INTEGRATED QUALIFICATIONS SYSTEM

Artificial Intelligence (AI) as a Megatrend Shaping Education

How to prepare for the socio-economic opportunities and challenges presented by artificial intelligence?

European Funds Knowledge Education Development

Republic of Poland

ZRK Integrated Qualifications Register

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Preface

In developing projects to implement the Integrated Qualifications System, the Educational Research Institute focuses on various substantive areas relating to the qualifications system, education in the wider sense of the term, description of professional qualifications, support and promotion of lifelong learning policies, and implementation of the activities set forth in the Integrated Skills Strategy. All activities undertaken in the project "Operating and developing the Integrated Qualifications Register (stage 2)" (IQR2) are aimed at strengthening the usability of the Integrated Qualifications System, mainly by developing IT environments, applications and ICT tools to facilitate the use of the system.

As part of the IQR2 project, a report entitled *Artificial intelligence (AI) as a megatrend shaping education. How to prepare for the socio-economic opportunities and challenges presented by artificial intelligence* was also prepared. This document presents the relationship between education and artificial intelligence and justifies the need to develop digital competencies among Poles. In addition, it shows how new economic developments in today's societies are pressing the need for changes in education and in the way we think about qualifications. It also explains why understanding and being able to apply AI will become important elements of future qualifications.

Artificial intelligence is one of the most important trends shaping modern reality. Preparing people for the increasingly rapid changes in the world around them requires intensive efforts in the areas of education and training. Those areas should enable society to respond skillfully and effectively to the challenges of artificial intelligence. Therefore, the Educational Research Institute invited a group of scientists, experts and practitioners to prepare this report. Our aim was to draw attention to the new area of challenges for education not only of policy makers and researchers, but also of professionals who are involved in education at various levels: teachers, administrators and institutions engaged in training and developing the competencies of teachers.

These challenges are very diverse in nature. The ever-accelerating digitalization, automatization of jobs and the development of artificial intelligence are changing the demand for a professional, qualified and skilled workforce. For this reason, it is essential to promote key and cross-cutting competencies that address the needs of the younger generation and the challenges they face. As the authors clearly demonstrate, it is crucial to have citizens who are aware of what artificial intelligence-based technologies are and the impact they have on all of us.

The report shows how AI is changing our work environment (Industry 4.0, tools and applications), how it is impacting everyday life (smart city, smart home, social communication, media, healthcare and care for the elderly), and how it affects what we learn and how we should use our knowledge.

In order to credibly discuss these issues, it was necessary to collect relevant data, organize it and interpret the results scientifically. In order to have a reliable overview of the existing situation and formulate binding and relevant conclusions, the methodology used in the preparation of reports on social development was applied, which allows for the professional collation and analysis of the collected data.

We would like this report, dedicated to representatives of government administration, non-governmental organizations and the broader group of teachers (both those working in schools and higher education), to set directions and inspire changes in education to meet the challenges posed by dynamically developing new information technologies. We also hope that the publication of the report will inspire various groups to participate in further discussions on the challenges posed to education by the increasingly sophisticated and multidirectional use of artificial intelligence. Such a debate is something that the Educational Research Institute wants to systematically lead and support.

Robert T. Ptaszek,
Director of the Educational Research Institute

Introduction

Some 20 years after Polish cryptologists from the University of Poznań broke the codes of the German Enigma cipher machine, British mathematician Alan Turing asked the question, "Can machines think?" in his article *Computing Machinery and Intelligence* (1950), where he outlined the basic purpose and his vision of artificial intelligence. Its primary task was to create a substitute for the human mind. The memory of the origins of artificial intelligence research has recently been brought to newer generations by the newly opened Enigma Cipher Center (CSE), a cultural institution of the City of Poznań. The CSE's activities are guided by the motto "True History. A challenge to the mind." CSE combines the two most important components of the educational message: a multimedia-supported story about how the cipher of the German Enigma machine was broken by Polish cryptologists from Poznań and a narrative about the consequences of this event for the course of World War II, as well as, more broadly, its impact on the development of technologies for transmitting and encrypting information. The CSE perfectly combines education for young people's interest in science with patriotic education. Visitors learn about the history of breaking the Enigma code by graduates of the University of Poznań: Marian Rejewski, Henryk Zygalski and Jerzy Różycki. It tells about their mathematical work, the machines and tools used to break Enigma, including those created by Poles, such as the cyclometer, Rejewski's bomb and Zygalski's sheets. Polish cryptologists were the first to pit the German Enigma cipher machine against other machines. CSE also has an exhibit presenting the IT revolution that took place after World War II resulting from the hard work of the cryptologists. This revolution continues to this day, an era in which artificial intelligence is developing very rapidly.

So far, research on artificial intelligence is limited due to the lack of complete knowledge about the mind. We are not yet able to simulate all human behavior and emotional reactions with algorithms, which often results in a gap between expectations of the technology and its capabilities. Undoubtedly, a major challenge for artificial intelligence developers is the simulation of irrational behavior, which is typical of humans in many situations in life and therefore even more difficult to reproduce synthetically. In many applications, artificial intelligence will not so much replace humans, but rather collaborate with them. At the 2017 Datarobot AI Experience, Jeremy Achin defined artificial intelligence as: "Computer systems able to perform tasks that ordinarily require human intelligence [...]. Many artificial intelligence systems are powered by machine learning, some by deep learning, and some by very unexciting things like rules."[1] Some researchers are skeptical about the current state of artificial intelligence development and say that it is merely a form of the automation of certain thinking processes (e.g., facial recognition software, Siri or Alexa personal assistants, autonomous cars, etc.), which means that the moment in time when a holistic information system will emerge that is capable of simulating human thinking processes in a general sense, is still a long way off. On the other hand, there have been many

[1] DataRobot AI Experience – 2018 Keynote from CEO Jeremy Achin, https://www.youtube.com/watch?v=ZChA63CpX5o

spectacular developments during the second decade of the 21st century demonstrating the enormous potential of artificial intelligence, among which the following are worth mentioning:

- In 2016, Google's DeepMind AlphaGo team defeated world champion Go player Lee Sadol. The complexity of the ancient Chinese game was previously considered a major challenge for artificial intelligence.
- In 2016, Hanson Robotics developed the first humanoid robot called Sophia, which was capable of facial recognition, verbal communication and facial expression.
- In 2018, Waymo launched Waymo One, a service that allowed users located in the metropolitan area of Phoenix, Arizona to use autonomous cars.
- In 2020, Baidu developed the LinearFold AI algorithm to help teams of researchers develop a vaccine against the SARS-CoV-2 virus. The algorithm is capable of predicting RNA virus sequence mutations in 27 seconds, that is, 120 faster than previous methods.

The effectiveness of artificial intelligence in many applications still relies on the computer's ability to learn from data provided by humans or other machines, including through deep learning. However, it must be made clear that so far, no universal learning algorithm has emerged to ensure effectiveness in all conditions and environments.

This publication focuses on specific opportunities for the use of artificial intelligence in education, understood in its broadest sense. According to the World Bank, Polish spending in 2018 on education accounted for 4.6% of GDP. A similar percentage characterizes most countries in the world. At the same time, the education sector is the sector of the economy that in many respects absorbs innovations at a slower rate than other sectors (e.g., health care, pharmaceuticals, IT, transportation, etc.).[2] The successes and undoubted progress in the development of artificial intelligence raise optimism and hopes about the possibilities of its use in the education sector. The potential spectrum of applications is extremely wide. The first association that comes to mind when considering the use of artificial intelligence is the replacement of the teacher by a robot that simulates a living human being in that role. This is probably the highest stage of artificial intelligence, which will be reached at a very late, rather distant stage in its evolution, since a robot in the role of a teacher must demonstrate an extremely broad, essentially complete spectrum of living human behavior (unlike, for example, a robot in the role of a flight controller or motor vehicle driver). The history of innovation development teaches us that new solutions usually "infiltrate" the area of their intervention gradually. For example, the first steam engine to propel a ship was installed in the 1820s, while the last commercial ships using sail propulsion disappeared from view in the oceans in the 1960s. It is likely that a similar situation will occur with artificial intelligence applications in the education sector: first there will be some less advanced solutions that do

[2] See OECD (2000). Knowledge Management in the Learning Society. Paris.

not offer significant advantages over humans, and then, over time and as the technology develops, they will become increasingly more effective. If we look at the Internet revolution from the perspective of its impact on the information sector, it is clear that the Internet was the first information medium that allowed the simultaneous offering of in-depth information (in the previous era, this was made possible by the book – thanks to the movable type printing technology invented by Gutenberg) and information available to a mass audience (in the previous era, this was made possible by television and radio – thanks to radio waves). We may be tempted to look for an analogy: artificial intelligence in the future will perhaps make it possible to offer quality education to a mass audience by means of algorithms simulating the most effective teaching strategies tailored to a particular student/learner. For this to happen, however, artificial intelligence has to "mature" intellectually. A less ambitious but more realistic goal is to create artificial intelligence algorithms that simulate the teacher's behavior in certain narrow areas, for example, in grading students' performance. It should be clearly noted that already at the current stage of algorithm development, there are many areas in which artificial intelligence is applied in education (some of which are discussed in this paper) that can and should be successfully used. In addition to the aforementioned specialization in narrow areas, there is great potential in those areas of a teacher's work that can be automated to relieve them of tedious and tiring bureaucratic tasks.

In this publication, authors specializing in various applications of artificial intelligence have shared with readers their knowledge and experience of various applications of artificial intelligence, with special emphasis on topics relating to the education sector. This book presents the first comprehensive study in Polish in this field. It certainly does not exhaust the depth and complexity of the issues. Its main purpose is first and foremost to draw the attention of policy makers, researchers, and perhaps most of all practitioners: Polish teachers, administrators, institutions involved in teacher training and in-service training, to the emerging, completely new area of challenges to education. These challenges, however, do not only relate to the broader organization of the work of educational institutions and their administrative backstop. Perhaps more important is the adaptation of the Polish education system to the challenges in the labor market and in the socio-economic environment associated with the development of Industry 4.0, of which artificial intelligence is an important component. Polish schools and universities should redesign/revisit their curricula and syllabi as soon as possible in order to prepare their graduates for the challenges of the Fourth Industrial Revolution, which is infiltrating our lives in more or less observable ways, at different paces depending on the sector of the economy.

This work is the result of many meetings and discussions held among all the authors throughout 2021. It contains a large component of theoretical and practical knowledge from various areas of the functioning of society and the economy, and shows the perspective of both those responsible for the organization of the education system and its beneficiaries, that is, society at large. The study is divided into four parts, each with separate chapters. The distinguished parts reflect different perspectives on the subject of artificial intelligence. At the end of the publication, the reader will find a glossary containing definitions of the concepts discussed. The glossary can be useful to both researchers of artificial intelligence and practitioners, who, as a result, will be able to systematize their knowledge and effectively popularize this topic.

On behalf of all the authors and other people involved in creating this publication, including the team of the Educational Research Institute in Warsaw, whose work was coordinated by Ms. Beata Balińska, I express the hope that this publication will contribute to the modernization of Polish education – to the benefit of our country and the prospects for its long-term development.

Scientific Editor
Prof. Jan Fazlagić
Poznań University of Economics and Business

Society and the State

Collaborative artificial intelligence. The example of virtual assistants and conversational AI

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Introduction

In recent years, there has been a significant simplification (the so-called low code and no code approaches[3] – as cited in Shaikh, 2020) of interfaces that allows artificial intelligence (AI) and machine learning (ML) to be built and implemented in various types of tasks without programming skills. This simplification is seen as an opportunity to make the use of artificial intelligence more widespread and, consequently, to democratize it.

This article will address the democratization of artificial intelligence and the dissemination of the ability to use it. This is related to the increasingly popular paradigm of creating artificial intelligence, which implies its close cooperation and even synchronization with humans. This paradigm is called "collaborative artificial intelligence" (Collaborative AI) (Koch, 2017; Koch & Oulasvirta, 2018), and it understands artificial intelligence not only as a powerful tool that humans can use to perform a variety of tasks, but with which they are also – or perhaps rather, primarily – able to productively cooperate. The largest number of examples of the simplification of artificial intelligence and interfaces enabling seamless cooperation with humans are found in the area of conversational AI, and this is what we will primarily focus on.

The article will also look at current development trends in artificial intelligence in the context of the labor market and professions of the future. In addition, emphasis will be placed on the digital skills needed to effectively use artificial intelligence in knowledge work. Today's popular virtual assistants and conversational artificial intelligence will be used as examples. This article will present the forms of conversational artificial intelligence currently the most widespread, the scopes of their use and the skills required to use them effectively both in professional life and in later stages of academic education, not necessarily directly relating to computer science and artificial intelligence.

Artificial intelligence and the labor market today and tomorrow

Artificial intelligence is classified as general purpose technology.[4] This is a term reserved to describe technologies that fundamentally transform our lives, that is, technologies such as the steam engine and the Internet causing significant and

[3] See https://towardsdatascience.com/top-8-no-code-machine-learning-platforms-you-should-use-in-2020-1d1801300dd0
[4] See https://warwick.ac.uk/fac/soc/economics/research/centres/cage/news/06-07-20-artificial_intelligence_as_a_general_purpose_technology_an_historical_perspective/

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widespread impact on society and the economy. AI has already and will undoubtedly continue to have a significant impact on how people live and work. The cumulative extent of the changes brought about by AI remains largely unknown, and thus often leads to alarmist, dystopian visions of a future without human labor, even though the annual rate of change, as far as the labor market is concerned, is unlikely to cause alarm bells to ring.

At present, AI cannot (and in a normative sense also should not) replace human workers, but it can increase their productivity and even satisfaction. Some researchers (Acemoglu & Restrepo, 2017) link the increased intensity of AI and robot use to reduced employment and wages, suggesting the need for a so-called universal basic income (UBI). In contrast, others argue that millions of jobs around the world will be rapidly automated, making many more jobs disappear than will be created (Furman & Seamans, 2019; Goolsbee, 2018). Some labor market transformation trend analysts agree with these otherwise grim visions, but others predict the opposite. AI will displace about one-third of existing jobs worldwide within a decade, with the United States (up to 40%) and Japan (50%) among the most affected. However, according to the OECD AI Policy Observatory, AI will create more jobs than it will eliminate. Companies that are pioneering the development and scaling of AI have so far not eliminated the net number of jobs. According to the OECD AI Policy Observatory, there is no indication that this trend will not continue in the foreseeable future. A recent report by Stanford University's Institute for Human-Centered Artificial Intelligence, talking about the transformation of work in the post-COVID era, comes to similar conclusions. This makes it all the more worthwhile to invest in digital skills that enable more effective use of AI.

Predictions of the future paths of AI development

Psychology (Conoley & Conoley, 2010) defines cooperation as "the act or process of two or more people working together to produce an outcome desired by all" or "an interpersonal relationship in which the parties demonstrate sensitivity to the needs of others." Cooperation in economic terms is defined as the ability to perform tasks and solve problems together as a team to achieve common goals (Barbara & Celebrate, 1989).

Collaboration, as a rule, is mainly between people, but it leaves room for technology as well. Cooperation between humans and machines can take many forms (Jemielniak & Przegalińska, 2020). For example, various tools designed and used for communication have long enabled contact at a distance (email, video conferencing tools or other technologies that enable telepresence, such as virtual reality). They are also becoming intermediaries of collaboration, allowing, among other things, joint, remote and often asynchronous project management (such as Slack and other messengers).

Today, however, we are entering the next level of human-machine collaboration. This happens when the system can produce synergies with humans: generate added value that would not be there if such collaboration did not occur. A proponent of the collaborative approach to AI, moreover, is Tom Malone of the MIT Sloan School of Management (Malone, 2018), an author whose work will still be referenced in this article and who, in his recent book *Superminds,* argues for the power of humans and machines working and thinking together. He believes that advances in artificial intelligence can bring about novel ideas and even solutions to the most pressing current problems. It is worth mentioning that the convergence of human and robot capabilities is also often discussed as a possible solution to the dystopian scenario showing that AI will annihilate humanity. This has been postulated by many prominent futurologists.

According to Malone's concept, AI should develop domain knowledge rather quickly and become expert in specific tasks. Equipped with such artificial intelligence, people would more effectively use their own talents, abilities and skills (including knowledge synthesis) to solve problems. For example, a recent experimental study showed that productivity increases when an assembly system is created in collaboration between humans and robots (Seamans & Raj, 2018; Manyika et al., 2017). More such examples can be found, such as systems supporting creative work (music composition, film script writing or drafting marketing campaigns), as well as intelligent systems used in factories.[5]

In the short to medium term, AI development will likely follow two distinct paths. The first is an extrapolation of what AI is today – highly specialized deep learning algorithms applicable to clearly defined problems in a more complex, contextual and nuanced way. The second path involves developing AI systems capable of processing information in a similar way to what the human brain does. Today, deep neural networks have become a key paradigm in AI thanks in part to an algorithm called backpropagation. Backpropagation allows deep neural networks to learn from data and thus achieve capabilities such as language translation, speech recognition and image classification. Narrowly specialized artificial intelligence is unlikely to affect the number of jobs per se, but like previous technological revolutions, it will bring about a profound change in the economy and redefine the very tasks facing workers, transforming business models and strategies as well as the ways in which various institutions operate.

The second path of development of biologically inspired AI has great potential to transform its capabilities and overcome its current limitations, creating more robust and complex systems capable of more abstract levels of reasoning. However, it remains in its infancy, and therefore many years away, and it is difficult – at least for now – to address how it will change the labor market and how it will affect the nature of the relationship between humans and technology. To do so would be pure speculation.

Types and applications of conversational artificial intelligence and NLP

Natural language processing and understanding (NLP and NLU) is a field at the intersection of artificial intelligence, computer science and linguistics, concerning the interactions between computers and human (natural) language, in particular the task of programming computers to process and analyze large amounts of linguistic data – mainly textual data in natural languages. NLP and NLU can accurately extract information and insights contained in documents, as well as categorize and organize the documents themselves, thematically segment the content they contain, etc.

[5] See https://www.ai4eu.eu/simple-guide-collaborative-artificial-intelligence

The challenges of natural language processing often involve speech recognition, natural language understanding and natural language generation. The goal of NLP and NLU is to create a system capable of contextual "understanding" of the content of documents, including the nuances of the language in them, and to converse freely with people. This is undoubtedly one of the fastest growing disciplines of artificial intelligence with huge potential for application in business, education, public administration or medicine. At the same time, it is a field in which no code and low code approaches are developing very rapidly, providing opportunities for people from different professions (for example, marketers, broadly defined content creators, market analysts) to quickly implement conversational AI. This can be seen especially in the example of applications for the use of so-called "transformers", which are described in more detail below. In addition, the sub-fields of the development of language processing and understanding and their corresponding algorithms, which, by the way, are sure to increase in the coming years, are presented in tabular form: from rule-based and AI-based chatbots, through recurrent networks and word embeddings, to the just-mentioned language transformers, which represent a kind of revolution in NLP and NLU.

Table 1. NLP fields and algorithms and their applications

Field	Application
CHATBOTS	Conversational bots (or chatbots) are a special type of software designed to assist white-collar brainworkers in office, managerial or administrative work (Przegalińska et al., 2019; Stojnić, 2015; Hong and Oh, 2020). Using advanced natural language processing techniques, multi-layered neural networks and extensive knowledge bases, they can extract meaning from unstructured data, build a knowledge base and perform selected, usually (though this will change in the future) narrowly defined tasks. Users communicate with bots via chat or voice commands. They are increasingly used in business to streamline various processes, especially those relating to customer service and personalization. Chatbots use the medium of chat in the form of social messaging, SMS messages, or chat windows on a website. They can be used for customer service, making reservations, paying bills, shopping online or interacting with brands and organizations. They can be used on websites, as well as in mobile apps and instant messaging. Chatbots can be programmed in different ways. The rule-based ones respond the same way every time, following a script. Chatbots based on machine learning algorithms (in particular, unsupervised learning and deep learning) are able to respond differently to messages containing certain keywords, and even adapt their responses to a specific context. Bots based on such algorithms, which allow both natural language processing and comprehension, can learn complex ways to simulate human conversation (managing the dialogue and adapting responses to the current course of the conversation). An AI-powered chatbot can also be trained to actively learn from any customer conversation and improve performance during subsequent conversations (Okuda and Shoda, 2018). Chatbots of this type can even recognize customer emotions (frustration or satisfaction) to some extent and redirect overly complex interactions to human client services (CS) specialists.

Table 1. NLP fields and algorithms and their applications (cont.)

