be able to actually build simple AI systems: they should know how to code and be able to assemble blocks in order to obtain more complex systems, run artificial intelligence algorithms, build models and use them. The second approach supposes people do not learn how to design but only how to interpret and use. They will then necessarily interpret things through their very limited own physical world values.

[1] The 2018 Turing award, which is the most important prize in Computer Science, was jointly awarded to Yoshua Bengio, Yann Le Cun and Geoffrey Hinton for their work which allowed the development of Deep Learning[1].

2 AI and Education

The links between AI and Education are not new. They have worked in both directions, but one of these has received, up to today, much more attention than the other [15].

2.1 AI for Education

The first conference on Artificial and Education dates back to more than 20 years ago: the challenges have since been wide ranging and are now addressed by strong multidisciplinary communities. Research projects have been funded by the European Union, Foundations and individual countries. The goal is to make use of artificial intelligence to support education. An emerging industry has developed, covered by the name Edutech (which isn't strictly AI) and the question has been studied in a number of reports: [23, 15, 25, 20].

2.2 Education for AI

Whereas the question of educating everyone to artificial intelligence is new, the one of training experts for industry has been dealt with for some time.

Artificial intelligence has been taught in Universities around the world for more than 30 years. In most cases these topics require some strong foundational knowledge in computer science and in mathematics. The increasing importance of data science, artificial intelligence and machine learning is currently leading to a modification of the computing curricula [16].

Education to artificial intelligence, prior to University, is in 2019 a whole new question. If it has not appeared before, this can be due to several reasons:

- The need is novel: if AI has been around for some time, applications for everyday life have been limited. Today, through mobile phones or ambient companions, interaction with AI occurs in a routine way, at least in the more industrialised countries [12].
- The issues surrounding education as a global question are huge and AI may not be perceived as essential [14], even when the goal is that of studying education in a digital setting [22]. The efforts made in many countries to introduce an Information and Communication Technologies curriculum have not even been able to produce yet results, and, with AI, it seems we are asking for more today [24]!
- It is difficult to introduce the topic without trained teachers. As an example, in 2018, the French government decided to add a new computing curriculum at high school level (16-18 year old students) with the ambition of introducing artificial intelligence. This was impossible due to the numerous resistances.
- It is still unclear what should be taught if we consider a teaching which should have some form of validity over the years. What will artificial intelligence be in 20 years, or even 10 or only 5?

2.3 Why should we train teachers in AI?

AI applications are going to be present in all areas [12]. As such, one could just add the usage of the applications to the individual skills required by a teacher. But this would probably limit in many ways the capacity of the teachers to adapt to new applications.

One can also state that the children are going to be brought up in a world where artificial intelligence will be ambient and can therefore be called *AI natives* [26].

Should a teacher just know about the key ideas of AI? Or should she be more aware of other questions?

2.4 Is teaching AI an enhanced version of teaching computational thinking?

Teaching coding and computational thinking has been advocated strongly since 2012 [28, 7]. Many countries have now introduced the topic. Learning to code isn't just about acquiring a technical skill: it is about being able to test one's own ideas instead of just being able to run those of someone else. And of course, there is a strong dose of ideas in artificial intelligence, which means that both knowing how to code can help one use AI in a creative way and also understand the underlying questions and concepts.

AI is an extension of computing. It comprises it but also introduces some new ideas and concepts.

2.5 Why should a teacher be AI aware?

Many of the reasons for training the teachers to some understanding of AI are very close to those advocated to prepare them to digital skills [24]. Whereas a first goal is to make sure that teachers are digitally aware, and this goal is not reached yet, how important/urgent is it to be AI aware? Why would that be necessary? Let us discuss some reasons.

The role toward community. If artificial intelligence is to impact every aspect of society, as many are predicting, citizens and future citizens are going to require guiding, some help to understand, decrypt these technologies

In order to train skilled learners. An aspect put forward by many analysts is the impact of artificial intelligence on jobs. The more optimistic analyses point out that where many jobs will be lost to robotisation, new jobs will emerge.

And even if these jobs seem to require soft skills, it would seem reasonable that many will be linked directly or not with the technical aspects of AI.

If in 2019 it seems neither relevant nor possible to train every child to AI, it would on the other hand be necessary that each child be given the principles and bases allowing her to adapt and learn at a later stage.

Because the learning environment is changing and will include AI. Intelligent tutoring systems, tools which will allow to propose individualised learning experiences, tailored companions... are some of the projects under way which will necessarily lead to situations where the learner is helped. Understanding these tools will be an asset, if not a necessity.

