Artificial Intelligence – a new topic in Computer Science curriculum at primary and secondary schools: challenges, opportunities, tools and approaches

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Abstract - Within the context of the Industrial Revolution 4.0, the issue of Artificial Intelligence is becoming an important challenge throughout society. School plays an important role in preparing the young generation for emerging labor market changes. This paper presents opportunities for Computer Science curriculum innovations at primary and secondary schools that are currently being addressed in Slovakia. We present main ideas how to implement new available tools and approaches to teaching the topic of Artificial Intelligence. Based on the new educational materials we have developed, we have gained valuable experience from teacher training, pupil workshops as well as the pilot phase of testing directly in schools confirming that this topic can also be taught in an attractive and age-appropriate way.

Keywords - artificial intelligence; curriculum; school informatics; teaching methodology

I. INTRODUCTION

Over the past few years, we have witnessed the significant rise of artificial intelligence (AI) in various areas of our daily life. The digital tools we encounter bring AI already built into their functionalities to simplify and enhance user experience - digital voice assistants, photo editing and recognition, optical character recognition, natural language processing, and more. Especially important is the impact of AI in industry and manufacturing, transport, medicine or even education. Good understanding of the current situation in AI and its possible prospects in the future raises new questions for educational institutions on new ways of learning, teaching and education [1] - the shift from strictly knowledge-based content to non-routine cognitive tasks (often referred to as 21st century skills) is increasingly resonating in recent pedagogical documents in many countries around the world. It also appears to be necessary to change the existing school curriculum with an emphasis on core concepts, interdisciplinary themes and competencies in order to make learning more enjoyable, meaningful and useful to pupils [2]. There is a clear need to define "AI competencies" beyond basic ICT competencies that would provide pupils with skills necessary for identification and solving problems using computing techniques, methods and technologies [3].

While educational robotics has already found its place in school informatics thanks to Arduino, LEGO and other programmable robotic kits, the AI-related curriculum is still under discussion. Touretzky et al. suggested 5 "Big Ideas" in AI that should be addressed in the K-12 classroom [4]:

Big Idea #1: Computers perceive the world using sensors

Big Idea #2: Agents maintain models or representations of the world and use them for reasoning

Big Idea #3: Computers can learn from data

Big Idea #4: Making agents interact comfortably with humans is a substantial challenge for AI developers

Big Idea #5: AI applications can impact society in both positive and negative ways

Currently, it is possible to find ideas for a variety of unplugged activities on AI [5] and machine learning [6], or examples of using AI tools for STEM projects [7]. Over time, new educational platforms are emerging, bringing appropriate didactically processed content and the necessary software (or hardware) tools to make it accessible, e.g. MIT Cognimates [8] suitable for kids aged 7-10, Machine Learning for Kids [9] for kids aged 10+, Microsoft AI School[10], or IBM TJ Bot [11] for upper secondary school pupils.

Popular educational programming tools also bring new extensions designed to work with AI/machine learning components. Scratch 3.0 [12] comes with two extensions - Text to Speech (collaboration with Amazon Web Services) and Translate (collaboration with Google). MIT App Inventor [13] allows image classification for mobile apps using a personal image classifier, which can be trained using our custom images.

In Slovakia, Computer Science is a compulsory subject from primary to upper secondary school. However, AI is not explicitly found in educational standards, which is also one of the reasons why teachers
do not address this topic in classrooms. Other reasons are the lack of teaching materials as well as the unpreparedness of teachers who have not met the AI topic during their university studies. As the results of our recently published secondary school survey [14] show, Slovak pupils perceive AI as a very interesting and important topic, but are aware of the fact that they lack knowledge, drawing all their information almost exclusively from movies and the Internet. Reflecting these results, we decided to create an AI extension to the existing national Computer Science curriculum followed by a basic set of educational materials, and to prepare teachers for their use in schools as part of the National Project "IT Academy - Education for the 21st Century" (accompanied by a set of subsequent minor projects).

II. AI CURRICULUM

We found the opportunity to broaden the existing curriculum in the educational standards section called "Information Society - Digital Technologies in Society". Our curriculum design is based on five pillars:

- **Tools**: What digital tools use AI? What abilities/features does AI add to these tools?
- **Processes**: How does AI work? How to embed AI functionality into a program?
- **Data**: Where does the data come from? What can we extract from the data? How do they affect AI during and after learning?
- **Applications**: Where is AI already used? What are the opportunities/limits?
- **Impacts**: What are the potential impacts on society? How might AI affect our life, work, study, career?

Our aim was to give priority to active, experiential learning methods that would enable each pupil to build the necessary knowledge, skills and attitudes. Discussion, cooperation, active inquiry and creative work of all pupils must be an important part of the teaching process. The proposed pillars do not have to represent separate learning units - they should be continuously linked to create a comprehensive picture. From a practical application to a particular tool, to discovering how the tool works and what data it uses, to considering new opportunities, limits and impacts.