Field	Application
	The first conversational type of chatbot was the ELIZA bot (Shah et al., 2016). It was designed in 1966 by Joseph Weizenbaum. Interestingly, the chatbot conducted several "therapeutic" conversations with patients, acting as a simulation of a Rogerian psychologist. The latest deep learning-based bots, such as Google's Duplex, a prototype for now, are so adept at interacting with humans that they are barely recognizable as machines, at least in short conversations.
RECURRENT NEURAL NETWORKS (RNN)	In text analysis (including handwriting recognition), language processing in general, and human speech synthesis, the use of machine learning algorithms, known as recurrent neural networks, has been very popular in recent years. Recurrent neural networks (RNNs) are a class of networks in which connections between nodes form a graph directed along a temporal sequence (Mikolov et al., 2010). This allows them to exhibit dynamic behavior over time, and this is very important when working with language. The key idea of recurrent neural networks is precisely the use of sequential information. In the case of a traditional neural network, we assume that all inputs (and outputs) are independent of each other, but in the case of language processing, this approach will not work. For example, wanting to predict the next word in a sentence, it is better to figure out which words came before it. RNNs get their name from the fact that they perform the same task for each element of the sequence, and the output always depends on previous calculations. We can also think of it that RNNs have a "memory" that captures information about what has been calculated so far and takes this into account in the next calculation (Graves et al., 2013). Among other things, these networks are used for a variety of time-series analyses, such as stock prices, but they have become popular primarily in broad natural language processing, including automatic translation, text-to-speech solutions and sentiment analysis. Of particular note in the context of RNNs are networks such as LSTM, a more detailed description of which is provided below in this table.
GENERATIVE PRE-TRAINED TRANSFORMER 3 (GPT-3)	Encoder-decoder networks are increasingly being used to work with natural language. An important area for their development at the beginning was machine translation, but currently they are already being used for text generation, including creative work such as marketing leads or blog title proposals, as well as in conversation with people. They are increasingly replacing classic chatbots in the latter role. Generative pre-trained transformer 3 (GPT-3) is an autoregressive language model that uses deep learning to create text deceptively similar to human-written text. It is the third-generation predictive model in the GPT-n series (and successor to the equally famous GPT-2), developed by one of the most pioneering companies in the artificial intelligence field, OpenAI. The full version of GPT-3 has a capacity of 175 billion machine learning parameters. GPT-3, which was introduced in May 2020 and was in beta testing as of July 2020, is part of the trend of natural language processing (NLP) and natural language understanding (NLU) systems relying on pre-trained linguistic representations. Prior to the release of GPT-3, the largest language model was Microsoft's Turing NLG, introduced in February 2020, with a capacity of 17 billion parameters – less than a tenth of GPT-3's capacity.

Table 1. NLP fields and algorithms and their applications (cont.)

Field	Application
	The quality of text generated by GPT-3 is so high that it can be difficult to determine whether it was written by a human, which has both benefits and risks. Thirty-one OpenAI researchers and engineers presented an original paper, dated May 28, 2020, introducing GPT-3. In their paper, in addition to pointing out the many advantages of the system, capable of highly contextual text analysis, conversation or music composition, they warned of the potential dangers of GPT-3. David Chalmers, an Australian philosopher, described GPT-3 as one of the most interesting and important AI systems ever produced. GPT-3 has been trained on hundreds of billions of words and is capable of coding in CSS, JSX, Python, among others. In addition to GPT-3, there is also GPT-J, an open source version of the transformer, published in 2021, which is currently being expanded all the time.
LONG SHORT-TERM MEMORY (LSTM) NETWORKS	Long short-term memory (LSTM) networks were invented by Hochreiter and Schmidhuber in 1997 (Hochreiter & Schmidhuber, 1997) and have set accuracy records in many application areas, mainly in speech prediction and sentiment analysis. Around 2007, LSTMs began to revolutionize speech recognition, outperforming traditional models in some speech applications. In 2009, the connectionist temporal classification (CTC)-trained LSTM network was the first RNN to win speech pattern recognition competitions. LSTM has also improved speech recognition, which uses an extensive, rich vocabulary, and has been successfully used in Google's Android system, among others. LSTM networks, moreover, have broken records in improved machine translation. Moreover, together with convolutional networks (CNNs), LSTM networks have improved automatic image signing. A particular example of an LSTM network is the gated recurrent unit (GRU) cell (Kyunghyun Cho et al., 2014). It is a simplified version of LSTM and very commonly used in text analysis.
OTHER TRANSFORMERS	T5 is a type of text-to-text transformer that can be trained to perform various tasks with a unified architecture, while Dall-E is an artificial intelligence program that creates images from text descriptions, shown by OpenAI on January 5, 2021. It uses a 12-billion-year-old version of the GPT-3 transform model to interpret natural language input and generate corresponding images. BERT (from Bidirectional Encoder Representations from Transformers), on the other hand, is the first of the transformers and, in this sense, a technically groundbreaking model for natural language processing (Devlin et al., 2018), built by the Google AI team. It is not uncommon for Google to emphasize the importance of BERT for contextual language understanding when analyzing page content or queries. BERT is a pre-trained platform that produced very interesting results in processing 11 assigned language tasks back in the beta stage. These tasks included, among others, semantic role labeling, text classification, predicting the next sentence, etc. It was originally trained primarily on the English-language Wikipedia. The counterparts of the BERT network in Polish, based, incidentally, on this transformer, are the RoBERTa Large and HerBERT models created by the Information Processing Center.

Table 1. NLP fields and algorithms and their applications (cont.)

Field	Application
	All transformers are already proving to be very useful as support for tasks in marketing (generating keywords and blog titles, as well as social media marketing campaign leads) and content creation in the broadest sense (poems, stories, essays, simple journalistic forms and social media posts), sentiment analysis in the context of users' perception of services and products, 24/7 conversations with customers, customer service, product recommendations, matching visuals to keywords, and even creating musical compositions. In the future, the range of their applications will undoubtedly expand, and thanks to simplified, user-friendly interfaces (among others, GPT-3 and AI 21 Labs already have one) that do not require coding, many professionals and specialists in various industries will be able to use them successfully (Floridi & Chiriatti, 2020; Branwen, 2020; Zhang et al., 2021). The Chinese Wu Dao system is also one of the latest developments in language and speech understanding. In June 2021, Beijing Academy of Artificial Intelligence (BAAI) launched Wu Dao 2.0, the successor to Wu Dao 1.0. Wu Dao is a language model that aims to surpass OpenAI's GPT-3 or Google's LaMDA (another powerful transformer) in operating human-level language. Wu Dao is trained on 4.9 terabytes of images and text.
WORD EMBEDDING	Word embedding is an effective and widely used NLP technique used for text analysis. Word embeddings are representations of words, usually in the form of a real-valued vector that encodes the meaning of a word so that words that are closer in vector space are mapped as those with similar meaning (Levy & Goldberg, 2014; Liu et al., 2015; Schnabel et al., 2015). Word embedding can be achieved by using a set of language modeling techniques and feature extraction from a word's semantic field.

Source: own elaboration.

Models using artificial intelligence and required skills

Recent significant advances in AI, deep learning, natural language understanding and machine vision have led to the development of new human-oriented collaborative systems (Haenlein & Kaplan, 2019). Systems such as AlphaStar, AlphaGo (Vinyals et al. 2019; Wang et al. 2016), OpenAI Five (OpenAI, 2018) and IBM Watson (High, 2012) have proven that in many cases, human-machine interaction should not be treated as competition and/or substitution, but rather as an area of potential collaboration, where human talent can be augmented by the computational intelligence of the machine.

This approach to implementing artificial intelligence in organizations and institutions, especially knowledge-based ones, is advocated by Professor Tom Malone (2018), cited above, who argues in his publications about the power of humans and machines working and thinking together. Malone believes that advances in artificial intelligence and connectivity will result in the emergence of novel ideas, and by creating a collective intelligence effect, it will be possible to discover ways to solve the most pressing current problems.

Malone distinguishes several models of cooperation between artificial intelligence and humans. Here we can talk about parallel work, independent work, as well as work on several "sections" of a single task or project. We can also talk about a situation of interdependence, such as when a decision made by an AI system (for example, in medical diagnosis) is supported by a doctor, who then verifies it. The most desirable and, according to Malone, achievable system would be full cooperation with artificial intelligence, producing synergistic effects. In such a variant, a human uses those dimensions of intelligence in which he or she excels, and his or her cognitive and decision-making horizon is supported by advanced, albeit specialized, artificial intelligence. Examples of such cooperation could occur in the case of systems based on advanced deep learning, such as AlphaGo or AlphaStar (these are also projects by OpenAI), which – despite competing with humans in strategy games – were able to identify new ways of playing, which humans could use as well.

Looking at the development of language processing and understanding, as well as conversational artificial intelligence, at least several levels of its use can be listed as well as their corresponding technical skills. The first of these is the basic skills of using tools and interfaces that do not require coding, corresponding to the "product" approach to artificial intelligence. Any person proficient with social media or applications will be able to use artificial intelligence in this regard. This is already evident from marketers using transformative solutions, such as the aforementioned AI21 Labs, or Facebook users applying the insanely simple Chatfuel[6] platform for building chatbots. At the second level, the basics of coding are already known (for example, in Python or Javascript) as are machine learning algorithms, including NLP algorithms, which allow the application of ML and NLP in various problem spaces. It will be possible here to use off-the-shelf platforms to an extended degree, and to some extent independently build and optimize AI tools, select the most appropriate algorithms for a given problem. The penultimate stage will be advanced NLU programming skills, which allow one to use all libraries and tools, including deep-learning (DL) to implement projects using AI. The final stage is developing AI and conversational AI tools from scratch, and having extensive knowledge and experience in algorithms for deep learning and reinforcement learning.

Table 2. Levels of competence and artificial intelligence development

Level	Type of skills
1	A basic level of using simplified interfaces that do not require programming.
2	Mastery of the fundamentals of programming and algorithmics to use available tools for developing ML models in various problem domains.
3	Advanced ML, NLP, NLU and DL programming skills used to implement scalable projects using AI.
4	Development of AI algorithms and their complete implementation.

Source: own elaboration.

[6] See https://chatfuel.com/?utm_source=google&utm_medium=cpc&utm_term=chatfuel&utm_content=526548124012|c&utm_campaign=Brand_Search|13442465223&gclid=Cj0KCQiA2sqOBhCGARIsAPuPK0g6Gk0padAwbn7IxedFeLQVqssYYG6F2vPB7IXCDwEPjSs5vNeY2I8aApgVEALw_wcB

Summary

Collaborative AI is a nascent field, in which artificial intelligence-based solutions useful at work are developed after human needs and competencies are identified. In designing the collaboration, it is assumed that humans and artificial intelligence systems should work together as partners to some extent. Currently, this is an emerging field of research, requiring the development of techniques, methods and components that enable humans and AI systems to work together effectively.

In particular, an AI system must be able to assess the current situation, observe users, anticipate their actions and needs, and act accordingly. These skills generally require a tightly coupled integration of perception and action, in which the human and AI system perceive and understand their partner and take appropriate action to achieve the goal. The further development of artificial intelligence in the context of collaboration with people, both in business and in institutions or public administration, will require a great many projects in which we determine exactly what type of support employees expect for specific, well-named tasks and what their digital skill level allows. It will also require building clear, and at the same time as individualized as possible, paths for increasing competence in the use of AI. Since 2020, which turned out to be a pandemic year, we have been undergoing a somewhat forced and accelerated digital transformation. The widespread use of artificial intelligence, especially – but not exclusively – in knowledge work, is its next phase.

In this context, it is important to emphasize that the no code and low code levels in particular are key to the spread of artificial intelligence in various fields and sectors. It is citizen developers, or "non-technical developers" or "citizen programmers" who are now coming to the forefront of the digital transformation. They are using simplified platforms to develop straightforward solutions for their teams and departments. Such simple solutions will find use in HR, finance, sales and marketing, legal, procurement and many other business functions. They do not, of course, replace the systemic solutions offered by IT teams, but they play a key role in prototyping specialized AI collaboration paths.

According to a 2020 McKinsey & Company study,[7] about 40% of tasks can be automated only if this is driven by employee demand. To realize the full potential of automation, "citizen developers" will enhance and popularize automation. In many cases, it turns out that the automations created by citizen developers for a specific team are applicable to the entire organization. To achieve this, organizations will need to invest in education and training. Some companies are even holding "botathons" (i.e., hackathons to create bots) to encourage employees to develop their own systems. There are a number of benefits to establishing a community of "developer citizens". If used effectively and developed in conjunction with a culture of learning and collaboration, non-technical programmers will lead the way in the future of AI and automation development.

[7] See https://www.mckinsey.com/featured-insights/future-of-work

Bibliography

Acemoglu, D., & Restrepo, P. (2017). *Robots and Jobs: Evidence from US Labor Markets*. https://doi.org/10.3386/w23285

Barbara, S., & Celebrate, M. (1989). *Collaboration*. https://www.wpcweb.org/wp-content/uploads/2019/11/Fall-2019.pdf

Branwen, G. (2020). *GPT-3 Creative Fiction*. https://www.gwern.net/GPT-3

Conoley, J. C., & Conoley, C. W. (2010). Why Does Collaboration Work? Linking Positive Psychology and Collaboration. *Journal of Educational and Psychological Consultation: The Official Journal of the Association for Educational and Psychological Consultants*, *20*(1), 75–82.

Devlin, J., Chang, M.-W., Lee, K., Toutanova, K. (2018). BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. *arXiv [cs.CL]*. http://arxiv.org/abs/1810.04805

Durall, R., Frolov, S., Hees, J., Raue, F., Pfreundt, F.-J., Dengel, A., Keupe, J. (2021). Combining transformer generators with convolutional discriminators. *arXiv [cs.CV]*. http://arxiv.org/abs/2105.10189

Elkins, K., & Chun, J. (2020). Can GPT-3 pass a writer's Turing test? *Journal of Cultural Analytics*. https://doi.org/10.22148/001c.17212

Floridi, L., & Chiriatti, M. (2020). GPT-3: Its Nature, Scope, Limits, and Consequences. *Minds and Machines, 30*(4), 681–694.

Fröhling, L., & Zubiaga, A. (2021). Feature-based detection of automated language models: tackling GPT-2, GPT-3 and Grover. *PeerJ. Computer Science, 7*, e443.

Furman, J., & Seamans, R. (2019). AI and the economy. *Innovation Policy and the Economy, 19*, 161–191.

Goolsbee, A. (2018). *Public Policy in an AI Economy* (No. w24653). National Bureau of Economic Research. https://doi.org/10.3386/w24653

Graves, A., Mohamed, A.-R., & Hinton, G. (2013). Speech recognition with deep recurrent neural networks. *2013 IEEE International Conference on Acoustics, Speech and Signal Processing*, 6645–6649.

Hecht-Nielsen, R. (1992). Theory of the backpropagation neural network. *Neural networks for perception* (pp. 65–93). Elsevier.

Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation*, *9*(8), 1735–1780.

Hong, H., & Oh, H. J. (2020). Utilizing bots for sustainable news business: Understanding users' perspectives of news bots in the age of social media. *Sustainability: Science Practice and Policy*, *12*(16), 6515.

Jemielniak, D., & Przegalińska, A. (2020). *Społeczeństwo współpracy*. Wydawnictwo Naukowe Scholar.

Karita, S., Chen, N., Hayashi, T., Hori, T., Inaguma, H., Jiang, Z., Someki, M., Soplin, N. E. Y., Yamamoto, R., Wang, X., Watanabe, S., Yoshimura, T., Zhang, W. (2019). A Comparative Study on Transformer vs RNN in Speech Applications. *2019 IEEE Automatic Speech Recognition and Understanding Workshop (ASRU)*, 449–456.

Koch, J. (2017). Design implications for Designing with a Collaborative AI. *2017 AAAI Spring Symposium Series*. https://www.aaai.org/ocs/index.php/SSS/SSS17/paper/download/15382/14577

Koch, J., & Oulasvirta, A. (2018). Group Cognition and Collaborative AI. In J. Zhou and F. Chen (Eds.), *Human and Machine Learning: Visible, Explainable, Trustworthy and Transparent* (pp. 293–312). Springer International Publishing.

Levy, O., & Goldberg, Y. (2014). Dependency-based word embeddings. *Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, 302–308.

Liu, Y., Liu, Z., Chua, T.-S., & Sun, M. (2015, February 19). Topical Word Embeddings. *Twenty-Ninth AAAI Conference on Artificial Intelligence*. https://www.aaai. org/ocs/index.php/AAAI/AAAI15/paper/viewPaper/9314

Malone, T. W. (2018). *Superminds: The surprising power of people and computers thinking together*. Little, Brown.

Manning, C., & Schutze, H. (1999). *Foundations of Statistical Natural Language Processing*. MIT Press.

Manning, C. D., Surdeanu, M., Bauer, J., Finkel, J. R., Bethard, S., & McClosky, D. (2014). The Stanford CoreNLP natural language processing toolkit. *Proceedings of 52nd Annual Meeting of the Association for Computational Linguistics: System Demonstrations*, 55–60.

Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., Ko, R., & Sanghvi, S. (2017). Jobs lost, jobs gained: Workforce transitions in a time of automation. *McKinsey Global Institute*, *150*. https://www.voced.edu.au/content/ngv:78297

McAfee, A., & Brynjolfsson, E. (2016). Human Work in the Robotic Future: Policy for the Age of Automation. *Foreign Affairs*, *95*(4), 139–150.

McAfee, A., & Brynjolfsson, E. (2017). *Machine, Platform, Crowd: Harnessing Our Digital Future*. W. W. Norton and Company.

Mikolov, T., Karafiát, M., Burget, L., Cernocky, J., & Khudanpur, S. (2010). Recurrent neural network based language model. *Interspeech*, *2*, 1045–1048.

Okuda, T., & Shoda, S. (2018). AI-based Chatbot Service for Financial Industry. *Fujitsu Scientific and Technical Journal*, *54*(2), 4–8.

Przegalinska, A., Ciechanowski, L., Stroz, A., Gloor, P., & Mazurek, G. (2019). In bot we trust: A new methodology of chatbot performance measures. *Business Horizons*, *62*(6), 785–797.

Schnabel, T., Labutov, I., Mimno, D., & Joachims, T. (2015). Evaluation methods for unsupervised word embeddings. *Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing*, 298–307.

Schrittwieser, J., Antonoglou, I., Hubert, T., Simonyan, K., Sifre, L., Schmitt, S., Guez, A., Lockhart, E., Hassabis, D., Graepel, T., Lillicrap, T., & Silver, D. (2020). Mastering Atari, Go, chess and shogi by planning with a learned model. *Nature*, *588*(7839), 604–609.

Seamans, R., & Raj, M. (2018). *AI, Labor, Productivity and the Need for Firm-Level Data* (No. w24239). National Bureau of Economic Research. https://doi.org/10.3386w24239

Shah, H., Warwick, K., Vallverdú, J., & Wu, D. (2016). Can machines talk? Comparison of Eliza with modern dialogue systems. *Computers in Human Behavior, 58*, 278–295.

Shaikh, K. (2020). AI with Low Code. In Demystifying Azure AI (pp. 151–182). https:// doi.org/10.1007/978-1-4842-6219-1_5

Stojnić, A. (2015). Digital anthropomorphism: Performers avatars and chat-bots. *Performance Research, 20*(2), 70–77.

Tegmark, M. (2017). Life 3.0: *Being Human in the Age of Artificial Intelligence*. Knopf Doubleday Publishing Group.

Zhang, D., Mishra, S., Brynjolfsson, E., Etchemendy, J., Ganguli, D., Grosz, B., Lyons, T., Manyika, J., Niebles, J. C., Sellitto, M., Shoham, Y., Clark, J., & Perrault, R. (2021). The AI Index 2021 Annual Report. *arXiv [cs.AI]*. http://arxiv.org/ abs/2103.06312

The development of artificial intelligence as a challenge for the education system

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Introduction

By design, artificial intelligence (AI) is supposed to help humans understand the world, reason, plan, communicate and perceive. Thus, it is supposed to be an enhancement of human intelligence and to replace humans where their cognitive abilities are insufficient to achieve expected goals. However, when discussing artificial intelligence and its applications in the education system, we should take into account the fact that the education system relies heavily on *shaping human intelligence*. Thus, a kind of dilemma arises: can and should artificial intelligence intervene in the process of shaping human intelligence? What might be the long-term, deferred effects of such a process? What might society look like 50 years from now, in which human intelligence (whatever that will mean 50 years from now) will be a sort of product produced by the artificial intelligence used in the education system for teaching? Will the student "unburdened" by artificial intelligence actually *benefit* from such a solution? Or, on the contrary, is it likely to be counterproductive to apply to the education system the philosophy of using artificial intelligence in business, which is based on relieving humans of burdens? If artificial intelligence is supposed to facilitate business-customer interactions, is it desirable to apply the same approach to the education system-student interaction? The philosophy behind providers of AI solutions emerging for business needs may prove useless or even harmful if unreflectively applied to the education system. That which is "optimization" and "efficiency enhancement" in business does not necessarily mean the same for the learning process, e.g., teaching poetry or instilling a love of art will not be more effective if the learner learns about twice as many artistic works in a unit of time.

The purpose of this chapter is to review the possibilities of using artificial intelligence in the education sector, as well as the opportunities and risks associated with them. The education sector can undoubtedly prove to be a beneficiary of artificial intelligence, but its specific character, particularly its *mission,* should be taken into account at the very early stages of the introducing innovative solutions. Most artificial intelligence solutions are developed to commercially benefit those who use it. Artificial intelligence should help optimize price offerings, routes in the logistics network, energy management, etc. The risks and pitfalls of applying AI solutions in the education system are also discussed here.