Because AI is a valuable tool for teaching. AI is used today to help the teacher. For example, project X5-GON recommends open educational resources adapted to the needs of a particular teacher [29]. In the same way as today a teacher is penalised by not being able to make use of the digital tools available, tomorrow's teacher may lose out if she cannot access AI tools in a simple way.

3 Towards a curriculum. The proposed five pillars.

Artificial intelligence has not reached its maturity. The topic as it was defined in 1956, studied during 40 years, reached its spectacular results since 2012 is still difficult to understand. It is even more difficult to forecast how the technologies will evolve, even in a close future. If building a full curriculum is beyond the reach of this document, it is possible to put forward five pillars and propose to build upon these. We represent our proposal in Figure 1: we believe five pillars or core questions should be added to the training of teachers (lower part of the figure) and on these, in due time, AI would be able to be taught (top of figure).

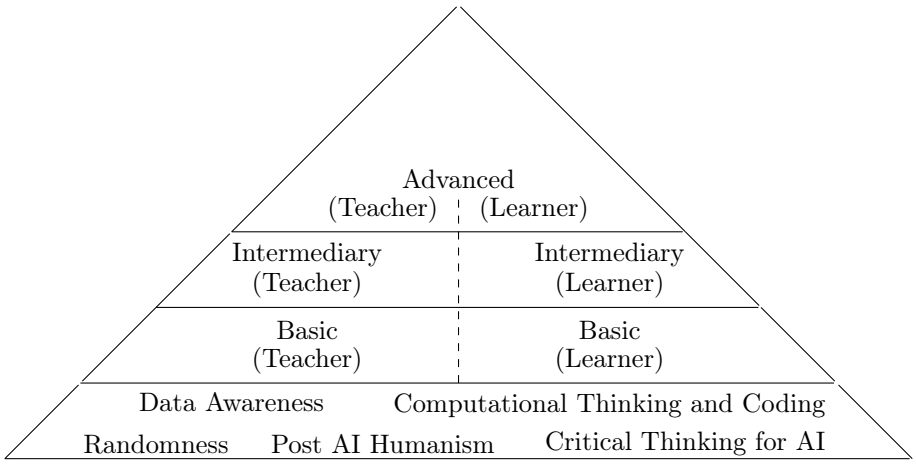

Figure 1: The AI competences

3.1 Uncertainty and Randomness

Data is inconsistent. It does not demonstrate a strict causal nature. With data, a same cause can lead to different effects. Dealing with this *legitimate* non determinism in the modelled world, which is going to be used for AI based decision making, requires the acquisition of alternative skills. Probabilistic reasoning and statistics will need to be taught, but before that, activities allowing children to understand the stochastic nature of most modelled processes and those encouraging to make the best use of the imperfections of the data are necessary.

Yet AI both also means a new form of determinism which deserves our attention: when predictive systems are taken (too) seriously and we are told that our child aged 1 will develop into a scientist or have a complicated social life through a misuse of data, not understanding how these predictions work can cause a lot of damage. An understanding that the forecasts proposed by AI are not ground truths, but estimations, and how these are to be interpreted is of great need.

Teaching this may be complicated for didactic reasons: accepting uncertainty also means teaching without implying that the teacher is omni-scient and makes no mistakes.

3.2 Coding and Computational Thinking

Coding and computational thinking are today in the curricula of many countries, following the recommendations of experts [10, 18]. In many cases the AI code it is about using libraries for the programming languages which allow us to manipulate large amounts of data with very few instructions. But a proper usage of these techniques does involve some coding skills [19, 28, 6]. Furthermore, it has been argued that expert users of AI (for example the doctors) will need to understand the algorithms in order to know when **not** to trust the machine learning decision.

Efforts have taken place in different countries to address this question and the related question of training the teachers [10]. In France, project Class'Code [5, 4] relies upon Open Educational Resources to allow teachers and educators to learn.

Computers and robots are obvious artefacts, but an alternative approach is that of Computer Science Unplugged [2].

3.3 Data Awareness

AI is going to rely on data. Whereas the algorithm is at the centre in computing, this is much less the case with AI, where, often, most of the effort will concern the collection, preparation and organisation of the data [16]. An education to data (science) will rely on activities where data is collected and visualised, manipulated and analysed [15]. As a side effect, large amounts of data justify that algorithms get taught with more care as testing becomes much more complex.

3.4 Critical Thinking

Social sciences can and should contribute with many of the ethical questions AI raises. Critical thinking is one important aspect but it is essential that it relies on a real understanding of the way technology works.