A. Educational materials

We designed the educational materials for the upper secondary Computer Science course as a general education subject in all types of schools (after some modifications some parts can be used also at the lower secondary school level). They are thematically divided into three areas each of which is elaborated into one lesson:

- Discover artificial intelligence
- How a computer learns
- What we need data for

We don't focus on specific software products - they serve only as demonstration tools for exploration. Also, we don't expect program implementation of neural networks by pupils - considering the planned time allocation, the main point is to show the possibility of using elements of artificial intelligence to extend the functionality of other programs (e.g. games, controls for Internet of Things, mobile applications, etc.). As specific software tools are gradually changing and evolving, we focus on the generalization of concepts and knowledge that arise during pupil research and experimentation itself.

A key part of the first lesson is the phase of exploring various web-based tools integrating AI:

- **Thing Translator** [15] for object recognition and translation into another language
- **Watson Speech To Text** [16] for speech processing and analysis
- **Watson Visual Recognition** [17] for recognizing objects in photographs
- **Watson Natural Language Understanding** [18] for text analysis

Pupils work in groups - each group has a specific tool. For each of these instruments, pupils have a brief instructional video and then explore the tool, its inputs, outputs, and suggest options for further use. Then, after a short presentation of the results of the pupil exploration, the activities continue with the **AutoDraw** tools [19] and **Quick, Draw!** [20], where they see the process of AI learning based on user interaction, which will be the starting point for the next lesson.

The second lesson is devoted to the presentation of the functioning of machine learning tools and neural networks. The aim is not to master these procedures in terms of programming, but to understand their principles, advantages, but also pitfalls or limitations. Initial inquiry activity demonstrates a way of recognizing faces in machine learning through feature extraction and then searching the database. The pupils first analyze the prepared photos of people and fill in the table with monitored symptoms to identify who is in the new photo.

The inquiry continues with group work again - pupils have to prepare suitable data for neural network learning, and then train and test the neural network. The **Teachable Machine** [21] web tool is used. After completing the activity, the pupils are explained the basic idea of neural networks. Their own inquiry should also lead them to the need to start to think intensively about the suitability of the data to be used in neural network learning, as well as the possible consequences of their inappropriate choice.

The last lesson demonstrates data and their use in machine learning and data mining. Pupils explore various examples of data usage on the Internet e.g. traffic monitoring in Google Maps, or using **Google Trends** [22]. The main activity is to interactively explore the network graph of pizza community using the **ConnectTheDots** [23] web tool from the Databasic.io portal, through which they discover the functioning of customer recommendation systems that pupils can encounter when shopping online.
B. Teacher training

As mentioned above, when introducing our educational materials into teaching, we had to think about teacher training as well, as the teacher plays a key role in successful implementation. In Slovak schools, an active, inquiry-based learning approach represents still an innovative way of teaching for Computer Science teachers, as instruction-based teaching still dominates schools. Therefore, in the pilot phase, we trained 90 teachers in an intensive course focusing on innovative approaches in teaching as well as working with our educational materials. The task of trained teachers is now to verify the effectiveness and appropriateness of the prepared educational materials and to provide valuable feedback for their further improvements.

C. Further steps

Since educational materials and teacher training were just the beginning of building our AI curriculum, there is now a demand from teachers for additional AI-based activities suitable for teaching. That is why we invited also IT companies and research institutes for further cooperation. We are working on an advanced collection of ideas for simple, but interesting programming tasks using AI components and the use of other AI-based teaching tools. Creative AI workshops (e.g. robotics, generative art, data analytics and machine learning) for teachers and pupils and webinars with AI experts are starting to take place all over Slovakia in the near future.

III. Conclusion

The aim of education is to prepare pupils for successful participation in society - and scientific predictions agree that the society of the future will be strongly influenced by AI. The school should be a place where pupils acquire the necessary knowledge, skills and attitudes to be beneficial and well-prepared members in this society. All countries will face this challenge - Slovakia, as a strong industrial country, will be significantly affected by the impact of Industry 4.0. That is why the National Project "IT Academy - Education for the 21st Century" is trying to reflect these trends and bring to schools a change in Computer Science curriculum, as well as innovative and attractive approaches that have the potential to reach and motivate pupils to further study of STEM subjects towards STEM-related professional careers.

We started to test the presented educational materials with pupils during workshops and with Computer Science teachers during teacher trainings, where we confirmed that when processed in an active and attractive way, the topic AI can attract both pupils and teachers and support their interest in discussing the topic of AI and its impact, benefits and pitfalls on society. Pilot verification in education is currently taking place at secondary schools throughout Slovakia. Teacher feedback is very promising and confirms the fact that AI as a topic should - along with progressive task-based digital skills - have a firm place in the curriculum.

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