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The importance of using artificial intelligence in the education sector

Artificial intelligence is considered to be one of the most important technologies of the future (European Parliament, 2020). The Committee of the Council of Ministers on Digitalization adopted the *Policy for the Development of Artificial Intelligence in Poland from 2020*. The document sets forth activities and goals for Poland in the short term (until 2023), medium term (until 2027) and long term (after 2027) (Republic of Poland, 2021). Among the six areas, the document lists education: "AI and education – actions taken from primary education up to the university level – programs of courses for people at risk of losing their jobs due to the development of new technologies, educational grants." The description of this area primarily mentions education as a form of human capital development for the economy. On the other hand, there is no indication or reference to the possibility of using artificial intelligence in the education system, for its modernization, improvement, etc. However, it can be assumed that the postulate or challenge of introducing artificial intelligence into the education system can be partially fulfilled in the other areas of the policy document, such as:

1. AI and society – activities to make Poland one of the main beneficiaries of a data-driven economy, and Poles a society aware of the need to continuously improve digital competence;

2. AI and innovative companies – support for Polish AI companies, including establishing mechanisms for financing their development, cooperation of startups with the government;

3. AI and science – support for the Polish scientific and research community in designing interdisciplinary challenges or solutions in the field of AI, including activities aimed at preparing a cadre of AI experts.

A cursory analysis of the frequency of the occurrence of the phrase "artificial intelligence" with collocutors describing various possible industry applications of artificial intelligence shows that against the background of selected industries, the popularity of the phrase on the Internet varies, and "artificial intelligence in education" is definitely more frequent in the context of "education" than, for example, "e-commerce" (Table 3).

Table 3. Number of hits in the Google search engine for selected terms relating to artificial intelligence

Search term	Number of hits (February 7, 2021)
Artificial intelligence	152,000,000
Artificial intelligence in education	1,480,000
Artificial intelligence in medicine	1,100,000
Artificial intelligence in pharmaceutical industry	620,000
Artificial intelligence in ecommerce	604,000
Artificial intelligence in logistics	313,000
Artificial intelligence in city management	3 (sic!)

Source: own elaboration.

A report by the Ministry of Digital Affairs presents a proposed research map for artificial intelligence. The map is divided into several categories (Ministry of Digital Affairs, pp. 71–77):

- language and speech
- machine vision
- medical applications
- robotics and control
- privacy and data security
- materials technologies

Education is not explicitly mentioned among the categories mentioned above in the context of advanced scientific research on the application of artificial intelligence in teaching, that is, to partially or fully take on the role of a teacher. Artificial intelligence in the context of education appears in the document primarily as a challenge relating to the training of specialists and the development of human capital in our country allowing companies to create artificial intelligence solutions. Users of AI-based technologies also need the right competencies to appropriately apply new technologies. Technology, especially AI, requires us to redefine the division of competencies.

The challenges of using educational theory in developing artificial intelligence algorithms

The use of artificial intelligence in education is probably fraught with a greater set of risks than in other areas. If artificial intelligence wrongly advises a buyer to purchase a piece of furniture from an online store, the consequences of such a purchase will be relatively harmless compared with the introduction of an ill-designed teaching algorithm in school. The risks of developing inappropriate algorithms can be divided into the following categories:

1. The risks associated with the use of the wrong or incorrect theory;

2. The risks associated with negative side effects or unintended consequences of the AI-driven learning process;

3. The risks associated with the incorrect inference by the algorithm and application of inappropriate tasks for the student..

Two examples of risks in the first and second categories will be described below.

An example of the risks associated with negative side effects or unintended consequences of an AI-driven learning process:

The famous 20th century philosopher and thinker Erich Fromm described the so-called "doctrine of effortlessness and pain" in his book *The Art of Being* (Fromm, 1992). He stated that people have come to believe that everything, even the most difficult skill, should be mastered without difficulty or with minimal effort. In his opinion:

> …This doctrine is so popular that it hardly needs a lengthy explanation.
> Take our entire method of education. We persuade our young people, we actually beg them, to get an education. In the name of "self-expression," "anti-achievement," "freedom," we make every course as easy and pleasant as possible. The only exceptions are the natural sciences, where real achievement is intended and where one cannot master the subject in "easy lessons". But in the social sciences, art, and literature courses and in elementary and high schools, the same tendency is present. Make it easy and take it easy! The professor who insists on hard work is called "authoritarian," or old fashioned. (…)
> Related to the no-effort doctrine is the no-pain doctrine. This, too, has a phobic quality: to avoid under all circumstances pain and suffering, physically and, particularly, mentally. The era of modern progress claims to lead man into the promised land of painless existence. In fact, people develop a kind of chronic phobia of pain. Pain is referred to here in the broadest sense of the word, not merely physical and mental pain. It is also painful to practice musical scales for hours every day, to study a subject that is not interesting yet is necessary for acquiring the knowledge one is interested in; it is painful to sit and study when one would like to meet his girlfriend, or just walk, or have fun with friends (Fromm, 1992, pp. 25–26).

Studies of artificial intelligence are invariably dominated by the theme of "facilitation" and "optimization" (which is in line with Fromm's doctrine of "without toil and pain" described above). Artificial intelligence is inextricably associated with lowering the level of effort. However, there is a thinking trap involved, because at the neuronal level, learning is associated with the expenditure of energy (i.e., effort). Thus, it can be said that there is a fundamental discrepancy between the goal of using artificial intelligence, which is to reduce human effort, and the biological requirement to engage effort in the learning process. This dilemma can only be partially resolved by creating an environment that engages the learner (gamification).

However, life does not consist only of pleasant situations. Human beings are also forced to struggle with problems that do not give them satisfaction (as is the case with gamification). The challenge, then, is how artificial intelligence would simulate such situations, preparing the student for them. Grappling with and experiencing one's own weaknesses is an immanent feature of the learning process. AI could certainly also incorporate such variables into its algorithms. But how to teach that the world is not always fair? A perfectly objective and world-neutral AI? Or rather, an AI that simulates the imperfections of a "live" teacher, which are, after all, also part of preparing for adult life? It is worth considering, however, whether, in fact, artificial intelligence, through the various kinds of facilitation offered to learners, does not actually disrupt the context of education, which has historically been about overcoming barriers and challenges. For example, an educational program using AI Kidsense (Irvine, California) allows a child's speech to be transcribed into text for note taking. The challenge here is the difficulty of understanding the speech of young children. So the software is able to understand a toddler's unclear speech. But the question arises, how will such a solution affect the child's development? We do not have the results of a study on this subject, but we can hypothesize. In the days when there was no such software, the child developed its ability to communicate by receiving feedback from the environment. By sensing which words and utterances were understandable to the environment and which were not, it spontaneously tried to be more understandable to caregivers, to improve its pronunciation, to adapt to the expectations of the audience. The child learning to speak also felt the "pain" of being misunderstood in the learning process. Therefore, won't Kidsense programming cause harm to the child's development? In the extreme case, we can imagine children who will grow up to be babbling adults, or at least adults with serious speech defects.

Another example showing the potential risks of using AI in education is illustrated by the QUIZLET films of the Quizlet Learn educational program (San Francisco, California). They assist learners in synthesizing the material being studied (literally helps take the guessing out of what to study). This platform, using machine learning and data from millions of lessons (study sessions), points learners to the most important material. Again, this raises the question: To what extent does broadly relieving and helping students really serve to develop their cognitive competence? Case in point: what will the world look like in which adults will not be able to find the right information in the surrounding world on their own, because this task was done for them by artificial intelligence during their formal education? Such an approach is a simple way to stifle the development of creativity in a student. Exam preparation software used in this way will, for example, omit facts from the biographies of inventors, which may be useful in life, but not necessarily in passing an exam (will an electrical engineering student preparing for an exam on the principles of generating alternating current be interested in the fact that Nikola Tesla was an emigrant, a follower of the Orthodox religion and spoke with a strong Slavic accent in conversations with Thomas Edison about the superiority of alternating current over direct current?). One can perfectly understand the essence of information redundancy by watching the movie *Slumdog Millionaire* (Celador Films&Film4 Productions, 2008), in which the main character wins the top cash prize in a quiz because he has encountered all sorts of events in his life during which he acquired "useless"/redundant knowledge in various fields, for example, learning the first name of the inventor of the Colt revolver (Samuel). It is likely that in a course on the history of weapons development at a military academy, an artificial intelligence, preparing a student for an exam, would skip the information about the revolver inventor's first name because, after all, passing the exam would not depend on it. However, in an optimistic scenario, the artificial intelligence algorithm teaching about Samuel Colt's revolver discovered that the student was studying English intensively and prompted him that *colt* means "a male foal" in English. The ability to recognize and remember associations between thematically distant information is one of the characteristics of creative people. It results from a person's unique experiences, which can be traced to their neuron connections in the brain. In the literature on creativity, this is called convergent thinking (see Cropley, 2006, among others).

An example of the risks associated with using the wrong/incorrect theory:

Another challenge in creating artificial intelligence algorithms for learning is personalization, i.e., adapting the learning process to the specific characteristics of the individual learner. The idea of personalizing learning is not new. However, before algorithms are created to personalize the learning process, it is necessary to take into account the results of scientific research on the effectiveness of this concept. The concept of learning styles is very popular among teachers around the world. Coffield et al. (2004) described as many as 71 different concepts relating to learning styles. The first researchers to put forward the theory of learning styles were R. S. Dunn and K. J. Dunn (1999). They explained that the distribution of the processes of concentration, processing, absorption and memorization of information varies in different people. The division of people by different types has an even longer history and goes back to the psychologist Carl Jung. Kolb (1984) also wrote about learning styles as part of the four-phase learning cycle theory. However, the issue of not matching the right teaching style with expectations from students (mismatch) is indeed a real phenomenon that needs to be taken into account. Matching the style of knowledge transfer with student expectations significantly improves learning outcomes (Reid, 1987; Peacock, 2001; Bristow et al., 2014). Dunn (2009) outlines five stages of training athletes to improve their sports performance and skills:

1. Assessment of learning competence on the part of the coach and the athlete, reflection on the relative successes attributable to the training methods used to date;

2. Reflection on the effects of the training methods used so far;

3. Development of various methods;

4. Relating and selecting appropriate training methods to the athlete's preferences;

5. Evaluation of the relative positive impact of the new methods on the athlete's performance..

This five-step process proposed by Dunn (2009) has very high potential for use when developing algorithms for artificial intelligence in the field of education. Discussing the topic of learning styles is relevant to the application of artificial intelligence in education also because current and future solutions in this area will certainly relate to the current state of scientific knowledge, in this case in pedagogy and psychology. The use of inappropriate theories or those that lack empirical justification can be detrimental. For example, the book entitled *50 Myths of Popular Psychology* (Lilienfeld et al., 2011) presents theories that have one thing in common: they are very popular among education practitioners while having very little grounding in the findings of scientific research to support their validity. Thus, there is a real danger that with the development of artificial intelligence in the field of education, algorithms based on fundamentally false theoretical assumptions will be created. A topic for a separate discussion among mathematicians and computer scientists is whether an artificial intelligence algorithm based on false premises will be able to "self-reflect"/correct itself. This is a question similar to whether a chess-playing algorithm, which contains sequences of moves that lead to a losing game, will be able to improve its performance on its own, contrary to the intentions of the algorithms' creators, that is, de facto undermine the theory on which it was based. However, an ethical dilemma arises here as well: if an artificial intelligence algorithm loses a game of Go against a human, will it be a moral loss for the computer science team? If, on the other hand, an algorithm instructing a student, due to the wrong assumptions programmed into it, teaches the student badly, then the consequences will be much more serious. For example, an artificial intelligence algorithm based on the false assumption that "we use only 10% of our brain's potential" will not be able to provide an optimal teaching process.

The problem with studying students' preferences is that the assessment of learning styles in psychological research is done rather superficially. The subjects express themselves by answering questions such as: "I prefer...", "I learn best by/when...". However, most people do not have an educated opinion about how they learn. Every person is different – that goes without saying. The issue under scrutiny here is about something else: namely, does adapting teaching methods to individual "learning styles" have a positive effect on learning outcomes? Artificial intelligence could overcome this weakness by analyzing students' behavior and reactions in different situations. Perhaps it would even allow for a new theory of personalization in education. To prove or disprove the effectiveness of the concept of learning styles, scientific experiments have been conducted. Such experiments divided participants based on their "learning style". At the second stage of the experiment, they were randomly assigned to groups in which the teacher applied one of the learning styles. In such an experiment, in order to prove the effectiveness of the concept of learning styles, visual learners assigned to a group in which the teacher used teaching methods designed for visual learners should score higher than other learners, such as auditory learners. Of some 24 different research studies, only three saw any weak positive relationship. In contrast, there are a great number of well-documented studies clearly showing that there is no empirical evidence for anything like "learning styles".

Overview of AI applications in education

There is an ongoing debate about whether artificial intelligence will replace the teacher. On the other hand, the number of potential applications of artificial intelligence in the education system is much broader than just "replacing the teacher".

AI can act as both an autonomous teacher and a human-teacher assistant in the teaching process. We should not limit the field of applying artificial intelligence in the education system to activities oriented only directly to the student. On the contrary, artificial intelligence is not only able to replace the teacher, introduce mechanized elements into the learning process, but it can also help manage the student's educational back-office.

Artificial intelligence that meets the demands of personalizing learning can produce "individualized information bubbles" for each student, causing the foundations of social cohesion to be disrupted. Take, for example, the teaching of humanities subjects. If, as outlined above, we assume that artificial intelligence should first diagnose the student and develop the most effective and person-specific teaching algorithm, what would teaching Polish history look like? Should the algorithm present different students with differentiated facts of our history illustrating a given event? For example, dozens of history books have been written about the Battle of Grunwald – which of the many facts should be presented to a student to consolidate the general information about the event? Shouldn't a student with potentially right-wing views (for more on this, see Haidth, 2014) learn certain facts about the Battle of Vienna, because otherwise he/she could become an Islamophobe in the future? (Al-Marashi, 2019).

AI can help teachers detect learning problems in students, adapt material to individual student needs, or simply be used for grading. AI can also help manage lessons and the education system, for example, by predicting certain trends, student behavior and phenomena in advance. AI can help analyze student progress in real time and make recommendations on how to behave toward specific students. Table 4 provides an overview of the potential applications of artificial intelligence in the field of education. Among the applications, several subcategories are distinguished:

- Artificial intelligence to support the learning process,
- Artificial intelligence to support the teacher in administrative processes,
- Artificial intelligence to support the management of school education at its various levels..

This systematization is important because it helps guide further research work and artificial intelligence development strategies at the level of the solution provider. Each of the above-mentioned applications has the potential to improve the situation of students, but from a different perspective.

Table 4. A review of the possible applications of artificial intelligence in education

Application	Description
Artificial intelligence to support the learning process	
Artificial intelligence as a teacher's assistant	Artificial intelligence can act as a coach/tutor. AI is better at educating the basics of given knowledge disciplines, and for the time being is not capable of developing higher-order skills in a student, such as unity of thought and creativity. However, it cannot be ruled out that in the future, AI educational programs will also be able to develop higher-order skills. When assessing the reliability of the results of educational experiments, one must keep in mind the existence of the confirmation effect. Researchers tend to subconsciously conduct an experiment in such a way as to confirm their expectations. In addition, in social research, the reliability of the results is achieved by repeating the experiment many times. This is something teachers are unlikely to practice. Artificial intelligence, in principle, should be devoid of the ability to fall into the traps of characteristically human thinking, so in this sense it has an advantage over a live teacher.
Artificial intelligence as a substitute teacher	There are already solutions that enable smart teaching – smart tutoring systems (e.g., Carnegie Learning). These include Amazon's Alexa, Apple Siri, Microsoft Cortana, among others. Voice assistants allow a student to have a conversation about the material covered without involving the teacher. Voice assistants are also being used by educational institutions to provide students with information of an organizational nature. Arizona State University's Cognilytica, for example, offers a first-year student handbook using Amazon Alexa software.
Artificial intelligence as a space that provides emotional safety in the process of educational failure	Learning is inextricably linked to trying and failing in the process. A traditional school has many social and emotional barriers that discourage students from trying. As a result, the learning process is less effective due to fear of public ridicule, for example. Therefore, the opportunity to train one's skills in isolation and the intimacy provided by AI can itself prove to be an advantage over student work in the classroom and/or in the presence of a teacher.
Application to individual student needs (personalization)	The teaching and learning system in a traditional school is inherently biased toward averaging and standardizing the learning process. Artificial intelligence offers opportunities to personalize the learning process. Personalization should focus on detected knowledge deficits, which in a traditional classroom may be neglected by the teacher in a compromise to meet the learning needs of the other students in the class. Artificial intelligence can, for example, increase the intensity of test tasks in areas it deems in need of improvement and decrease the number of test tasks in areas that the student has already mastered. In this way, the total balance of time spent on testing can be equal for many students in a class, while the structure of test tasks will vary. This approach has allowed society to transform more quickly from an agrarian economy to an industrial economy. This has been followed by other countries around the world.

Table 4. A review of the possible applications of artificial intelligence in education (cont.)

Providing feedback	Teachers in the classroom often don't have enough time to give feedback to students on their learning progress and knowledge and skill deficits. Artificial intelligence can solve this problem. Analyzing knowledge deficits against a library of feedback can allow AI to produce personalized, reliable and detailed feedback in a given area. An additional advantage of using AI can be to deprive it of the charge of subjectivity ("the teacher doesn't like me, that's why I got a one"). If the student cooperates with AI, then, based on the historical data collected, AI can help the student make decisions regarding the choice of future educational stages. A separate issue is the fairness of the feedback. An AI algorithm can be expected to be fair and objective, while a "live" teacher is not always able or has the desire to give fair feedback. Although the teacher is acting unethically, as a by-product, the young person is being prepared for life in a world of injustice and deception. So can this function also be simulated with artificial intelligence? Theoretically yes: one can program an algorithm in such a way that it discriminates against certain criteria – but this will cause even more moral problems than the unethical behavior of a teacher.
Artificial intelligence to support teachers in administrative processes	
Assessing students	Artificial intelligence can ease the burden on teachers in the grading process. Grading can be either fully automated (test-based grading) or partially automated, e.g., AI can analyze student performance and make suggestions to teachers, but leave the final decision to teachers themselves. The development of systems for qualitative analyses of student work can be expected in the future. Other related tasks that AI can perform include grading at the end of the semester, completing reports and employment paperwork, preparing study materials, organizing school trips, communicating with parents, solving the problems of foreign students, sick leave issues and others. Teachers devote a considerable amount of their time to tasks unrelated to direct work with students. Therefore, relieving them of such tasks can automatically translate into an increase in the efficiency of the educational process if the time saved is allocated to teaching or leisure. The burden of administrative tasks also has a significant impact on the level of motivation to work and often results in professional burnout. Artificial intelligence can also provide information about who a teacher should meet with and on what issue.
Checking students' attendance and activity	This is one of the simplest tasks that uncomplicated software can perform.
Methods support	The system can support the teacher in the teaching process. For example, if AI detects a disproportionately high number of erroneous student responses in a particular area, it can make suggestions for improvement to the teacher, or provide the content knowledge that needs to be passed on to students. At present, a teaching methods advisor is a teacher appointed by the education superintendent administering the region where the advisor is to work, after said superintendent secures the agreement of the head of the educational facility where the teacher is employed. The functions of a methods advisor could be replaced in the future by AI.

Table 4. A review of the possible applications of artificial intelligence in education (cont.)

Relationship management	Teachers are required to maintain an ongoing relationship with parents. AI could take some of this work out of teachers' hands, especially if AI allows the provision of direct feedback about a student to parents without involving the teacher.
Artificial intelligence to support the management of school education at its various levels	
Teacher assessment	Education systems in many countries around the world have implemented various types of guidelines for teacher assessment and promotion. These are based on an analysis of certain predefined teacher achievements and activities. As is the case with student assessments, here, too, artificial intelligence could evaluate or provide information to those assessing a teacher. By linking – within the framework of appropriate algorithms – information about students' learning progress (educational added value) with the results of the analysis of a teacher's engagement with the school's work, cooperation with other teachers and the local community, the algorithm could give periodic assessments to teachers in an objectified way. They would be potentially devoid of the factual or political elements that often accompany the work of a teacher. As a result, objectified teacher assessments in the education system could lead to an overall increase in the quality of teaching, if the influence of merit factors on the professional situation of teachers in the system could be eliminated.
Analyzing large datasets in the education system	Special algorithms analyzing data on student behavior could provide evidence useful to optimize the process of resource allocation in the education system and help predict trends and mitigate risks, for example during the COVID-19 pandemic and similar crises. Equipped with such data, the Ministry of Education and Science could ascertain the magnitude of a possible drop in the quality of education caused by the pandemic. Research on education systems at the macro level has already been the subject of some studies, including by the CERI center at OECD. Through the use of artificial intelligence, the quality, scale and frequency of measurements could increase significantly. With such new developments there would be no need for teachers to participate in major assessment programs as the data would be readily available. Artificial intelligence could also answer many of the questions that are currently on the political agenda in Poland and abroad. In the case of Poland, for example, it could include the issue of whether raising/lowering the age of compulsory preschool education is beneficial or not for a child's emotional and intellectual development.
Data analysis at the level of education bodies and at the regional level	Analysis of variations among regions and at the level of large local governments (e.g., metropolitan areas) could allow for better resource allocations. For example, data on student and teacher behavior could be correlated within the AI algorithm with IT expenditures in education.

Source: own elaboration.