A typical example: when attempting to detect fake news and information –a truly important question– it is often suggested that the answer consists in finding the primary source or in relying on *common sense*. This is a great 20th century answer but is of less use in many situations on the web from AI generated texts, images or videos. Today, the answer comes through a combination of understanding the digital literacy concepts and being able to make use of algorithms to build one's convictions. In other words, the human alone is going to find it difficult to argue with a machine without the help of another machine.

Yet it would be just as much a mistake to only teach the technology without giving the means to understand the impacts, evaluate the risks and have a historical perception of media. In most reports on AI there is an agreement that an analysis of the ethical implications should be taken into account before deploying. Researchers from *Media Sciences* have worked on the question for some time [27] and should be encouraged to work with AI specialists.

3.5 Post AI Humanism

The previous 4 pillars can be matched to existing competences, skills and teaching profiles. The one we introduce now may be more difficult to fit in. The key idea is that the progress of AI is making us, as human beings, reconsider some ground truths. It is already known that our interaction with technology has an impact on non technological attitudes: for examples, teachers agree that the children's use of the smartphone and the specific type of multitasking is introduces has an effect on their capacity of studying, at least in the formal settings proposed by schools. With artificial intelligence, these changes may be even more formidable.

We introduce this idea through four examples.

3.5.1 Truth

In 2017, system Libratus was built by researchers at Carnegie Mellon University [3]. This system beat some of the best poker players in the world. For this, the system used reinforcement learning to build its optimal policy. This includes the fact that it learnt to bluff -a necessary skill in poker- without being explicitly trained to bluff. But Libratus did learn that the better strategy to win was to *lie* from time to time.

In other words, the system was trained to win. And if this included bluffing –which is a socially acceptable form of lying– it did just that.

3.5.2 Experience

In 2016 system Alphago beat go champion Lee Sedol by four victories to one [17]. The system, like most till then, made ample use of libraries containing thousands of games played by experts: the machine built its victories on top of the human history and knowledge. A few months later, the new version called Alphago-zero was launched, beat Alphago by 100-0, and then was adapted to chess. The main difference was that Alphago-zero discarded all the human knowledge, just used the rules of the game and the capacity of the machine to learn by playing against itself.

The question this raises is: do we need to build society upon its experience?

3.5.3 Creativity

This question is regularly posed. It can matter legally and intellectually. Today, artificial intelligence can compose music, write scripts, paint pictures, modify our photographs. Through artificial generation new artefacts can be created.

It should be noted that in such cases where artificial intelligence is used for artistic creation it is most often reported that a human artist was part of the project. Whilst this may be in part true, it may only be that we need to be reassured.

Yet, again in the area of games, it is interesting to see specialists comment online the games played by the latest artificial intelligence programs. Whereas some years ago the “brute force" of the machine was put forward, this is much less the case today: the creative nature of the moves is admired by the human grand-masters.

A question raised here is: can a machine create without feeling nor conscience? One answer is to say that the result is what matters: if we believe there is creation, do we need the feeling? [9].

3.5.4 Intelligence

Intelligence itself is being impacted by the progress of AI. Each time a progress is made and machine beats man at something which up to now was considered to be an activity requiring intelligence, experts invariably announce that the given activity didn't really need intelligence. More and more, the goal seems to define intelligence in such as way as to make it unachievable by a machine.

4 Extending the model

The pillars described in the previous section must be understood as being able to support a larger framework of competences the teachers and learners will need to master in order to use and create AI systems (see Fig. 1).

But they can also be seen as self contained 21st century skills which would allow them better to make use of the technologies introduces by and with artificial intelligence.

5 Linking with the UNESCO ICT-CFT

AI will have to be taught by teachers. There is a big difference between the countries in teacher training, for example over the basic ICT skills we can rely on to be able to install an AI teaching agenda.

As a uniform starting point and framework we take the approach promoted by the UNESCO, namely the UNESCO ICT-Competency Framework for Teachers (ICT-CFT), and reflected in a series of evolving documents (over the past 10 years) [24].

In [24], the 6 aspects of a teacher's work are scrutinised with respect to a goal of making use of ICT for better teaching:

- A1 Understand ICT in Education: how ICT can help teachers better understand the education policies and align their classroom practices accordingly;
- A2 Curriculum and assessment: how ICT can allow teachers to better understand these questions but also intervene and propose new modalities;
- A3 Pedagogy: how the actual teaching itself can be positively impacted through the informed use of ICT;
- A4 Application of Digital skills: how to make use of the new skills acquired by the learners to support higher -order thinking and problem solving skills;
- A5 Organisation and administration: how to participate in the development of technology strategies at different levels;
- A6 Teacher professional learning: how to use technology to interact with communities of teachers and share best practices.