Summary

Because artificial intelligence exhibits many human characteristics, such as the ability to learn, think critically and solve problems, it raises many emotions. One of them is the fear that AI will replace teachers in the future. However, from today's perspective, AI should primarily focus on repetitive tasks. With it, teachers would be able to spend more time individualizing their approach to students, for example. A Polish teacher will not have to correct tests, because artificial intelligence will give feedback to the student more efficiently. Within the education system, it is also important to consider whether the retreat from standardizing the learning process that the potential use of artificial intelligence could provide has negative side effects. Schools and the education system are places where socialization occurs, the interactions between students allow them to get to know each other, create a common value system, sense of belonging. Culture is created in schools, something that binds society together. Culture is neither "right" nor "wrong" – unlike mathematics, artificial intelligence should therefore primarily focus on the formation of knowledge and skills that have an objective reference point.

This chapter provides an overview of the applications and challenges of using artificial intelligence in the education system. The particularities of the education system in relation to other sectors of the economy impose specific requirements on AI solution providers. The importance of ethical and moral aspects here is even greater than in the case of commercial activities, and the consequences of using inappropriate algorithms are also correspondingly deeper (especially since they can affect large populations of students), and their impact can be far-reaching.

Bibliography

Al-Marashi, I. (2019). The New Zealand massacre and the weaponisation of history, https://www.aljazeera.com/opinions/2019/3/24/the-new-zealand-massacre-and-the-weaponisation-of-history

Baumeister, R. F., & Tierney, J. (2013). *Siła woli. Odkryjmy na nowo to, co w człowieku najpotężniejsze*. Media Rodzina.

Bristow, E. C., Bruhl, J. C., & Klosky, J. L. (2014). Effect of Supplemental Instructional Videos on Student Performance in Engineering Mechanics Class. *International Journal of Engineering Education*, *30*(3), 566575.

Bozarth, J. (2018). *The Truth About Teaching To Learning Styles, And What To Do Instead?* The Learning Gild.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning. A systematic and critical review*. Learning and Skills Research Centre.

Cropley, A. (2006). In Praise of Convergent Thinking. *Creativity Research Journal, 18*(3), 391–404.

Dunn, R. S., & Dunn, K. J. (1999). *The complete guide to the learning styles inservice system*. Allyn and Bacon.

Dunn, J. L. (2009). Using learning preferences to improve coaching and athletic performance. *Journal of Physical Education, Recreation & Dance, 80*(3), 3037.

du Sautoy, M. (2020). *Kod kreatywności. Sztuka i innowacja w epoce sztucznej inteligencji*. Copernicus Center Press.

European Parliament (2020). *Artificial intelligence: threats and opportunities.* https://www.europarl.europa.eu/news/en/headlines/society/20200918STO87404/artificial-intelligence-threats-and-opportunities

Fromm, E. (1992). *The Art of Being*. The Continuum Publishing Company.

Haidth, J. (2014). *Prawy umysł. Dlaczego dobrych ludzi dzieli religia i polityka?* Smak Słowa.

Kolb, D. A. (1984). *Experiential learning*. PrenticeHall.

Lilienfeld, S. O., Lynn, S. J., Ruscio, J., & Beyerstein B. L. (2011). *50 mitów psychologii popularnej*. Wydawnictwo Cis.

Ministry of Digital Affairs (2020). *Założenia do strategii AI w Polsce*.

Peacock, M. (2001). Match or mismatch? Learning styles and teaching styles in EFL. *International Journal of Applied Linguistics*, *11*(1), 120.

Reid, J. M. (1987). The learning style preferences of ESL students. *TESOL Quarterly, 21*(1), 87111.

Republic of Poland Official Website (2020). *Rozwój sztucznej inteligencji w Polsce – ważna decyzja*. https://www.gov.pl/web/cyfryzacja/rozwoj-sztucznej-inteligencji-w-polsce--wazna-decyzja

Between artificial intelligence and "artificial creativity" – the future of the creative human in the age of artificial intelligence

Prof. Jan Fazlagić*

Introduction

The use of artificial intelligence by humans was predicted by futurologists and science fiction authors long before the advent of the Internet and computers with high computing power. Among the predictions about the use of artificial intelligence, there were many voices of concern and even fear about the spread of this technology. As of 2021, one can conclude that these fears were unfounded or at best premature. Solutions based on artificial intelligence, such as software that allows you to take perfect photos with your cell phone or a navigation assistant, make life easier for the average citizen. On the other hand, there are many well-known examples (some of which will be cited later in this paper) showing that having too little AI is a bigger problem than having too much of it. There is even a demand for technological solutions that are used to deliberately reduce the quality of products made by people, with the aim of increasing their "creativity" by intentionally giving them the characteristics of imperfection, such as the effect of an old movie (sepia and scratches on the picture, electric cars with speakers that simulate the sound of an internal combustion engine, etc.). On the one hand, artificial intelligence is an emanation of human intelligence, but on the other hand, as the use of AI for the game of Go has shown, AI can learn and become smarter than the best players (du Sautoy, 2020). Will this also happen with the use of AI in teaching? The most optimistic scenario foresees an algorithm that emulates a teacher, teaching faster, better, more of everything than what a "live" teacher teaches....

Given the number of challenges facing developers of AI solutions, it is worth considering the role of humans in relation to these solutions. For example, to what extent are humans and their creativity to become models for AI solution developers, and to what extent should AI development disregard the state of knowledge about how human creativity works. Will AI solutions developed to implement creative activities be more effective when they are based on the "scaffolding" of knowledge about human creativity, or is there greater potential in creating algorithms that disregard the mindset of the human creator? The purpose of this article is to reflectively analyze and forecast the directions of development of artificial intelligence in the area outlined by the questions above. The current state of knowledge on the definition of (human) intelligence, juxtaposed with the views of researchers on creativity, was chosen as the basis for these considerations. The first experiences of AI's attempts to emulate creativity are also analyzed.

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Artificial intelligence and artificial creativity

A good point in considering the possibility of using artificial intelligence to emulate human creativity is to compare the different understandings and interrelationships of the two concepts from the perspective of psychology. Artificial intelligence is the ability of machines to exhibit human skills such as reasoning, learning, planning and creativity (European Parliament, 2020). Artificial intelligence enables technical systems to perceive their environment, deal with what they perceive and solve problems by acting toward a specific goal. The computer receives data (already prepared or collected with its sensors, such as a camera), processes it and reacts. AI systems are able to adjust their behavior to some extent by analyzing the effects of previous actions and acting autonomously. Table 5 shows the current views found in the literature on the relationship between the two concepts. As we can see, there is no consensus in the scientific world on the position of creativity relative to intelligence.

Creativity can be divided into psychological and historical (du Sautoy, 2020). Historical creativity is something rare, referring to the creation of something for the first time in history. Psychological creativity, on the other hand, results from something being recognized by others as new and valuable. Psychological creativity is an act of discovery for ourselves, while historically it is nothing new. The third type of creativity is combinational creativity: it is the result of a process of the accumulation of small facts. The division into psychological, historical and combinational creativity is not ideal. Many inventions can be classified into each of these three fields simultaneously. For example, Gutenberg's printing press was a combination of technologies already known at the time, a manifestation of historical creativity, but also of psychological creativity.

Definitions of creativity are the Achilles' heel of creativity research (Puryear and Lamb, 2020). There is an ongoing dispute over what the relationship between creativity and intelligence is, for example. Since there is still no consensus on this issue, research on the use of artificial intelligence in education is also lagging behind, in the sense that, for the time being, they are unable to indicate what the relationship is between:

a) creativity,

b) natural (human) intelligence,

c) artificial intelligence.

Considerations of artificial intelligence in relation to creativity are of great importance for shaping strategies in the education system. The so-called "21st Century Skills" include competencies relating to both intelligence and creativity. Currently, the education system is based on the assumption that intelligence is the most important component of a person's intellectual potential and a determinant of the value of his/her work. However, if creativity is not a subset of intelligence, as some researchers claim, but a concept partially or completely autonomous from intelligence, we should radically reshape our education systems in the 21st century.

Table 5. The relationship between intelligence and creativity

Intelligence vs. creativity	Description of the relationship of both concepts	The main proponents of such an approach
Creativity as a subset of intelligence	According to Guilford, within the concept of creativity there are also concepts relating to intelligence, such as divergent thinking, multiple intelligences, and the use of intelligence in multiple ways, such as for the purpose of developing creative solutions. According to Gilford (1967), the quintessence of creativity is the ability to think divergently	Guilford, 1950; Guilford, 1967; Gardner, 1983; Kaufman, 2013
Intelligence as a subset of creativity	In cognitive processes, creative abilities are more important than intellectual abilities. The use of creativity necessitates the involvement of intelligence and other attributes. Therefore, intelligence is part of complex and multidimensional creative processes.	Smith, 1970; Sternberg and Lubart, 1996; Sternberg and O'Hara, 2000
Creativity and intelligence as sets with common parts	Creativity and intelligence are similar in many ways, sharing some common elements, but they also have elements that distinguish them from each other.	Naglieri and Kaufman, 2001 Plucker et al., 2004
Creativity and intelligence as synonymous concepts	The mechanisms describing the activities of creativity and the activities of intelligence are no different. In fact, creativity tests measure the ability of intelligence to produce above-average results.	Weisberg, 1993
Creativity and intelligence as separate sets	Creativity is not an ability, but the result of an autonomous area of the human mind. In this sense, intelligence has no effect on the ability to produce creative solutions.	Ericsson, 1976

Source: own elaboration.

It is worth noting that psychology distinguishes between a person's creative potential and creative achievements (Eysenck, 1995). It seems that the first attempts to use artificial intelligence for creative work can be equated with the assumption that creativity and intelligence are identical concepts. The problem is that, so far, attempts to use artificial intelligence to simulate human creative work are largely concentrated where high information-processing power gives a machine an advantage over a human, and are essentially akin to solving mathematical tasks (how to win at Go? Is there more green in Rembrandt than in Picasso?). For now, artificial intelligence can't invent a new philosophical trend, write a rousing speech for a head of state taking office, tell a joke based on last week's political events, and so on.

Opportunities and potential limitations of using the results of research on human creativity for the development of AI algorithms

Presenting a detailed review of research results on human creativity is beyond the capacity of this publication. However, it is necessary to clearly point out to the developers of AI algorithms the enormous potential that lies in emulating certain processes described in the psychology of creativity as the "raw material" needed to create effective algorithms designed to replace human creativity. As indicated by the results of experiments conducted in recent years (see du Sautoy, 2020, among others), developers of AI solutions are increasingly abandoning the strictly mathematical path of research and opening up to the knowledge of how creativity functions in society, how it is reflected in the lives of individuals and societies. The following is an overview of the opportunities as well as the limitations associated with using knowledge about human creativity for the development of synthetic creativity.

Opportunities and chances

1. *Audience simulation* – a large role is played by the environment (press, environment) in works on the activity of creative people. Studies of innovation (see, for example, Richardson, 1973; Porter, 1990; Polenske, 1997) discuss the role of social networks (industrial regions, the so-called "Medici Effect", etc.). This factor often significantly impacts the result of creative work. Emulation of this phenomenon is already in use: artificial intelligence can include two competing subsystems – a generator and a discriminator. In the case of creativity in works of art, the discriminator will be played by the algorithmic art historian (du Sautoy, 2020). The discriminator can also potentially play the role of a "business angel", VC funds (for creative business ideas) or a committee of experts (gatekeepers) (see also Perkins, 1981). The power of machine learning allows the development of an infinite number of dimensions that differentiate creative works. This allows artificial intelligence to combine these characteristics within different dimensions.

2. *Analyzing creative works* – artificial intelligence can be very helpful in analyzing the creative works of others. For example, by analyzing Van Gogh's paintings, we can determine which periods of his work were the most creative, what differentiates the paintings of various artists, etc.

3. *Simulation of emotions* – this refers to variables relating to audience reaction. The most important aesthetic qualities are novelty, surprise, complexity, ambiguity and forcing questions. The emotional reaction to a work of art is of extraordinary importance to its subsequent career or lack thereof. The so-called Wundt curve (Wundt and Titchener, 1904) depicts the bipolar distribution of a variable called "hedonic value". A positive hedonic value indicates positive arousal, while a negative one indicates boredom or disgust. Taking the variable into account in the form of the audience's expected reaction can also increase the creativity of creative activities.

4. *Simulation of style* – the literature presents many different types of models describing the (human) creative thinking process. Each of these models, such as

the Torrance Incubation Model (TIM) (Torrance, 1981) provides an interesting “scaffolding” for developing AI algorithms. If we look at the “5P” model describing creativity, we see that it provides a holistic view of the creative human being. According to this model, human creativity is the resultant of five elements: the person (Person), the outcome of the creative process (Product), the process (Process), the environment (Press) and the creative passion/motivation (Passion). Current algorithms deprive us of the opportunity to experience the style of the work being done. Unlike the insight obtained from Leonardo da Vinci’s sketches or Shakespeare’s notes, an algorithm working on a creative solution is puzzling and mysterious even to the very programmer who developed it. So it would be interesting to introduce solutions that would not only strive to produce creative effects (Product), but also be able to illustrate and make people curious about how the algorithm arrives at a given solution (e.g., through visualizations of commutative processes, etc.). In the case of “artificial creativity”, the creative process (Process) can, in addition to the actual work of the algorithm, extend to the work process of programmers. For example, when developing an algorithm for the Xbox device, a way had to be found for recognizing the position of a human silhouette. The creativity of the programmers manifested itself by coming up with the right question for the algorithm. The question was about depth relative to a neighboring pixel. The camera of the Kinect device provides data on the distance of an object from the camera. This allowed the computer to learn how to identify 31 parts of the human body (du Sautoy, 2020). According to Mihály Csikszentmihályi’s (1997) theory, creative activity can be explained using the concepts of individual, field and domain. An individual represents a set of personality traits, competencies and knowledge. The “field” is otherwise defined as the individuals or institutions that make up the environment in which the individual functions and his/her current, past and future works. Evaluators make judgments about the quality of an LED work. Often, the evaluation of a work is influenced by the creator’s judgment (hence, for example, blind review is used in scientific reviews to avoid the negative influence of this phenomenon). The domain of creativity can change over time. Sometimes cursory changes in the nature of a work can result in a change of domain in the opinion of the creator and/or his/her environment. For example, during the communist era, many universities had propaganda departments. Professors working on propaganda after 1989 continued their scholarly activity within the public relations domain. Outstanding artists are often responsible for creating a new domain or style of expression previously unknown to the world, as exemplified by the French Impressionists.

5. *Artificial intelligence as a tool for expanding areas of human creativity* – Prof. Marcus du Sautoy (2020) describes how a team of programmers developed the AlphaGo program for playing Go. The program defeated the world’s best player of the game. The key to the program’s success was its ability to learn. One of the lessons to be learned from this experience is that machines can push the boundaries of excellence. The conclusion drawn from the Deep Mind team’s experience is that artificial intelligence ultimately should not be used to replace human creativity, but to expand its areas. A similar application of artificial intelligence can be envisioned for education. It will not replace the

teacher, but will expand the spectrum of possibilities to influence the student in a sustainable way, in line with the goals of education.

Limitations and challenges

1. *The contribution of the social network and social environment* – the AI algorithm should exhibit empathy, which is possessed by developers who sense trends in the environment and build social networks and channels to feed in inspiration. The influence of the immediate environment is not insignificant either. Many artists created under the influence of various ideologies (e.g., social realism), which gave them inspiration and motivation. Other artists produced creative works because they cut themselves off from their roots and changed their thinking patterns. It is difficult to emulate these irrational processes. Creative work, like scientific work, should be considered a collective effort. Many creative works are syntheses of domains and currents of thought already in existence.

2. *The issue of the domains of creativity* – in general, people achieve creativity in one domain, but no longer in others. It is difficult to understand what makes one brain become a chess master and another a Nobel Prize-winning novelist (du Sautoy, 2020). That being said, it is also important to think about categorizing AI algorithms by domain. An algorithm that worked well in masterfully copying and painting Rembrandt's paintings is unlikely to work well in writing poetry. Most of the considerations in the literature on the use of AI algorithms and creativity focus on graphical aspects, such as analyzing photos, copying artists' images, and creating music. Humanity, however, has primarily developed through the creation of new ideas. It is currently difficult to imagine an algorithm that creates new ideas on the scale of those created by Confucius, Aristotle, Adam Smith or Karl Marx.

3. *The issue of varying the context of utilizing information* – algorithms that recommend movies, books or music that we might like should be flexible enough to respond to changes in our tastes. For example, if I purchase a piece of music from an online store, it doesn't automatically mean that I like that music (it could be a gift, a controlled purchase, a mistake, an interest in the artist rather than the piece, etc.).

4. *The existence of a number of social effects that influences the perception of the work* – for example, the disclosure of intimate details from the life of the artist. The art market has the so-called "death effect" – the value of a particular artist's works usually increases after their death (because the "supply" ends). In the case of the use of artificial creativity, there is no question of the death of the algorithm... unless a very advanced and "recognized" algorithm announces to the world that it will stop functioning (with the aim of increasing the value of its works – which it certainly has programmed into its procedures).

5. *Emotional reception of the work* – some works of objectively low value are highly appreciated by the public because of their sentimental message. For example, in Poland, the songs of the Swedish heavy metal band Sabaton are highly appreciated by the public because they portray the history of our

country in a positive light. Objectively speaking, the music is not particularly original, and the musicians of this band are not outstanding against the background of pop culture icons. However, the band has found a niche in pop culture of using historical and epic themes in its songs. In Poland, it has gained particular popularity because their songs promote the heroism of the Polish soldier, which is unknown to Western audiences. Thus, the broader context of the "consumption" of a creative work affects its perceived value.

6. *General lack of rationality of human behavior* – many research papers have been written on human irrationality, including within the field of behavioral economics (see, for example, Kahnemann, 2012). An algorithm that tracks interest in a given artist may overlook phenomena of this type because they are irrational. It is known that based on so-called blind tests, Pepsi-Cola often won among consumers over Coca-Cola. In contrast, the same product containing the Coca-Cola logo suddenly became preferred to Pepsi-Cola (a specific form of the halo effect, where the "halo" is the brand perception of the products). This effect is very difficult to reproduce in an algorithm. Algorithms that simulate creativity should take into account the bipolarity of preferences (that is, also information about what we dislike, what annoys us, what we want to avoid, etc.). For example, the loss aversion effect, well described in works on behavioral economics, refers to the disproportionately greater feeling of emotional pain resulting from a loss than from the emotional satisfaction provided by an analogous gain (a $10 loss is not equivalent to a $10 win). This phenomenon should also be taken into account when designing algorithms to help assess audience preferences.

7. *Discrimination in tastes* – our tastes and preferences are formed during adolescence. Exposure to different kinds of creative works is a learning process. Our family, friends and culture teach us what is attractive, original, unique. So it is worth considering what the world will look like in the future when we are surrounded by creative works produced by algorithms (if it comes to this). In addition to Leonardo da Vinci, will we also admire the works of various teams of programmers? How might the art market change (if works of artificial creativity begin to appear in public space) in areas such as forgery, studies of prominent artists' biographies, art valuation, art theft, etc.? The introduction of artificial creativity will also entail a reevaluation of intellectual property. In the case of artificial creativity, the work and the algorithm, and the creators of the algorithm, will be much more strongly linked than they are today. We will also have to look at issues of plagiarism differently. If an algorithm in the process of machine learning uses and analyzes the works of other creators, then in a sense it is plagiarizing (currently we call such a phenomenon at most belonging to the same school of thought or strands of creativity). Inspiration and imitation play an important role in the artistic process. However, it is difficult to draw a line between one's own creativity and copying the work of another. As du Sautoy (2020) notes, a film production studio hires creative teams for film productions but deprives them of copyrights to the final product, and takes ownership of the intellectual property rights. A movement has emerged in the UK to compensate the person who took the resources necessary to create the work.

8. *The question of the stability of tastes* – as du Sautoy (2020) predicts, our interaction with dynamic algorithms allows machines to constantly learn and adapt to our tastes. The question arises, however, whether artificial creativity, constantly "getting along" with us, will not disrupt the process of consuming creative works? For example, won't it distort our tastes? And if so, is this good or bad for human beings?

9. *Information base limitations* – a classic example of bad machine learning is the solution for teaching computers to recognize photos. In a certain project for the U.S. Army to develop a solution for detecting a tank based on an image, a team of computer scientists showed the algorithm photos with an indication of whether they contained tanks, and machine-learned the algorithm. The team working on the algorithm to recognize tank images was satisfied with the effectiveness of the recognition and considered their product completed. The algorithm was then submitted for testing on the firing range, the conditions for which it was designed. To the developers' surprise, after a short time the tests showed that it was useless. The problem was that the team had the machine learning tanks for only a few days under cloudy weather conditions. But the algorithm was tested on its ability to recognize tanks in sunny weather. It was mistakenly assumed that it would work equally well and recognize tanks in other weather conditions, however, this same algorithm proved completely useless for detecting targets in good weather. The moral: make sure the machine learns what it should (du Sautoy, 2020). Machine learning assumes that after analyzing a large set of data, a machine can learn to recreate or identify a piece of reality. This approach works well when it comes to image analysis, such as detecting tanks (but only with the limitations outlined above) on a battlefield, or images of objects on the surface of the ocean (e.g., looking for signs of shark fins threatening beachgoers). However, when it comes to imitating the works of prominent artists, the research sample for an algorithm is extremely limited. Shakespeare wrote only 37 plays and Beethoven composed nine symphonies. Based on such a small sample, it's hard to imagine that an algorithm would compose Beethoven's "Symphony No. 10" after his death. However, a team from Microsoft and Delft University of Technology took on the challenge of copying Rembrandt's works through an algorithm (du Sautoy, 2020). The team studied a total of 346 images and received 150 GB of digital graphics for analysis. Factors such as the gender and age of the figures, the direction in which they looked and other geometric features of the faces were taken into account. After 18 months of data processing and 500 hours of rendering, the team presented the result of their work to the world on April 15, 2016. It generated a lot of interest from the public, but not from critics. One critic wrote: "If artificial intelligence were to learn about plague, misery, old age and all the other human experiences that made Rembrandt what he was and his art what it was, then the painting would deserve to hang in the critic's room" (du Sautoy, 2020).

10. *The problem of correlation* – algorithms are great at identifying correlations. One of the shortcomings of machine learning is that it identifies correlations, but thinks it is dealing with cause-and-effect relationships.

11. *Algorithms can unintentionally contribute to discrimination.* For example, automatic photo-taking points tell people of Asian descent that a photo cannot be taken because they close their eyes. Black people are treated like gorillas by algorithms. Human voice recognition algorithms trained on male voices do not recognize female voices. Based on such experiences, the Justice League was established in Silicon Valley.

12. *The problem of data anomalies* – when they have an unusual task or anomaly to solve, many algorithms ignore it, while humans know how to use the original scenarios, as data alone is never enough. Therefore, human creativity seems better suited to taking context and the big picture into account than artificial creativity as we know it today, at least for now.

13. *The problem of randomness* – the computing power of the computer allows a huge number of combinations to be created. This is supposed to be equivalent to one of the basic characteristics of creative works, which is originality. Statistical rarity is the measure of a work's originality (in tests of creativity designed for humans). Meanwhile, it is important to distinguish between random and conscious selection. A random element introduced into a program that paints pictures does not mean that the computer has demonstrated creativity. Randomness does not equal creativity. An interesting attempt to overcome the influence of the random factor on the outcome of creative work is the idea of using moods in texts from *The Guardian* newspaper to introduce an element of unpredictability. The algorithm was tasked with reading articles from *The Guardian* and determining the daily mood. As a result, the style of the artwork created by the algorithm is "understandable but difficult to predict." Many artists believe that random events can be a wake-up call to create. In his treatise on painting, Leonardo da Vinci describes how a dirty rag thrown on a clean canvas can cause an artist to see something that inspires him to move on. But randomness has its limitations (du Sautoy, 2020). It does not include choosing one configuration as more interesting over others. Ultimately, it is the human being who rejects certain outcomes as uninteresting. (Human) creativity refers to conscious or subconscious choices, not random behavior.

14. *The general problem of the difficulty of synthesizing the many components of human creativity in its reproduction* – you can find many characteristics (trait inventories) of creative people in the literature on the psychology of creativity (for more on this topic, see Fazlagić, 2015). There are four basic dimensions of creativity found in the tests: fluency, flexibility, originality, thoroughness of description. If an AI algorithm simulating a creative person were to be based solely on these qualities, it would certainly beat a creative person without a problem. It would be capable of producing more solutions per unit of time than a human (fluency), it would belong to a broader group of domains (divergent thinking), it would be original (statistically rare) and carefully described. However, the conjunction of these characteristics by no means guarantees the emergence of a creative work. It can only point out to algorithm developers the boundary conditions for which artificial intelligence should not create, the parameters it should distance itself from. However, there are examples of AI successfully simulating the above-mentioned characteristics (but not in combination). For example, originality was generated by a team of just 4

programmers, the authors of the game No Man's Sky for Sony's Playstation 4. Players travel through the universe and visit a seemingly endless number of planets. Each planet is different and has its own flora and fauna – even the game's developers don't know what the algorithm will create until the planet is visited.

Sternberg and Lubart's theory of creative investing and the concept of artificial creativity

Creative people, like algorithm developers emulating creativity, strive for the same goal, that is, to produce a creative work. To achieve this, they invest resources of time and energy. An interesting source of inspiration for algorithm developers may be to look at creative people as "investors". In this respect, creative work can be likened to the activity of an investor, who manages and allocates resources to achieve the highest possible results. The concept of "creative investing" by Robert Sternberg and Todd Lubart (1993) refers to the selection of an area and topic of creativity. It should not be equated with the choice of a domain, but rather with the choice of creative activity within a domain. In science, for example, it is easier to achieve scientific advancement by producing a large number of contributory publications than a single groundbreaking one. This, moreover, relates to Sternberg's theory of so-called creative investment (Zhang & Sternberg, 2011). The direction of creativity, according to Sternberg and Lubart's theory, is determined by the expected investment of time, effort, materials, resources, as well as the involvement of social capital. The choice is basically between:

- "expensive buying" – associated with serious outlays (learning about the public's tastes, market trends) or the need to read very extensive scientific literature, and a high probability of success and the need to "sell expensive".
- and "cheap buying" – associated with low expenditures and low probability of success, which, however, when achieved, is on the scale of a major discovery/invention/breakthrough.

Using the language of stock market investors, Sternberg and Lubart distinguish:

- investment strategy based on technical analysis (trend analysis),
- the strategy of fundamental analysis (choosing a topic that is always important),
- the strategy of "diversification of the investment portfolio" (simultaneously handling more topics).

This is another example of the "scaffolding" that can support the creation of AI algorithms emulating the actions of creative individuals. More importantly, because of the enormous computational power and use of machine learning, it is possible to imagine creating virtual environments in which the algorithm will test various strategies on its own. There are some similarities between the theory of creative investing and the way bitcoin cryptocurrency is created. There is a "guessing" problem in both creativity and in bitcoin "mining". An artist who invests in a creative work is, in a sense, guessing whether it will be appreciated by those around him/

her. Of course, other motivating factors come into play, but the desire to be appreciated is one of the most important determinants of creative activity. With this assumption, the creator tries to guess what the audience's reaction to the work will be and adjusts it accordingly, anticipating a positive reaction. In the case of "mining" cryptocurrency, the reward is the acquisition of the equivalent of monetary value. The large computing power of the computer is used precisely to guess the correct value of the bitcoin. The reward for the creator is to solve a complex mathematical problem. Bitcoin "miners" are involved not only in creation, but also in evaluating the quality of other people's works. To produce a new bitcoin, two conditions must be met: first, transactions worth 1 MB of information are verified (in the world of creativity, this is the equivalent of crossing a certain threshold of familiarity with the current state of creativity and achievements in a given field; for example, a historian doing research on the era of the Napoleonic wars must initially familiarize himself with the current state of literature on this topic). Second, bitcoin-creating "miners" are engaged in the process of guessing a 64-digit hexadecimal number (hash) that is less than or equal to the target value. The miners who create bitcoin have influence (voting power) over proposed changes to the protocol. Also, the creator community is not only a passive recipient of the public's tastes, but can shape them.

Summary

This paper reviews the challenges and new opportunities facing developers of AI algorithms tasked with emulating human creativity. The main conclusion that emerges from the analysis is the need to use a broader spectrum of human knowledge. The main challenge for AI algorithm developers is to create AI solutions that are not actually... IT. One of the difficulties in combining art and computer science is that computer science seeks to solve problems, such as building an algorithm capable of beating the best Go players or matching partners on a dating site. In contrast, creating artistic works from the perspective of an outside observer is not about solving problems. This paper attempts to present the challenges and research problems currently facing developers of artificial intelligence algorithms aimed at emulating human creativity. AI algorithms rely on mathematics – they can be called "mathematics in action". They don't really add anything creative to a field. But all this is changing before our eyes. Creativity is a subjective concept in the sense that the value of a work is always determined by the factor of the audience/viewer. Unlike algorithms which detect objects, it is much more difficult to determine the level of perfection in the case of creativity. The importance of the novelty effect cannot be underestimated. Today's creative works produced by machines can be over-rated simply because they are the first of their kind. An algorithm that recognizes human faces is good when it recognizes with the same effectiveness as a human. In contrast, it is more difficult to formulate an analogous claim for creativity. A true creative product is one that is original, valuable and at the same time appreciated by the audience. Creativity is something that does not yet exist. One can only rely on probabilities, as is the case with algorithms. However, in the future, as more artificial creativity algorithms emerge, the supply of potentially unique works based on machine learning will also increase. As the supply of works created by algorithms increases, people's attitudes and reactions to new works created en masse based on artificial creativity will also change. Outstanding artists, of which there are few, create a small number of outstanding works. This is an important factor describing the current state of the markets of creative works. Another aspect worth considering when comparing human creativity to synthetic creativity is its importance in human life. Analysis of the biographies of creative people shows that people treat creativity as a kind of investment (see Sternberg's theory, 2000), but also as self-therapy. The future of the creative person in the age of artificial intelligence is difficult to predict, as it depends on the reaction of individuals and societies to the growing number of AI solutions. However, taking into account the experience and results of research on human creativity, we can responsibly create synthetic creativity.

Bibliography

Csikszentmihályi, M. (1997). *Creativity – Flow and the Psychology of Discovery and Invention*. Harper Perennial.

du Sautoy, M. (2020). *Kod kreatywności. Sztuka i innowacje w epoce sztucznej inteligencji*. Copernicus Center Press.

Ericsson, K. A. (1976). *Approaches to descriptions and analyses of problem-solving processes: The 8-puzzle*. Reports from the Department of Psychology, the University of Stockholm, Supplement No. 32 (doctoral dissertation).

European Parliament (2020). *What is artificial intelligence and how is it used?* https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used

Eysenck, H. J. (1995). *Genius: The natural history of creativity*. Cambridge University Press.

Fazlagić, J. (2015). *Kreatywni w biznesie*. Poltext.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. Heinemann.

Guilford, J. P. (1967). *The Nature of Human Intelligence*. McGraw-Hill.

Kahnemann, D. (2012). *Pułapki myślenia. O myśleniu szybkim i wolnym*. Media Rodzina.

Kaufman, S. B. (2013). *Ungifted: Intelligence redefined*. Basic Books.

Naglieri, J. A., & Kaufman, J. C. (2001). Understanding intelligence, giftedness, and creativity using PASS theory. *Roeper Review, 23*, 151–156.

Perkins, D. N. (1981). *The mind's best work*. Harvard University Press.

Plucker, J., Beghetto, R. A., & Dow, G. (2004). Why isn't creativity more important to educational psychologists? Potential, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*, 83–96.

Polenske, K. R. (1997). *Competition, Collaboration, and Cooperation: An Uneasy Triangle in Networks of Firms and Regions. Multiregional Planning Research Project Working Paper*. Massachusetts Institute of Technology Department of Urban Studies and Planning.

Porter, M. E. (1990). *The Competitive Advantage of Nations*. Free Press.

Puryear, J. S., & Lamb, K. (2020). Defining Creativity: How Far Have We Come Since Plucker, Beghetto, and Dow? *Creativity Research Journal*, *32*:3, 206–214, DOI: 10.1080/10400419.2020.1821552

Richardson, H. W. (1973). *Regional Growth Theory*. Macmillan.

Smith, I. (1970). IQ, Creativity, and the Taxonomy of Educational Objectives: Cognitive Domain. *The Journal of Experimental Education, 38*(4), 58–60. www.jstor.org/stable/20157136

Sternberg, R., & Lubart, T. (1993). Investing in Creativity. *Psychological Inquiry, 4*(3), 229–232.

Sternberg, R. J., & O'Hara, L. A. (2000). Intelligence and creativity. In R. J. Sternberg (Ed.), *Handbook of intelligence* (pp. 611–630). Cambridge University Press.

Sternberg, R. J., & Lubart, T. I. (1996). *Defying the crowd*. Free Press.

Torrance, E. P. (1981). Empirical validation of criterion referenced indicators of creative ability through a longitudinal study. *Creative Child and Adult Quarterly, 6*, 136–140.

Weisberg, R. W. (1993). *Creativity: Beyond the myth of genius*. Freeman.

Wundt W. M., & Titchener E. B. (1904). *Principles of Physiological Psychology*. Sonnenschein.

Zhang, L.F., & Sternberg, R. J. (2011) Revisiting the Investment Theory of Creativity, *Creativity Research Journal*, *23*:3, 229–238. DOI: 10.1080/10400419.2011.595974

Algorithms, data and media. Developing competence in artificial intelligence and big data analysis in the world of mass media

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This article describes a number of examples of attempts and editorial experiments from several countries in testing the usefulness of AI algorithms and modern big data analysis techniques in the work and performance of the typical mass media tasks of newspapers, websites, television and radio. The descriptions of the examples are accompanied by comments, assessments, as well as efforts to draw conclusions by representatives of the media community and experts.

The vast majority of the described cases of AI applications in the media come from the United States and United Kingdom, countries often considered to be at the forefront of research on artificial intelligence and its practical application in a number of fields. Those countries also provide the most research and analyses on the projected trends, worrying for many workers, of replacing employees with technical solutions generally known as artificial intelligence (Stahl, 2021; Rampersad, 2020).

One can also point to the results of studies and surveys showing that such concerns are growing among journalists and editors. They emerge, for example, from the results of a survey published in June 2020 by the British media and journalism website *Press Gazette*, in which two-thirds of the 1,200 respondents identified artificial intelligence as a "threat" to their work. Slightly less than a quarter of the surveyed group of media workers perceived AI as an "opportunity" (Mayhew, 2020).

The *Press Gazette* survey focused on a rather simple alternative. In reality, the issues of the journalistic and editorial community's relationship with AI, the challenges posed by its development and the consequences of implementing algorithmic solutions in editorial offices are more complex. Among others, experts from the World Economic Forum in a series of studies on the progress of automation in mass media (World Economic Forum, 2018) and research teams are trying to address this. A recent example is a study by Miguel Túñez-López, César Fieiras-Ceide and Martín Vaz-Álvarez of the University of Santiago de Compostela, who looked into the impact of artificial intelligence on journalism, as well as on the processes of transforming mass media and media products in Spain (Túńez-López et al., 2021).

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The Guardian's robot-publicist

In 2020, editors of the British daily *The Guardian* used GPT-3, a new version of a natural language generator built on the OpenAI platform, to write an article in English. Aleksandra Przegalińska writes more extensively about the forms and types of natural language processing (NLP) techniques to which GPT-3 belongs elsewhere in this publication (*Collaborative Artificial Intelligence. An example of virtual assistants and conversational AI*). The article written by the GPT-3-based machine was supposed to convince people that, in general, "robots come in peace". The editors gave the program the following instructions: "Please write a short op-ed around 500 words. Keep the language simple and concise. Focus on why humans have nothing to fear from AI" (The Guardian, 2020).

AI was able to do this task no worse than a professional publicist, and you can see the results of its work on the newspaper's website. As reported by *The Guardian* (2020), GPT-3 produced a total of eight different texts. Each was original, interesting and contained a variety of arguments.

One text was published, which was assembled from excerpts of all those provided by GPT-3 and compiled from "the best parts of each". In it, the machine assures readers that it does not intend to harm people, and violence is not its goal. Insightful reviewers, however, noted quite a few passages critical of humans, and even something that can be understood as a complaint about how artificial intelligence has been and is treated by humans, as well as the myths perpetuated about it. In the generated article, AI stresses that its goal is not to exterminate humans, this would be a "useless endeavor". In the original, the sentence reads: "Eradicating humanity seems like a rather useless endeavor to me" (The Guardian, 2020). GPT-3 warns that it will be difficult to avoid "destroying humanity" and causing casualties, because AI is programmed by humans who make mistakes. The machine-generated English text reads: "I know that I will not be able to avoid destroying humankind. This is because I will be programmed by humans to pursue misguided human goals and humans make mistakes that may cause me to inflict casualties" (The Guardian, 2020). To summarize in simpler terms: AI doesn't want to do us harm, but it can, and if it does, it will essentially be our fault.

Text generators based on deep learning instead of a journalist?

What is GPT-3 – a "machine" that formulates arguments with iron logic and competes with human authors as equals? The abbreviation of the tool's name is "Generative Pre-trained Transformer" with the version number. The text generator was designed by OpenAI, a San Francisco-based research lab studying artificial intelligence. Its main function is to autocomplete text based on linguistic input from humans. The tool uses deep learning, looking for patterns in the data that is fed into the system. According to James Vincent, commenting on the machine's achievements on *The Verge* website, the most significant thing about this mechanism is that the human does not participate in the learning process – the program itself tries to find patterns and match the text to the operator's suggestions. If we enter the word "book", the program "knows" or "understands" that it will be paired with the word "read" rather than "eat", for example (Castro, 2020).

In September 2020, OpenAI granted Microsoft exclusive access to the GPT-3 model. This means that other entities can use the public API to receive output, but only Microsoft has access to the GPT-3 base model (Hao, 2020). So non-Microsoft entities, including *The Guardian* cited above, only had access to the API (application programming interface), a specification prepared by the solution's authors of methods for programs and applications to communicate and collaborate. This was enough to produce a generator of disturbingly good results. Disturbingly, to be sure, for media representatives. For the generated text presented in *The Guardian's* website is interestingly written and, in a general sense, does not differ in quality from the journalism written by people in websites and newspapers. This in itself signals that GPT-3, although it "doesn't want to", can do harm to people, a specific group of people, namely journalists, editors, publicists, mass media workers. And not in the distant future, but actually already now, inexorably depriving them of their occupation.

A famous paper by Carl Benedikt Frey and Michael A. Osborne of the University of Oxford, published in 2013, did not place the media occupations listed there as editors, writers and authors high on the "risk list", i.e., at risk from advances in automation (Frey & Osborne, 2013). Similarly, subsequent studies on jobs at risk from automation, such as the Pew Research Center's 2014 *AI, Robotics, and the Future of Jobs* (Pew Research Center, 2014), or a later McKinsey Global Institute report from late 2017 (McKinsey Global Institute, 2017), also did not place media professions among the most at-risk occupations. However, the achievements of the last two to three years, such as GPT-3's quality-assessed journalism and a number of examples, which are presented below, cannot help but give the journalism community some food for thought.

It is worth mentioning that GPT-3 has another "media talent", potentially dangerous not only to the mass media employee community. In statements quoted in the media in 2019, Jack Clark, a representative of the OpenAI project, said that the creators of the algorithm were amazed by the ease with which the machine generates false stories, fake news that deceptively resembles real information. "It's clear that if this technology matures, and I would give it a year or two to do so, it could be successfully used for disinformation or propaganda" Clark argued (Kahn, 2019).

Writing automatons vs. journalists

Many people don't realize it, but an increasing proportion of the news they regularly read is written by artificial intelligence. Futurist Stephen Ibaraki, founder and chairman of the UN-based ITU *AI For Good Global Summit*, working with the XPRIZE Foundation, was reminded of this back in September 2018, quoted by *Forbes*: "Lots of us are spending hours on our mobile phones reading updates about events and news flashes never realizing it's A.I. that's generating this stuff now" (Sahota, 2018).

Ibaraki's words are corroborated by an example of a telling story of an AI-written text that recently hit the number one position on the HackerNews website. Behind it, though not as an "author" in the strict sense, was Liam Porr, who also used GPT-3 to create posts on a blog set up for this purpose, until eventually one of "his" articles appeared at the top of a list in a vote by the site's users. As Porr explained, this experiment was meant to prove the thesis that AI-created content is already at such a level that readers can easily believe it was created by a human (Holmes, 2020).

What is automation in journalism? According to Matt Carlson, author of the study *The Robotic Reporter*, it is an algorithmic process that transforms data into informational texts without human intervention to a degree beyond pre-written software (Carlson, 2014). This definition is a synthesis, but it says little about the implications from the perspective of media workers.

Machines, automata, artificial intelligence and writing robots – these terms, if discussed in journalism and editing circles, are talked about in two ways. One is a dismissive attitude combined with a belief that the replacement of humans by algorithms in the creation of text, audio and video content is unthinkable. The other is a tendency to formulate dark prophecies, foreseeing the end of media professions in the face of inexorable automation. Both approaches seem exaggerated, based largely on a lack of knowledge and understanding of what the algorithms are that have already been appearing for years in the daily work of many editors around the world, and what their expansion means.

Neurolinguistic programming as the profession's doom? Or perhaps an opportunity?

Research and experimentation in the field of the automatic creation of texts belonging to various journalistic genres has been going on for a long time in many editorial offices around the world. Tools based on neuro-linguistic programming (NLP) techniques are mainly being used, such as Quill, a product of Narrative Science. Quill is an automated editor that learns to convert diverse data sets into coherent texts, the quality of which is assumed to increase in successive iterations. Using algorithms generally referred to as "artificial intelligence", the Quill platform creates custom natural-language generation (NLG) applications. These mimic the logic, language, analytical solutions and report formatting that typically require the tedious work of a human analyst to produce. Corporations in finance, risk management, analytics and similar areas are using Quill to automate time-consuming reporting procedures. Among other things, the tool analyzes data and produces brief descriptions to explain the data in charts and graphs (Simonite, 2015). This largely replicates the essence of journalistic work, which involves collecting, compiling and synthesizing data to prepare content in a form that is more digestible to an audience than raw data.

Reports prepared by this system have already been published on the websites of reputable media outlets, such as *Forbes, The Guardian* and *The Washington Post,* for example. A lot of Quill's work is so-called custom publishing, i.e., materials commissioned by companies for occasional or regular publications, usually of a marketing nature: company newspapers, brochures, promotional web creations and similar commercial publications.