Each aspect is then analysed, regarding the impact towards ICT, following three stages: technology literacy (.1), knowledge deepening (.2) and knowledge creation (.3).

The report raises two questions:

1. In what measure does the ICT-CFT offer a good framework for teachers to be trained to AI?
2. In what measure would the ICT-CFT benefit from the impact of AI?

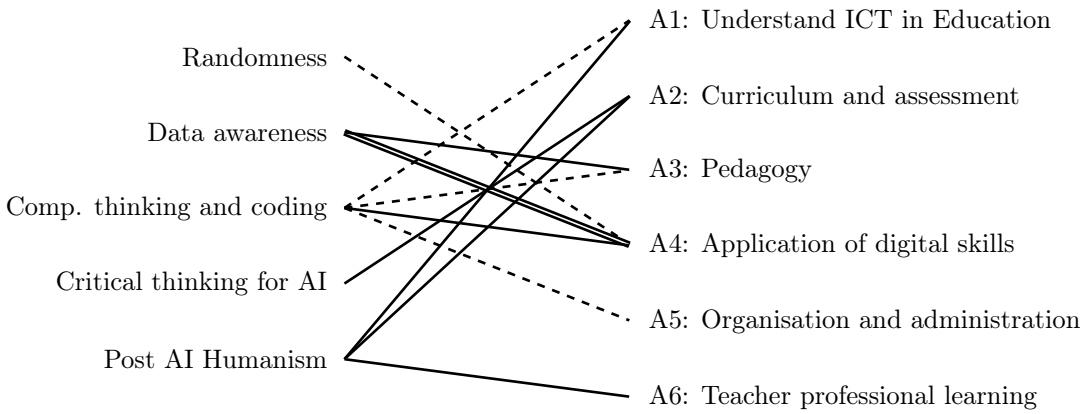

Figure 2: The alignment between pillars and aspects. full lines indicate an impact of an aspect on a pillar; dashed lines indicate a contribution of a pillar to an aspect. Double lines work both ways

5.1 How the ICT-CFT allows teachers to move on to AI

The ICT-CFT aims at allowing teachers to know how to use, in an experimented way, and to develop new ideas, learning material, curricula through ICT.

As the different AI pillars presented in this paper all rely on an understanding of how computers, algorithms, data works, the ICT-CFT will be an important stepping stone towards AI.

Teachers who will be able to master the different tools, strategies and skills proposed in the ICT-CFT would be able to interact better with the questions raised by the proposed pillars.

We represent, in Fig. 2, with a full line, the main contributions of the ICT-CFT aqpects to the five pillars.

5.2 The impact of AI on the ICT-CFT

The arrival of new AI tools for education (like [29]) will probably help motivate better teachers to the usage of ICT: the advantages will become clearer and we can hope that the usage will be simplified. Typically, OER are today difficult to construct, to offer, to find. AI and related technologies should make them much more accessible, which would ensure their wider adoption.

On the other hand, a better understanding of the key questions raised by the proposed pillars will have a positive effect on the motivation of the teachers to progress in levels across the different aspects proposed in the ICT-CFT.

For example, better understanding the social and ethical implications (Critical thinking and post AI humanism) would have a positive impact on the way teachers react and their motivations in training.

The ambitions proposed with the 5 pillars can also impact positively the ICT-CFT by requiring extra ambition: Coding and computational thinking are mentioned but not recommended, whereas for AI the proposal is that these are necessary skills. Learning to code would, on its own, render the ICT-CFT much more fulfillable.

We represent, in Fig. 2, with a dashed line, the main contributions of the five pillars to the ICT-CFT.

6 Artificial Intelligence and Open Educational Resources

ICT Teachers are very much the forerunners of sharing open educational resources (OER): as they naturally use the computer as an object of learning and a learning artefact, they have been very active in producing ans sharing OER. This is also the case for AI: one can predict a great benefit for all.

Artificial intelligence is also working today at provided better tools to publish, share and access OER [29]. Therefore, the education of AI or towards AI proposed in this document should make

ample use of OER.

7 Conclusion

We have presented in this preliminary report five competences or pillars which should be taking an increasing importance given the penetration of AI in society.

Further work should follow, to better understand at what age and in what way the relevant concepts should be introduced, studied, mastered. around which we expect to explain how AI should be taught, both to teachers and to learners.

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