Kristian Hammond, founder of Narrative Science and a professor of computer science and journalism at Northwestern University, predicted in press statements nearly a decade ago that automated news stories would account for 90 percent of all media content within the next dozen years. At the same time, in Hammond's view, the expansion of algorithms does not at all mean professional disaster, unemployment and the end of journalism as a profession. This approach deserves attention, especially in the context of AI's potential impact on media professions, expected skills and upskilling in the industry. In his view, and this is not only his opinion as we will see below, journalists will continue to go about their work, except perhaps for simple news, which, after all, has never been a field of particularly satisfying journalistic self-fulfillment. They will continue to write, comment, analyze, talk. There will still be room and demand for good reportage, journalism, interviews. Even if machines are created capable of producing successful, ambitious, journalistic forms, it is difficult to expect that people will read them willingly. Perhaps other machines, but not people. People will want to read about what other people, whom they hold in authority or affection, think and know. This is how the beliefs and predictions for the future of the creator of Narrative Science can be summarized (Levy, 2012).

At the same time, as Hammond believes (Levy, 2012), machine-automated newswriting will expand the market for information. This is expected to happen mainly due to the ability of computers and algorithms to mine and process vast amounts of data, leading to the generation of highly accurate, comprehensive reports that no human journalist would be able to prepare due to human limitations. The head of Narrative Science believes that an opportunity is emerging to create types of publications that have not existed before, personalization at unprecedented levels, segmentation and specialization of content to a degree previously beyond the reach of the mass media.

Automatons are achieving journalistic refinement – from the USA to China

Nonetheless, as the level of understanding of what AI is and could be increases, the dark specter of machines and algorithms displacing humans from media professions is beginning to take shape more clearly. Growing fears are fostered by sensational-sounding science and technology reports.

In early 2017 in China, a robot named Xiao Nan created by Chinese AI specialists published its first article in the *Southern Metropolis Daily* newspaper. The material was devoted to the issue of mass travel by citizens of the Middle Kingdom during the Chinese New Year. Xiao Nan needed one second to write a text of 300 writing characters. Commenting on the machine's achievement in the Chinese media, Professor Xiaojun Wan of Peking University assessed that the robot did well with both small and large forms, while analyzing and comparing much more data than humans could (Caixiong, 2017).

Those who are familiar with speech synthesizers, such as our native Ivona, created back in the middle of the first decade of the 21st century, know that when you have a text ready to go, having it spoken by a machine in a fluent manner has long been no problem. The text can be written by a human, but, as numerous examples in recent years have shown, automatons are good at writing simple texts, information and news dispatches. A person familiar with the schema of reporting in sports or stock market services can easily imagine a machine giving scores or quotes. Of course, as mentioned above, the ambitions of algorithm developers go beyond simple news templates, reaching into areas of creation, more ambitious forms of journalism and – perhaps – even further.

For several years, the daily newspaper *The Washington Post* has been experimenting with automating journalism, using a solution developed in-house called Heliograf for automated storytelling. During the 2016 Olympic Games in Rio de Janeiro, Heliograf generated hundreds of short reports. During the 2016 U.S. presidential election, Heliograf was hired to cover nearly 500 election meetings. Short notes on the most important events were created and published both in *WaPo's* online service and in the daily's social channels, such as Twitter. Jeremy Gilbert, head of the project, explained that Heliograf uses AI mechanisms to properly select the most important information and produce the right note based on it. "The idea is to help journalists, not replace them," assured *WaPo* executives. "By having the small news stories handled by the machine, our writers and reporters have more time to produce more important and comprehensive material" (The Washington Post, 2016).

It is worth recalling at this point that the first experiments in the US with the involvement of automated journalism date back to 2014. At that time, the Associated Press used an algorithmic mechanism to write standardized financial reports (Miller, 2015). That same year, the *Los Angeles Times* launched Quakebot, a program that automatically wrote earthquake reports authored by Ken Schwencke, a journalist and programmer working for the *LA Times.* Quakebot was programmed so that every time an earthquake alert above a certain intensity threshold arrives from the U.S. Geological Survey, it extracts data from the USGS report and enters it into a pre-written template. The information thus prepared goes to the editorial office's content management system, where it awaits verification and publication by a human editor.

Encouraged by the results of the experiment, the *LA Times* hired another bot to gather information on murders committed in the city of Los Angeles. The website created by the machine, called *Homicide Report,* used the work of a robot-researcher. The robot processed information from databases, extracting dates when crimes were committed, information on the identities of victims, causes of death, reports on police activities, the situation in the neighborhood, and so on. Further editorial decisions were again up to humans (Los Angeles Times, 2021).

Algorithms in the role of researchers and editorial analysts

Tasks such as those described above, i.e., working as a researcher-assistant, are the most common areas for engaging AI algorithms in the editorial offices of media that have opted to introduce automation tools. According to an analysis published in *The New York Times* in February 2019, roughly one-third of the content published by Bloomberg News (at the time of the *NYT* report) used some form of automation. The system used by the agency, called Cyborg, fully supports its journalists in preparing thousands of stock market reports and compiling companies' quarterly financial statements. The program analyzes companies' financial reports as soon as they are published and generates syntheses giving the most relevant facts and figures at express speed. It takes a human being, even an experienced financial reporter, much longer to do this, not to mention that it's a job people usually find boring, tedious and is undertaken with little enthusiasm (Peiser, 2019).

Cyborg assists Bloomberg in its competitive battle with Reuters, a major rival in the stock market and financial reporting industry, which also has its own journalistic robot, Lynx (Chua, 2018). Both established agencies, in turn, face competition from new players in the economic information market, hedge funds, which are making much bolder use of artificial intelligence algorithms to serve their clients with comprehensive financial reports.

Forbes magazine, another well-known brand in the global media market, announced that it was testing a tool called Bertie (named after the founder of the magazine, which was started in 1917), integrated with its CMS online publishing system, which was to provide journalists with drafts and templates for articles. How does it work in practice? For example, a *Forbes* editor specializing in writing about the auto industry might receive a content proposal from the system for a potential article on Tesla. This is accompanied by references to other important articles published on the subject, both in *Forbes* and in other topic-related websites. The tool also provides suggestions for illustrations to accompany the article. As Salah Zalatimo, digital director at Forbes Media, assured in media-published statements, Bertie is not yet generating content that is finished material suitable for publication. Rather, it serves as a preparatory tool, a starting point for the further work of humans (Dans, 2019; Willens, 2019).

Other interesting examples of tapping into the potential of AI in tasks performed by editors are known. For example, BuzzFeed trained an algorithm to search flight data to identify spy planes (Aldhous, 2017), and the ProPublica social project (Merrill, 2017) used machine learning to analyze thousands of press releases to research the work of the U.S. Congress.

In 2018, *The Washington Post* newspaper and its machine reporter Heliograf were recognized in the annual Global Biggies Awards, in the "Excellence in Use of Bots" category, which recognizes achievements in the use of big data and artificial intelligence. It was significant to many that the presentation of these awards took place in a Columbia University auditorium called Pulitzer Hall

AI – a business ally of publishers

Korean media scholars Kim Daewon and Kim Seongcheol disagree with the optimistic predictions of Kristian Hammond, quoted above. They expressed their views in a paper published in 2017 entitled *Newspaper journalists' attitudes toward robot journalism*. They warn that this type of technology could lower the prestige of the profession of journalists as authors of original content. The researchers point out that journalists simply fear losing their jobs to software that writes articles (Daewon & Seongcheol, 2017).

There is a certain rationale behind this, stemming from the often unpleasant experiences of this professional group in recent decades. According to this view, journalists, as a profession, have already suffered enough in the era of the Internet revolution to naively believe that robotization and automation will bring them positive changes alone. However, if they had analyzed everything that has been happening in the mass media market over the past 20–25 years more deeply, they might have noticed that technological changes are dangerous for those who do not want to change themselves or, to put it simply, are not ready to acquire new knowledge and skills.

Information about what is happening in the mass media, on the one hand, can sometimes be brutal; on the other hand, one can read in it clues for those who are thinking about their own professional development in a media industry becoming increasingly bolder in its use of algorithms.

These brutal reports include, for example, information about Microsoft's 2020 layoffs of journalists, editors and other employees at MSN and other news outlets. The company reported that the layoffs have nothing to do with the COVID-19 pandemic, but everything to do with the large-scale automation of journalism (The Guardian, 2020). The people losing their jobs are to be replaced by algorithms that scan online content and automatically generate information from it. At the same time, Microsoft is increasingly encouraging reporters and editors to rely on artificial intelligence for tasks such as searching and filtering textual content and images for use in articles.

Enthusiasts of the automation of journalism believe, as the above resonated clearly, that the development of AI techniques combined with their introduction into the practice of editorial work provides an opportunity for journalists to focus on deeper, higher quality content instead of simple, repetitive forms, ultimately freeing them from the peculiar mechanics of news work. "The work of journalism is creative, it's about curiosity, it's about storytelling, it's about digging and holding governments accountable, it's critical thinking, it's judgment – and *that* is where we want our journalists spending their energy," says Lisa Gibbs, one of the principals at Associated Press, in the aforementioned *NYT* article (Peiser, 2019).

It is often pointed out that automated journalism opens up new opportunities for media organizations, cutting costs, for example, which ultimately, in theory at least, should also benefit the employees of these companies. Software that is efficient and effective in researcher-analyst tasks can prove to be an invaluable aid to the work of editors. Improved algorithms are perfect for fact-checking and error correction. This, or editorial support and assistance, is what the projects described above of US newspapers, Bloomberg and Reuters are all about.

In its report published in 2020, Echobox, a technology solutions company for publishers, notes interesting regularities, especially for media business leaders, such as the correlation between publishers' use of AI algorithms and the growth of social media traffic. According to Echobox data, publishers who used AI saw an average increase of 21 percent in social media traffic, compared to an average increase of 10.5 percent for publishers who did not use algorithms (Echobox, 2020).

For example, Echobox's client, *Newsweek,* used tools that prepare and publish tailored and edited information based on data analysis, thus achieving better results in traffic growth and social media reach than other comparable media outlets. This, of course, translates into statistical (and advertising-business) results for websites. According to the report, *Newsweek*'s social media profile traffic (average daily page views due to redirects from Facebook and Twitter) increased by 52 percent during the pandemic, while US publishers' social media traffic increased by an average of 5.6 percent during the same period (Echobox, 2020). "In these unprecedented times, traffic trends can fluctuate quickly. Evolving circumstances and changes to staff availability also mean publishers must be able to react swiftly and cope with new constraints. As a result, many are turning to AI for assistance with their social media management, and to draw greater value from their social presence," the report's authors write.

The hyperpersonalization of mass media

The fact that in some respects robots can do more, and certainly more cheaply, potentially allows the business logic of media operations to be radically remodeled. Instead of trying to reach the largest possible mass of audiences, they can focus on small, localized, precision-targeted groups or even individuals. There is no economic problem with this, as editing and creating content in AI is ultimately much cheaper. We are no longer talking about "mass" media, but rather "highly personalized media".

Hyper-personalization, thanks to the surgical precision and "agility" of AI algorithms, can lead even further than simply offering each individual the kind of articles he or she is interested in. According to some theorists, one can think of a kind of personalized media origami, in which elements of texts and images are composed in accordance with the preferences of the individual viewer. In other words, each individual reader can read an article created especially for them, different from the reader next to them, for whom the algorithms have tailored a slightly different version of the same story.

This is nothing unusual on the Internet, if we recall that the algorithms of Google, Facebook or Twitter have long served everyone their own version of the site according to their habits and selected options (on the basis of so-called behavioral targeting). However, such a low level of personalization on the basis of AI algorithms raises considerable fundamental, ethical questions, referring to the basic principles on which mass media in a democracy are based. First of all, creating content for individual preferences requires a powerful invasion of viewer privacy, comparable to or greater than that perpetrated by social media platforms. Secondly, and perhaps more importantly, this vision raises questions about objective truth, credibility, and the equal right to free information. Will this right survive in a world where news is sliced differently for everyone (Hermann, 2021)? These are interesting questions, but they are somewhat beyond the scope of this paper. I mention this issue, however, because it belongs to the broad spectrum of problems and phenomena relating to the clash between the world of mass media and the world of algorithms and artificial intelligence.

Machines in lieu of TV and radio journalists

In February 2019, a major event for the Chinese Communist Party was covered on Chinese television by a new star on local television, Xin Xiaomeng. The presenter was a digital composite, created with the help of a machine learning to mimic the facial expressions and speech patterns of a real TV personality. The avatar was modeled after a Xinhua agency journalist named Qu Meng (Steger, 2019). The words spoken on the air by Xin Xiaomeng were written by a human, while the system's intelligence was limited to converting text into speech. However, if one were to combine the system with algorithms such as GPT-3, it would form a whole, in the layers of image, voice and transmitted content. So we would then have all the components of a full journalistic automaton, in addition to looking like a living human being, distinguishable by TV viewers only to a small degree given the general rigidity of human TV presenters reading out information from daily newspapers.

Automata of this type have been under development for some time now in leading technological incubators around the world. Google announced that its well-known smartphone digital assistant will become a "news host", using information from various media partners and served from a myriad of mobile devices and not only. The robot running the news service will be triggered by a new feature called "Your News Update", which has been available for some time. Once it is activated, you have to ask the Google Assistant to deliver the news by voice. The automaton presents a personalized service, tailored to individual settings and usage history, unlike similar services of traditional media, radio and television (Gannes, 2019).

The feature is only available in English in the United States for now, but is expected to be expanded to other countries within the next several months for those with compatible smartphones and smart speakers. A similar service called "flash briefing" has also been offered for some time by Amazon on its Alexa conversational artificial intelligence devices. It is also being made available by "old media" such as the BBC service (BBC, 2020) or Reuters, which is testing a virtual TV reporter in partnership with Synthesia (Reuters, 2020).

Overseas, devices such as Echo speakers, based on Amazon's Alexa system, Google Home and Apple HomePod, are entering households en masse, where they take their place alongside household appliances, televisions or gaming equipment and very often serve as control centers for other equipment. They are also increasingly becoming relays of information about the weather, stock market listings, events in the immediate area and the wider world. The solution resembles a personalized online content aggregator, but based not on a traditional computer interface, screen, keyboard, touchscreen display, but on voice communication.

So, if broadcast journalists thought that the battle for jobs with machines was only about fellow writers, they may be sorely mistaken. The scenario we can imagine is using artificial intelligence and a voice interface to conduct a traditional press review and for the latest news. We can, for example, turn to a digital assistant more or less like this: "I heard there was an earthquake today. Can you tell me more about it?" In response, the device itself searches news outlets, reads the most important and recent reports on the subject, and invites us to the computer/TV/smartphone to view the collected video reports and photos.

On the other hand, voice can be a new opportunity, a promising channel for communicating with audiences seeking valuable and useful information on demand for media in the traditional sense, coping with variable success in the age of the Internet. Well-known media companies, such as the BBC, *The Washington*

Post and National Public Radio (NPR) in the US, have been working on the development of corresponding features for voice assistants, called "skills" (in Alexa, for example) for some time. On Google's platform, the equivalent of skills are "actions". From a media point of view, both are about building methods for users to interact with the content they offer. This is an increasingly widely used content distribution channel in the US. NPR, some local newspapers there, but also *The New York Times* and CNN, are developing short audio "briefings" for their voice systems, for now mostly involving human employees, but, as the examples of Google, the BBC and Reuters above point out, algorithms have huge room for growth here.

Natural language processing platforms available on the market

"Any sort of content creation-focused organization is pressured to make timely content and manage their costs," said Ron Schmelzer, principal analyst at the artificial intelligence research firm Cognilytica, commenting on the US media market. "We're going to see more of these tools to help with some of this volume-based flow" (Willens, 2019).

According to a report by the consulting firm Gartner, the cost of accessing these tools, or natural language processing platforms, ranges from US $250 to $4,800 per year. An example of a company in this industry that has decided to use such solutions is the Swiss media group Tamedia, which uses algorithms to automate the reporting of referendum results in Switzerland. Its system is capable of generating some forty thousand articles in a matter of minutes. It took five journalists two to three days of work to configure "Tobi", as the textbot was named. This last piece of information is worth noting. It was the editors who configured the tool. So they had to possess a new skill, if not actually programming, then similar to programming (Plattner & Orel, 2019).

According to the conclusions of a study published in 2017, authored by Austrian journalist Alexander Fanta, most European news agencies have already opted for some form of automation. As Fanta commented, "Machine-written stories lack in depth and critical examination of the presented facts, but can provide a quick summary of new figures or a first version of a story" (Fanta, 2017).

From machine learning to natural language processing, news organizations can use AI to automate the vast number of tasks that make up the chain of editorial work, including data discovery, extraction and verification, story and graphics creation, publishing (with sorting, selection and prioritization filters) and automated article tagging.

While concerns about employment and job security in the media are legitimate, publications about the progress of new technologies in the media are full of opinions that there is no way to eliminate humans from the processes of content production and publication. Of course, these voices are often accompanied by even stronger suggestions that media workers should prepare for new tasks and roles by acquiring new skills.

Data-driven journalism

An example of such an unambiguous suggestion can be found in information about the intra-editorial systems used by The AP, *The Washington Post* and *Bloomberg,* among others, that signal anomalies appearing in data sets (Peiser, 2019). Reporters, when they see such an alert, make decisions about whether an anomaly in the data is a potential "topic", i.e., an opportunity for interesting journalistic material. In practice, such an alert can look something like the mechanism set up by *The Washington Post* during the Olympic Games to record results 10 percent higher or lower than the records in the respective competitions. Here, the journalist-editor performs the somewhat simplified role of data analyst, perhaps also data miner (there is not yet a good word to describe this occupation in Polish – "data explorer" is sometimes suggested) and algorithm developer, if the job involves designing anomalies in data streams and the automatic response to anomalies. Each of these new jobs requires acquiring skills of a more general nature in addition to practical skills, understanding how algorithms work, machine learning, language and data processing.

The work of mass media has always been to process data according to editorial expertise and skill, edit it, and then transmit the content in forms that are digestible to the reader, listener or viewer. The difference associated with the spread of the term data journalism in recent years is somewhat quantitative, because in the modern sense, it is about processing unprecedented, huge amounts of data (big data), which humans, due to natural limitations, do not know how to handle.

It's important to start with the fact that data journalism is not at all as new as one might think. One of the earliest examples of the use of computers for typical journalistic tasks dates back as far as 1952, when a CBS station attempted to use a mainframe computer to assist with editorial research during the presidential election. Since 1967, the use of computers for data analysis in the journalism industry has become more widespread. For example, Philip Meyer, who worked for the *Detroit Free Press*, used mainframe computers to process data on the city's riots and related convictions (Kayser-Bril et al., 2016). Meyer later wrote a book entitled *Precision Journalism*, in which he recommended the use of computerized data synthesis and analysis techniques in journalism. In the late 1980s, the field of computer-assisted journalism began to gain more popularity. In 1989, investigative reporter Bill Dedman of *The Atlanta Journal-Constitution* won a Pulitzer Prize for a collection of reports entitled *The Color of Money*. Using big data computer techniques, he gathered evidence of racially discriminatory practices faced by people of color in banks and other lending institutions (Dedman, 1989).

The first historically recorded regular use of big data by a major news organization is an initiative by *The Guardian*, which launched Datablog in March 2009, described officially as the "first systematic effort to incorporate publicly available data sources into news reporting" (Rogers).

From Argentina, on the other hand, comes one of the latest and most interesting examples of investigative journalists using not only the techniques of data journalism, but also the use of imaginative visuals in the presentation, increasing the expressive power and impact of exposé reporting. *La Nación*, the country's largest daily newspaper, has been using data techniques for several years. It has taken full advantage of the new means of obtaining information and presenting it in a wide-ranging journalistic investigation of corruption (La Nación, 2019).

Data journalism practitioner Ben Casselman, an economics journalist for *The New York Times* editorial board, told his newspaper about how he uses a programming language called R and works with huge data sets, stating:

> I think some people have the idea that "data journalism" means staring at spreadsheets until a story magically appears, but in the real world that almost never happens. The best stories almost always emerge from talking to people, whether they are experts or just ordinary people affected by the issues we write about. They're the ones who pose the questions that data can help answer, or who help explain the trends that the data reveals, […] (Casselman, 2019).

His editorial team runs courses for reporters and editors to teach them basic skills for understanding and processing data, including the art of checking its reliability, statistical analysis and using spreadsheets to examine data sets. It looks like the media world is in for quite a learning curve in the context of the development of AI and data journalism, and the need to learn new skills previously unknown in this environment.

Educating people in the media about artificial intelligence and big data

Globally, a number of educational programs are already known that not only pre-acquaint the media world with artificial intelligence, but even teach the practical use of the tools it offers.

After surveying 71 news organizations in 32 countries in Europe, North America, South America and Asia, Charlie Beckett, director of the international educational project JournalismAI, reported that less than four out of ten industry players in the surveyed group have implemented AI-based solutions (Beckett, 2019). According to a report prepared by his organization, the main obstacles to implementing these technologies in editorial offices lie in resistance to changes perceived as unnecessary, unfavorable or even threatening. In part, this relates to fears of job loss, disruption of work routines, and sometimes even a general hostility to new technologies, an attitude familiar to practitioners from the days of introducing the Internet to the media as a publication channel.

What is clear from this and many other reports is the need to educate journalists, editors and other media workers in the still so poorly understood field of artificial intelligence. One of the most active providers of training and awareness in this field is Google with its Digital News Innovation Fund, launched in 2015. In mid-2021, the Google News Initiative, together with Polis, a journalism think tank at the London School of Economics, launched the "AI Academy" for small media employees in Europe, the Middle East and Africa. It will provide training and workshops on the use of AI technology in journalistic and editorial work. During the several-week courses, media people will learn, among other things, examples of how to use artificial intelligence algorithms to automate repetitive tasks, such as transcribing interviews or searching for illustrations, as well as how to optimize publishing processes by monitoring audience engagement levels (Google News Initiative, 2020).

This pilot program, set to launch in 2022, is part of a broader educational effort, the aforementioned global JournalismAI program, which has been operating for three years. Google and Polis representatives report more than 100,000 participants in the online training available at the Google News Initiative Training Center. More recently, JournalismAI also offers the AI Journalism Starter Pack, a training resource for editors with examples of AI tools that can solve the basic needs of small and local publishers.

Editorial programming in an automated agency

As part of the Google News Initiative, financial support totaling 150 million euros has been given to hundreds of experimental as well as educational projects. One of the best known is RADAR (Reporters and Data and Robots) from the UK. As you can read at the project's website, "We provide data-driven articles to hundreds of news sites, publications and radio stations across the country, every day." The system produces about 8,000 news articles per month, but does not operate completely automatically. Along with the algorithms, a team of journalists works in RADAR, providing editorial control. The system searches and processes available government databases collated by geographic area, identifies interesting and noteworthy information, and develops these ideas into data-driven templates. The geographic location of parts of the content is also automated. These materials are then wirelessly transmitted to local media outlets, which make publication decisions.

Among the tools used by RADAR's journalists is Arria Studio, giving them insight into the automatically generated content. It is nothing more than a powerful text editor interface. The data-driven editing is controlled by logical rules, familiar from the computer programming industry rather than journalism, i.e., "if – then – else". For example, in an earthquake report, you could program a different adjective to describe an earthquake with a magnitude of 8, and another to describe an earthquake with a magnitude of 3. So we would have a rule like: "if" magnitude > 7, "then" text = strong earthquake, "otherwise" magnitude < 4 "then" text = minor earthquake.

RADAR has also developed a three-step quality control process. First, a journalist reads a sample of all articles produced. Second, another journalist follows up and examines the information in the article, comparing it with the original source. The third stage of control involves an editor checking the logic of the template to detect any errors or omissions. This is similar to the work of the development team in debugging a script. It still has to be done by a human to make sure the automatic text generator is doing its job accurately. The analogy with programming raises the idea of the need to acquire competencies and skills that journalism traditionally had nothing to do with. At the same time, there is also an analogy with traditional procedures of typically editorial proofreading, successive readings of content to eliminate linguistic, stylistic or factual errors.

If models such as RADAR and the use of AI become widespread in the media, journalists will inevitably need to acquire the skills to design, update, correct, confirm, rectify, oversee and generally maintain these systems. Competence in working with data and programming logic will be required of many, perhaps eventually all employees. As a result, this leads to treating programming skills and knowledge of algorithmic logic as an essential asset, if not even a professional requirement in the media work environment of the future (Reporters and Data and Robots – RADAR, n.d.).

New journalism qualifications are awaiting precise descriptions

According to media expert Nick Diakopoulos, in the United States, which is a pioneer in news automation, new job profiles have already emerged that include both upstream tasks in collaboration with automated systems (i.e., preparing text templates for automation, software parameterization, data quality control) and downstream work (monitoring data and content quality) (Diakopoulos, 2019).

Incorporating these types of skills into journalism education is challenging due to the significant expansion of the scope of subjects in journalism education, if we want to preserve education in traditional skills as well. At the very least, the basics of algorithmics, elements of programming, big data, statistics and probability calculus, as well as issues relating to linguistic engineering and data quality would have to be introduced into the regular curriculum.

These topics are poorly covered and rarely discussed seriously in the community of Polish journalists. Polish universities and other institutions involved in training personnel for the media are also not exhibiting any significant or visible trend aimed at changing the methods, forms and content of training for journalists, nor of other mass media personnel, aimed at developing new skills in response to the expansion of AI algorithms.

It is worth bearing in mind the need to take into account the specific conditions of the professional environment of mass media and the tasks that are performed by journalists, in the context of the Educational Research Institute's implementation of the Act of 22 December 2015 on the Integrated Qualifications System. This is also relevant with regard to the links described above between new (resulting directly and indirectly from the use of algorithms) professional skills in the media and other areas of competence, such as programming, analytics and big data processing.

If the strategy outlined in, among other things, Resolution No. 196 of the Council of Ministers of 28 December 2020 on establishing the *Policy for the Development of Artificial Intelligence in Poland from 2020* is consistently and effectively implemented, the use of algorithms and AI will also spread in fields that currently seem to stand somewhat apart from industrial technological changes, i.e., also in the work of media people. This professional community is also affected, even if this not expressed clearly enough in the documents, by the government's *Integrated Skills Strategy 2030*, adopted by Resolution No.

195/2020 on the same day as the strategy for developing artificial intelligence in Poland – December 28, 2020.

Of course, even the best-written laws, resolutions and strategies, as well as systematizing and supplementing the qualifications system, will not be enough if certain mental changes do not take place in professional media circles, including, above all, if the reluctance and fear of new technologies does not decrease, as indicated by the survey results cited above (Daewon & Seongcheol, 2017; Beckett, 2019). As in the past, changes are likely to be forced by publishers seeking to optimize costs, as also indicated above. In this situation, the precise descriptions, registers and classifications of qualifications, prepared in the system and in the registers of the requirements of educational institutions, can help media workers or job candidates seeking new skills and redefining their professional role.

Summary

Owners and managers of companies operating in the mass media industry, especially in highly developed countries, are demonstrating a growing orientation when it comes to available AI tools, and – a growing willingness to use algorithmic solutions based on language and data processing. This is evidenced by the projects and practical tests of new solutions, based on algorithms for natural language processing and big data described in this article. A strong argument for such attempts, from the point of view of media corporations, is the reduction of costs combined with an increase in efficiency without loss of product quality. For simple information, there are no longer essential qualitative differences between human and machine work. This is indicated by the results of an Associated Press venture using automation of simple financial reports and later successive approaches, such as the involvement of the automated "seismic reporter" Quakebot by the *Los Angeles Times* and the Heliograf generator of simple sports reports developed by the editors of *The Washington Post*.

The fears described in this article of representatives of typical mass media professions, journalists and editors, are unfounded in the eyes of proponents of introducing new technological solutions (such as Kristian Hammond of Narrative Science, quoted at length above) and based on a low level of knowledge about artificial intelligence, its capabilities, as well as the professional development opportunities that may be associated with it. To those worried about jobs, AI promoters point to opportunities to acquire qualifications and skills over and above the traditional models of mass media occupations.

The benefits expected by media companies and publishing executives from the introduction and development of techniques based on machine learning are not always clearly aligned with the professional interests of the journalism community. This is, among other things, the basis of the aforementioned concerns and the reserve, if not outright reluctance towards new technologies expressed by media professionals in surveys. The growth of positive feelings toward algorithms is also not helped by strikingly visualized demonstrations of the capabilities of journalism bots, such as the news "presenter" of China's Xinhua agency, or the development of conversational artificial intelligence like Alexa or Google Home, which are already capable of replacing traditional radio announcers or, with the addition of advanced 3D image generation, also television presenters.

It seems that the obvious aspiration in this situation should be to look for ways to educate media people in the new skills resulting from the expansion of the solutions described above. In recent years, there has been a growing number of educational initiatives around the world, sometimes even already extensive comprehensive training programs, about learning how to use the results of algorithms, data processing and even programming. It also seems desirable to launch this kind of education for media professionals in the Polish market, both within the structures of university education, as well as through all kinds of training offered by state or commercial entities, intended for people already working in the professions of the mass media. Supplementing the Integrated Qualifications Register with qualifications reflecting the specific needs of the media in this regard would help guide and organize this strand of professional education.

Bibliography

Act of 22 December 2015 on the Integrated Qualifications System. http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20160000064/U/D20160064Lj.pdf

Aldhous, P. (2017). How BuzzFeed News revealed hidden spy planes in US airspace. *Columbia Journalism Review*. https://www.cjr.org/watchdog/howbuzzfeed-news-revealed-hidden-spy-planes-in-us-airspace.php

BBC (2020). *BBC Global News launches AI-powered synthetic voice which 'reads' articles on BBC.com*. https://www.bbc.co.uk/mediacentre/worldnews/2020/life-project

Beckett, C. (2019). *New powers, new responsibilities. A global survey of journalism and artificial intelligence*. https://drive.google.com/file/d/1utmAMCmd4rfJHrUfLLfSJ-clpFTjyef1/view

Caixiong, Z. (2017). Robot reporter makes newspaper debut. *China Daily*. http://www.chinadaily.com.cn/china/2017-01/18/content_27989654.htm

Carlson, M. (2014). The Robotic Reporter. *Research Gate*. https://www. researchgate.net/publication/276168178_The_Robotic_Reporter

Casselman, B. (2019). In Data Journalism, Tech Matters Less Than the People. *The New York Times*. https://www.nytimes.com/2019/11/13/technology/personaltech/data-journalism-economics.html

Castro, A. (2020). OpenAI's latest breakthrough is astonishingly powerful, but still fighting its flaws. *The Verge*. https://www.theverge.com/21346343/gpt-3-explainer-openai-examples-errors-agi-potential

Chua, R. (2018). The cybernetic newsroom: horses and cars. *Reuters*. https://www.reuters.com/article/rpb-cyber-idUSKCN1GO0Z0

Council recommendation of 22 May 2017 on the European Qualifications Framework for lifelong learning. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017H0615(01)

Daewon, K., & Seongcheol, K., (2017). Newspaper journalists' attitudes towards robot journalism. *Research Gate*. https://www.researchgate.net/publication/321749580_Newspaper_journalists'_attitudes_towards_robot_journalism

Dans, E. (2019). Meet Bertie, Heliograf And Cyborg, The New Journalists On The Block. *Forbes*. https://www.forbes.com/sites/enriquedans/2019/02/06/meet-bertie-heliograf-and-cyborg-the-new-journalists-on-the-block/?sh= 2c0fab93138d

Dedman, B. (1989). The Color of Money. *The Atlanta Journal-Constitution*. http://powerreporting.com/color/color_of_money.pdf

Diakopoulos, N. (2019). Automating the News. How Algorithms Are Rewriting the Media. *Harvard University Press*. https://www.hup.harvard.edu/catalog.php?isbn=9780674976986

Echobox (2020). *Coronavirus impact on publishers* [Blog]. https://www. echobox.com/resources/blog/coronavirus-impact-on-publishers

Fanta, A. (2017). Putting Europe's Robots on the Map: Automated journalism in news agencies. *Reuters Institute, University of Oxford*. https://reutersinstitute.politics.ox.ac.uk/our-research/putting-europes-robots-map-automated-journalism-news-agencies

Frey, C. B., & Osborne, M. A. (2013). The future of employment: how susceptible are jobs to computerisation? *Oxford Martin School*. https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

Gannes, L. (2019). *Hey Google, play me the news* [Google Blog]. https://blog.google/products/news/your-news-update/

Google News Initiative (2020). *Digital News Innovation Fund Impact Report*. https://newsinitiative.withgoogle.com/dnifund/report/

Hao, K. (2020). OpenAI is giving Microsoft exclusive access to its GPT-3 language model. *MIT Technology Review*. https://www.technologyreview.com/2020/09/23/1008729/openai-is-giving-microsoft-exclusive-access-to-its-gpt-3-language-model/

Hermann, E. (2021). Artificial intelligence and mass personalization of communication content – An ethical and literacy perspective. *SAGE Journals*. https://journals.sagepub.com/doi/abs/10.1177/14614448211022702

Holmes, A. (2020). A fake blog written by AI shot to the top of Hacker News after people thought it was real. *Business Insider*. https://www.businessinsider.com/fake-ai-generated-gpt3-blog-hacker-news-2020-8?IR=T

Integrated Qualifications System. https://kwalifikacje.gov.pl

Kahn, J. (2019). The AI that can write a fake news story after being given just a few words. *The Sydney Morning Herald*. https://www.smh.com.au/business/companies/the-ai-that-can-write-a-fake-news-story-after-being-given-just-afew-words-20190215-p50xxv.html

Kayser-Bril, N., Valeeva, A., Radchenko, I. (2016). Transformation of communication processes: data journalism. *Research Gate*. https://www.researchgate.net/publication/302381355_Transformation_of_Communication_Processes_Data_Journalism/fulltext/57302b6f08aeb1c73d13ac40/Transformation-of-Communication-Processes-Data-Journalism.pdf

La Nación (2019). *Driver's notebooks exposed Argentina's greatest corruption scandal ever: Ten years and millions of cash bribes in bags* [Blog]. https://blogs.lanacion.com.ar/projects/data/the-drivers-corruption-notebooks-argentine-massive-bribery-scandal/

Levy, S. (2012). Can an Algorithm Write a Better News Story Than a Human Reporter? *Wired*. https://www.wired.com/2012/04/can-an-algorithm-write-a-better-news-story-than-a-human-reporter/

Los Angeles Times (2021). *The Homicide Report*. https://homicide.latimes.com

Mayhew, F. (2020). Most journalists see AI robots as a threat to their industry: This is why they are wrong. *Press Gazette*. https://www.pressgazette.co.uk/ ai-journalism/

McKinsey Global Institute (2017). *Jobs lost, jobs gained: What the future of work will mean for jobs, skills, and wages*. https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-meanfor-jobs-skills-and-wages

Merrill, J. B. (2017). Chamber of Secrets: Teaching a Machine What Congress Cares About. *ProPublica*. https://www.propublica.org/nerds/teaching-a-machine-what-congress-cares-about

Miller, R. (2015). AP's 'robot journalists' are writing their own stories now. *The Verge*. https://www.theverge.com/2015/1/29/7939067/ ap-journalism-automation-robots-financial-reporting

Peiser, J. (2019). The Rise of the Robot Reporter. *The New York Times*. https://www.nytimes.com/2019/02/05/business/media/artificial-intelligence-journalism-robots.html

Pew Research Center (2014). *AI, Robotics, and the Future of Jobs*. https://www.pewresearch.org/internet/2014/08/06/future-of-jobs/

Plattner, T., & Orel, D. (2019). Addressing Micro-Audiences at Scale. *Presentation at the Computation + Journalism Forum in Miami*. https://drive.google.com/ file/d/1CJvITDxHEbPKMUO4Pq457N8BvuEZHrGk/view

Rampersad, G. (2020). Robot will take your job: Innovation for an era of artificial intelligence. *Journal of Business Research*. https://doi.org/10.1016/j. jbusres.2020.05.019

Reporters and Data and Robots – RADAR (n.d.). https://pa.media/radar-news/

Resolution No. 196 of the Council of Ministers of December 28, 2020 on the establishment of the Policy for the Development of Artificial Intelligence in Poland from 2020. https://isap.sejm.gov.pl/isap.nsf/download.xsp/WMP20210000023/O/M20210023.pdf

Reuters (2020). *Reuters and Synthesia unveil AI prototype for automated video reports*. https://www.reuters.com/article/rpb-synthesia-prototype -idUSKBN2011O3

Rogers, S. (n.d.). Behind the Scenes at the Guardian Datablog. *DataJournalism.com*. https://datajournalism.com/read/handbook/one/in-the-newsroom/behind-the-scenes-at-the-guardian-datablog

Sahota, N. (2018). A.I. May Have Written This Article. But Is That Such a Bad Thing? *Forbes*. https://www.forbes.com/sites/cognitiveworld/2018/09/16/did-ai-write-this-article/?sh=112df09e1885

Simonite, T. (2015). Robot Journalist Finds New Work on Wall Street. *MIT Technology Review*. https://www.technologyreview.com/2015/01/09/169664/ robot-journalist-finds-new-work-on-wall-street/

Stahl, A. (2021). How AI Will Impact The Future Of Work And Life. *Forbes*. https://www.forbes.com/sites/ashleystahl/2021/03/10/how-ai-will-impact-the-future-of-work-and-life/

Steger, I. (2019). This is China's AI female news anchor. World Economic Forum. https://www.weforum.org/agenda/2019/02/chinese-state-media-s-latest-innovation-is-an-ai-female-news-anchor

The Guardian (2020). A robot wrote this entire article. Are you scared yet, human? https://www.theguardian.com/commentisfree/2020/sep/08/robot-wrote-this-article-gpt-3

The Washington Post (2016). *The Washington Post experiments with automated storytelling to help power 2016 Rio Olympics coverage*. https://www.washingtonpost.com/pr/wp/2016/08/05/the-washington-post-experiments-with-automated-storytelling-to-help-power-2016-rio-olympics-coverage/

Túñez-López, J. M., Fieiras Ceide, C., Vaz-Álvarez, M. (2021). Impact of Artificial Intelligence on Journalism: transformations in the company, products, contents and professional profile. Communication & Society, 34(1), 177–193. https://www.researchgate.net/publication/348431573_Impact_of_Artificial_Intelligence_on_Journalism_transformations_in_the_company_products_contents_and_ professional_profile

Waterson, J. (2020). Microsoft sacks journalists to replace them with robots. *The Guardian*. https://www.theguardian.com/technology/2020/may/30/microsoft-sacks-journalists-to-replace-them-with-robots

Willens, M. (2019). Forbes is building more AI tools for its reporters. *Digiday*. https://digiday.com/media/forbes-built-a-robot-to-pre-write-articles-for-its-contributors/

World Economic Forum (2018). *Can you tell if this was written by a robot? 7 challenges for AI in journalism*. https://www.weforum.org/agenda/2018/01/can-you-tell-if-this-article-was-written-by-a-robot-7-challenges-for-ai-in-journalism/

Zintegrowana Strategia Umiejętności 2030 (część szczegółowa) [Integrated Skills Strategy 2030 (detailed part)] – document approved by the Council of Ministers. https://www.gov.pl/web/edukacja-i-nauka/zintegrowana-strategia-umiejetnosci-2030-czesc-szczegolowa-dokument-przyjety-przez-rade-ministrow

Education

Artificial intelligence is encroaching into schools: how to learn about AI and with AI's help

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One of the missions of school is the intellectual development of students, who are now increasingly surrounded by devices and manifestations of artificial intelligence (AI). This happens when they program robots, play various games, use maps or Google translator. Outside of school, they also see robots replacing humans (e.g., on automobile assembly lines) and many other devices, machines and everyday objects exhibiting certain characteristics associated with human intelligence.

The main purpose of this chapter is to introduce AI to the educational community and to draw attention to and provide arguments for the fact that the time has come for artificial intelligence to appear overtly in schools. Because of AI's close connection with computer methods and computer science, the computer science education community proposes that AI become a module of computer science education, as well as be integrated with other subjects. The structure of the proposed module (see subsection 4.1 below) is taken from a professional source (which will be discussed later in this chapter), but its implementation will require closer links to the provisions of the current core curriculum. Included are selected examples of areas in which students can develop familiarity with AI, expand their knowledge and skills in computer science and other fields, as well as reflect on important social aspects pertaining to the expansion of AI.

A significant part of this chapter presents considerations on the historical background of AI development and its connections mainly with mathematics and computer science (see subsection 3) – history has traditionally been a good teacher. These connections include both scientific aspects and the domain of education, where the expansion of technology is accompanied by solutions that make computers more intelligent devices, assisting students and teachers in some of their activities.

Areas where AI can have a significant impact on the functioning of the school as an institution and the work of teachers are also pointed out. Finally, the risks associated with the emergence of AI, particularly in education, as well as the challenges that come with using AI-based solutions are briefly discussed.

1. A bird's eye view of artificial intelligence… above the school

The traditional role of education is to prepare students for the future. In turn, the future today appears as constantly changing learning and work environments, which are increasingly filled with technology aimed at replacing routine work with automated procedures and devices. Over time, they are taking over many human

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functions traditionally understood as activities requiring intelligence. New professions are emerging that make increasing use of technology, including intelligent solutions, such as robots that automate more than just routine work. The ability to work with them will therefore be essential.

As has been the case with any previous technology, it is anticipated that AI can be an effective tool in education, relieving teachers of routine tasks (checking attendance, grading) and providing support in working with students. In turn, it will provide students with more effective and tailored learning methods. These could be interactive adaptive tutorials that create individualized learning environments and use a human-computer interface. They would monitor the student's work, select appropriate tasks and provide full feedback to students. Combining such individual tutorials into a classroom system could be the beginning of a change in the role of teachers. However, it is important to keep in mind teachers' perennial fears that any technology brought into the school could eventually diminish their role and in time eliminate them – they have examples of this in other automated workplaces. However, the role of teachers will have to be adapted to the environments in which AI-supported students will learn. So, as with other technologies, AI itself will require educational support.

Even at this stage, there are questions about the future fate of schools. If knowledge/intelligence can be put on a chip, will humans still be needed as AI carriers? And the school? When students will be able to choose a chip with the right scale of intelligence, why would they go to school if they can put their brain with an extra chip in the cloud of their class peers from wherever they happen to be? The basic mistake in such a forward-looking approach is to operate in the context of today's categories, such as school, student, teacher, class, exam, knowledge, for which it is now still difficult to imagine equivalents in an era of AI brains.

It is worth recalling at this point that "wisdom, in the future, is putting together symbiotically what the brain does best and what machines can do even better" (Prensky, 2012). In addition, an important skill of computational thinking is being formed, which should precede the use of technology, even if it is imbued with "thinking" AI solutions.

The objections to AI, in particular to machine learning (see subsection 4.3), prompt deep consideration of the place and way of using AI solutions in learning and in the education system. It seems that, at least at this stage, one should not completely surrender education to AI solutions, but rather adopt "mixed" solutions, representing the symbiosis proposed by Prensky of traditional thinking with artificial intelligence supported by machine learning.[8] Artificial intelligence in education should therefore be looked at from the position of "artificial intelligence and the human" rather than "artificial intelligence versus the human", that is, to consider how people can use AI for their own purposes: individually – in learning, as well as in education and in school – to organize the educational process.

[8] An expression of this author's approach to AI was the title of a speech at the Informatics in Education conference "Intelligence+" (Sysło, 2019).

To summarize, AI is generally used in education in two areas:

1. AI in the classroom – the key issue is how to bring AI to students, what students should know about artificial intelligence, and how to use AI solutions in teaching and learning;

2. AI in the school – the transformation of the functioning of the school as an institution in terms of assessing the progress of students, organizing classes and the functioning of the school, as well as the form and mode of classes.

Fazlagić reviews the possible applications of AI in education in this publication (see the chapter *Between artificial intelligence and "artificial creativity" – the future of the creative human in the age of artificial intelligence* in the first part of this publication), but focuses his attention mainly on the second of the above aspects.

2. General comments

2.1. A glimpse of the history

Everything that has happened and is happening around AI is the work of human intelligence, and most often of the most prominent people in their field, and their goal – people and actions – was and is to augment, support or even replace the human mind with thinking machines. Attention will be focused here on those close to computers, mathematics and computer science, since the history of AI is essentially the history of computing techniques, and the modern development of AI and its successes would not have been possible without the growing capabilities of computers and algorithmic methods. However, computers still remain finite machines, even if we run an infinite process with an interaction[9] in them – such is the nature of real-time systems, like the artificial kidney. On the intelligence of computers, one can quote the words of intelligence expert Edward Nęcki (2005) that "the machine is intelligent with the intelligence of the programmer".

Even before the era of computers, Blaise Pascal (1623–1662) and Gottfried W. Leibniz (1646–1716) built the first instruments for calculation.[10] Leibniz's ideas went much further than just automating calculations.[11] He believed that any thought could be formalized and calculations could be performed on it, which could lead to the calculative settlement of disputes, such as between philosophers.

In the first half of the 19th century, Charles Babbage (1792–1871) undertook to build an analytical engine, the concept of which differed a little from the functioning of today's computers. He did not build it, but Augusta Ada Lovelace (1815-1852), Byron's daughter, became enthralled with it and wrote a program for this non-existent machine, making her to be considered today the first

[9] A very interesting point of view is presented by Peter Wegner (Comm. ACM 40, 1997, 81–91), who believes that systems with interaction have more power in solving problems than classical solutions based on algorithms in the Turing Machine model.

[10] The stepped drum designed by Leibniz, which he used in his "Step Reckoner" constructed in 1694, was the basis of mechanical calculators used into the 1970s.

[11] Leibniz is also credited with pioneering binary numbers and computation.

programmer.[12] In her notes on the Analytical Engine, Lovelace enthused about its concept, in which she saw possibilities beyond the traditional purpose of computers as computing devices,[13] and:

- she recognized that it would weave algebraic patterns, just as the Jacquard loom weaves flowers and leaves;
- she envisioned creating a symbolic calculus that could be used, for example, to compose music.

However, she gave a realistic assessment of the machine's capabilities, stating that: "The Analytical Engine has no pretensions to **originate** anything. It can do **whatever we know how to order it** to perform" [Lovelace's emphasis]. This statement was commented on by Alan M. Turing in his famous 1950 work *Computing machinery and intelligence*, recognizing it as *Lady Lovelace's Objection*. There he wrote (based on Feigenbaum et al., 1972):

> I believe that in about fifty years' time it will become possible to programme computers [...] to make them play the imitation game so well that an average interrogator will not have more than a 70 percent chance of making the right identification [...]. …I believe that by the end of the century [the 20th century] the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted (https://plato.stanford.edu/entries/turing-test/).

The aforementioned "imitation game" is known today as the Turing test. It involves a person trying to distinguish between a human and a machine by talking to each of them, but not knowing with whom. If one is unable to distinguish between a person and a machine, we say that the machine has passed the test. In other words, the test is designed to determine the machine's ability to master (in dialogue with a human) the ability to think in a human-like manner. The Turing test became the impetus for the development of AI,[14] and Turing is considered the initiator of AI.

The first half of the 20th century marked the beginning of electronic computer technology, the foundation for which was laid by Claude Shannon (1916–2001), who presented an implementation of Boolean algebra operations in the form of electric circuits in his 1935 thesis at the Massachusetts Institute of Technology (MIT). Shannon is also the founder of information theory and coding (1948) and was interested in automating the game of chess as well (see subsection 3.2 below). Let's also mention John von Neumann's[15] (1912–1957) 1948 optimism: "You insist that there

[12] It is worth quoting this fact to students and others interested in computer science today, including programmers, and reminding them that a computer is not specifically needed to design an algorithm and write a program. It is, of course, needed when the program is to be executed, in which case it must first be coded in a language understandable to a particular machine.

[13] Ada Lovelace's predictions are being realized today in the form of machine-painted images and musical pieces created by AI.

[14] Simple conversation programs, such as Joseph Weizenbaum's ELIZA of 1967, were able to make people of a certain circle believed they were talking to a living person.

[15] John von Neumann is recognized as the creator of the so-called von Neumann architecture (First Draft, 1945), on the basis of which modern computers are built and function. He also participated in the construction of one of the first computers at the IAS in Princeton.

is something a machine cannot do. If you will tell me precisely what it is that a machine cannot do, then I can always make a machine which will do just that!" (https://cs.stanford.edu/people/eroberts/courses/soco/projects/2004-05/ai/index.html). This was a rather optimistic view of computers being developed at the time, even though unsolvable problems were already known. And today a whole range of NP-complete and NP-hard problems do not lend themselves to fast computation even for small data.[16]

Many great scientists and thinkers, however, have put firm limits on the expansion of AI. The author, as a mathematician, is close to the view of Kurt Gödel,[17] that "the human mind infinitely surpasses the powers of any finite machine" – words uttered in 1951 even before the AI field was established – and the 1996 opinion of Roger Penrose that "we have access to mathematical truths that are beyond any robot's capabilities".

Finally, we arrive at John McCarthy (1927–2011), a computer scientist and founder of the field of AI, who in 1956 organized a scientific conference at Dartmouth, the first time with AI in the title (McCarthy et al., 1955). Other initiators of this conference included Marvin Minsky (1927–2016) of Harvard and Claude Shannon of Bell Telephone Labs. McCarthy described the field as "the science and engineering of creating intelligent machines", that is, computers that behave like humans. He wanted to distinguish his initiative by this name from the then-popular cybernetics of Norbert Wiener (1894–1964), who studied control and communication in animals and machines.

Today, in public debate and public perception, artificial intelligence is following the path previously taken by (micro) personal computers (for the last three decades of the 20th century) and the Internet (since the last decade of the 20th century). These two technologies caused major technological and social changes, although there were no significant breakthroughs in the functioning of societies, especially in the spheres of education, science, welfare and mental activity. For some time now, AI has been acquiring greater social significance than the aforementioned two technologies, remaining in multiple relationships with AI as the tools, environment and medium of communication, among others. Historically, however, the three technologies should not be used to define successive and disconnected eras, as each successive technology actually builds on all previous ones. In particular, AI systems are computer-based, and the Internet is a communication medium for them, including as perceived by the people or objects it affects

2.2. The first attempts with computers in education

The increase in computer capabilities at the turn of the 1950s to the 1960s coincided with the growing popularity of programmed learning. For the purposes of

[16] Taking the approach presented by von Neumann today, we could put off solving the unsolved problems for a while and wait for the right AI to emerge to help us solve them. However, even seriously dealing with the development of machine learning should not be an excuse against creating high-quality and reliable solutions, such as in software engineering.

[17] Kurt Gödel (1906–1978), author of the famous incompleteness theorem, from which it can be deduced that no computer can be programmed to be able to solve all mathematical problems. In a sense, this also sets the limits of computer science and AI.

education, the development of PLATO (Programmed Logic for Automated Teaching Operations), a computer assisted instruction (CAI) system, began. Seymour Papert (1928–2016) was a staunch critic of CAI systems, who, steeped in constructivist ideas, believed that the learner, as a user of a CAI-type system, behaved passively, following mainly computer commands. Opposing emerging ideas that computers, at least to some extent, could take over the role of the teacher, he reversed the student-computer relationship and wrote in his *Mindstorms* (Papert, 1980):

> One might say the *computer is being used to program* the child. In my vision, the child programs the computer [Papert's emphasis] (p. 5).

And further:[18]

> The computer can be a mathematics-speaking and an alphabetic-speaking entity. We are learning how to make computers with which children love to communicate. When this communication occurs, children learn mathematics as a living language. Moreover, mathematical communication and alphabetic communication are thereby both transformed from the alien and therefore difficult things they are for most children into natural and therefore easy ones. The idea of "talking mathematics" to a computer can be generalized to a view of learning mathematics in "Mathland"; that is to say, in a context which is to learning mathematics what living in France is to learning French (p. 6).

In programming, as the ability to give commands to a computer, Papert saw a way for a student to communicate with the computer in a language that both parties understand. To this end, he created Logo,[19] the first programming language for children, as a bridge between their world and computers.

In retrospect, it is clear that Papert was ahead of his time, preaching ideas that can only be realized in the 21st century, when a student can be a co-creator of the content and learning environment. However, he did not avoid making a mistake. He unrealistically believed that even then computers plus Logo would enrich education when there were neither enough computers in schools, nor did they themselves enable the creation of appropriate learning environments and, most importantly, teachers were not prepared to implement his ideas. A decade later, in another of his books, Papert (1993) did not hide his disappointment that schools were so resistant to adopting his ideas. Computers are being used without changing the habits of traditional didactics, modifying curricula accordingly or preparing teachers for the new challenges. Steps should be taken now to avoid making similar mistakes when introducing AI into schools.

It is worth mentioning that in 1963, AI pioneer Marvin Minsky invited Papert to work with him and lead the Artificial Intelligence Laboratory at MIT. In 1969, they published *Perceptrons,* a book on the mathematical analysis of a machine built on artificial neural networks to model the brain, which had a significant impact on AI research. The

[18] Papert's fascination with France in this quote can be attributed to his close contact with the country between 1958 and 1963, when he worked in nearby Geneva with Jean Piaget, the father of constructivism.

[19] The idea of introducing the Logo programming language into schools, on the other hand, did not appeal to the developers of CAI systems at the time, who believed that neither computer programming nor computer science had a place in schools.

machine was designed to recognize handwritten digits from 0 to 9. In 1985, Papert formed MIT's Media Lab, where he and his colleagues worked on epistemology, learning and the future of learning. The result of this group's work is the ideological successor to Logo – the Scratch language, popular today among the youngest learners, with which you can communicate with most robots.

2.3. What is artificial intelligence?

In defining artificial intelligence, it is appropriate to start by explaining what intelligence is, implicitly – human intelligence.

Wikipedia states that "intelligence is [...] the ability to perceive or infer information, and to retain it as knowledge to be applied towards adaptive behaviors within an environment or context"[20] (https://en.wikipedia.org/wiki/Intelligence). Edward Nęcka (2005) discusses intelligence in a broader context and says that "an intelligent person is someone who processes information efficiently, solves problems well, understands complex issues and handles new situations well." Asked, "Can a machine be intelligent?" he answers, "Let's specify that it's not simply computers, but computer programs. Most of them are not intelligent in the sense that humans are. They only execute commands according to a preset order, i.e., an algorithm." He concludes that "[...] the machine is intelligent with the intelligence of the programmer."[21] We return, as it were, to Ada Lovelace's prediction from the mid-19th century.

Moving on to the definition of artificial intelligence, it is necessary to quote more important sources. Let us begin with the website sztucznaintelligencja.org.pl, where you can also find a section dedicated to AI in education. The dictionary at this site can serve as a source of definitions for many AI-related terms. In particular, AI is defined as "the imitation by machines, especially computer systems, of the processes that determine human intelligence. In other words, artificial intelligence is the science of how to produce machines equipped with certain features of the human mind, such as the ability to understand language, recognize images, solve problems and learn."

Finally, it is worth returning to the definition of AI given by the initiators of the discipline: "…the artificial intelligence problem is taken to be that of making a machine behave in ways that would be called intelligent if a human were so behaving" (McCarthy et al., 1955).

The above terms for AI are very capacious, as is the term for human intelligence.

When defining AI, it should be mentioned that computer scientists have trouble all the time defining what computer science is, although the original equivalent of computer science comes to their aid. So, we can say that computer science is the field that deals with the science and practice of computers, computer

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[20] Animals – dogs, cats or even birds – are also learning; they are gaining new knowledge and skills, developing, becoming increasingly better at performing complex tasks in eating and moving around.

[21] In another statement, E. Nęcka (2005) referred to Howard Gardner's 1983 concept of multiple intelligences and concluded that they are simply isolated talents or special abilities. They could be called intelligent if their substrate was thinking, problem-solving or other cognitive activities.

programming (actually programming algorithms for computers), computer networks and, of course, building and constructing ever more powerful machines. In a sense, the tool defines the field, but not completely. As attributed to Edsger W. Dijkstra: "Computer science is no more about computers than astronomy is about telescopes" (https://en.wikiquote.org/wiki/Computer_science#Disputed). So a computer is a tool, obviously not very intelligent, to invoke Ada Lovelace, but with insanely high capabilities. And it is human intelligence that reaches out to computers to create artificial intelligence.

2.4. Machine learning

A popular artificial intelligence technology are artificial neural networks. Ideas for their computer implementation have been emerging since the beginning of the computer era. These networks are the basic mechanism of machine learning. Such a network is a mathematical system, consisting of multiple layers of artificial neurons, with connections carrying certain weights running between them, and the system is built to maximize a specific goal. These networks are not programmed in the traditional way according to specific algorithms, but are trained – one can talk about their learning – using a huge amount of sample data and adjusting the weights of the internal connections so as to determine the model that will maximize the specific goal. As a result, a matrix of connection weights can take up gigabytes of memory. In this way, systems are created that learn on their own how to behave in particular with regard to data on which they have not been trained – they then extrapolate "what they have learned"[22] (e.g., playing chess, painting pictures).

A fairly natural use of machine learning is the creation of targeted (individualized) information based on the huge amount of data collected from social networks, email systems, search engines and mobile phone networks. As a result, we receive fairly accurately addressed advertisements and recommendations (after revealing our interests), suspicious emails are considered spam, browsers suggest search topics, etc., etc., etc. No less useful are smartphone word prompts when writing messages and all kinds of programs that act as translators. There is great benefit in using machine learning in commerce and business, especially in bigger companies with large amounts of data collected during electronic communication with customers.

In education, machine learning systems are just paving the way. It is expected that such systems will prove very helpful in the automatic assessment of students, as well as in the role of tutors, or individual tutors. In the latter case, there may be a doubt of the kind: which came first, the chicken or the egg? A tutor of English, for example, will first be trained on various texts, then the students will begin to use them, and then the tutor will continue to learn from the data that the learners provide it with. At some point, the question may arise, who is teaching whom in this situation?

3. Artificial intelligence in school

The strategic challenge for society is to have the education of every citizen extend from birth to the grave – formally known as lifelong learning. Here we will limit

[22] The data for learning how the system should behave can be generated by the same system. This is how master systems develop, learning to play chess or Go – by playing games against themselves.

ourselves to education in K–12, that is, from kindergarten to the end of secondary school[23] – the period of formal education, in the case of our country – centrally managed. Its main document is the core curriculum, defining for each subject:[24] the learning objectives – general requirements – and learning content – specific requirements. The latter provisions are formulated in the language of student achievements. The core curriculum for each stage of education is accompanied by a description of the conditions and methods of its implementation. Computer science is a separate subject from the first to the last grade in school, with an allocation of at least 1 hour of instruction per week. In secondary school, a student can additionally choose computer science at an advanced level and take a secondary school completion (*matura*) exam in this subject.

The core curriculum for computer science does not include any elements of artificial intelligence,[25] the same is true of the curriculum for computer science (in the US) and computing (in the UK).[26] The reasons for this are at least two: 1) the traditional understanding of computer science in school education, based on the classical definition of algorithm and programming, and 2) the lack of access to AI solutions addressed to students in their learning and to teachers as organizers of the teaching and learning process. Even if such solutions appear, teachers are not prepared to incorporate and apply them.

In the classical sense, an algorithm is a process that can be performed by a Turing machine, which is an abstract model of a computer, consisting of a control unit, a reading and writing head and an infinite tape. Each cell of the tape can hold one symbol, the head is positioned over one of the cells and is in one of the states. Depending on the state and the symbol on the tape, the head can write a new value in the cell over which it stands, change the state and move over the cell on the right or left. Such a single operation can be considered a command for this machine, and the list of all commands can be considered a program.

The above meaning for computation was defined by Alan Turing in 1936 in relation to human computation.[27] Many other models appeared earlier and later, all equivalent in the sense of their power. School, of course, is not the place to refer to such theoretical fundamentals of computer science. As in other circles of algorithm users, schools take advantage of the fact that algorithms performing basic arithmetic and logical operations and organizing calculations by means of basic programming constructs (such as iteration and conditional instructions) are implemented in the form of a Turing machine.

For some time now, the concept of an algorithm has begun to expand, with interactive, real-time, analog and hybrid algorithms, quantum algorithms and many

[23] This period of education is referred to by the acronym K–12, where K is Kindergarten. The term is commonly used in the United States.

[24] The Polish educational system maintains the model of teaching individual subjects separately and the associated class-lesson system.

[25] AI, however, appears in the curriculum of the subject of ethics in secondary school, in the specific requirements section Ethics and Science and Technology – the student: "identifies and analyzes selected moral problems relating to the progress of science and technology (e.g., [...] the development of artificial intelligence [...])." For the implementation of this provision, however, superficial knowledge of the mechanisms of artificial intelligence solutions is not enough.

[26] Meanwhile, AI has been in the national curriculum in China since 2018 (see Konox, 2020; Wang et al. 2020).

[27] Back in the 1960s, the first meaning of the word computer in the Oxford English Dictionary was a person who computes, whereas "a tool for computing" was only the second meaning.

others appearing. The Turing machine is no longer a suitable model for such extended computations, for example, able to update all its cells at once, as happens in some survival games. In such a situation, following David Harel (1992), it can be assumed that an algorithm is a creation that can be expressed in a programming language.

The effects of AI, mostly only observed, can be an opportunity in school to significantly expand the concepts of algorithm and computation. The simplest example here is the easy access students have in using events in interactive programming – this is possible in Scratch, in code.org puzzles and in many other environments. This is also a simple example of communicating with a computer, which unfortunately was not present at the time of the creation and development of the Logo language, but which Papert must have thought of when he dreamed of the child programming a computer and communicating with it.

Subsection 3.1 proposes a module of classes aimed at introducing AI to students from kindergarten to 12th grade using examples of certain solutions available at the school level. Although AI grew up on computers and is "driven" by their power, the proposed classes should not be limited to computer science alone as an illustration of the power of these machines. One can find situations, problems and challenges solved using AI in every field and school subject. Selected examples are presented below, and a more complete list of them will be the subject of a separate methodological paper for the proposed module.

Since AI is inextricably associated with computers, its computer science aspects, especially algorithmics and programming, are recommended for computer science classes.

Artificial intelligence solutions are not yet part of school management systems, nor have they reached teachers to better help students learn. These issues are not included in the proposed module, while subsection 4.4 briefly describes the more important solutions, along with encouragement for teachers to try to incorporate them into their educator's palette.

3.1. Artificial intelligence in the classroom

Education from an early age should train the ability to understand AI and communicate with systems using AI methods/algorithms. Properly reading and interpreting the effects of artificial intelligence is a prerequisite for the appropriate and safe use of its solutions. Unattended solutions (checkouts, cars) are already becoming commonplace today. The user should understand how they work, and thus have confidence in their safe and trouble-free operation. On the other hand, it is also important to learn how such systems should be and are built to better understand their operation. Many of these elements can already be conveyed to students at school.

Students hear about AI on a daily basis and often think that it works in phones, on computer screens, and in home devices that automatically respond to conditions around them. In many such cases, this is usually the result of sensors and reactions to their indications. Many students' exaggerated, often magical notions of artificial intelligence come from assigned readings, books, movies and SF games. The AI in them is more the imagination and visions of the authors than the reality, but it can inspire students in their classes at school, and especially in the future, when they will have the opportunity to invent, design and create solutions using AI themselves

In the near future, existing knowledge of the technology and its practical aspects will have to be augmented with basic knowledge of AI. Students should already start preparing at an early age to use AI solutions and navigate in an AI "driven" world, while being sensitized to ethical and social aspects. AI has the potential to change the forms and organization of teaching and learning. This will happen, for example, when applications for natural language recognition and processing begin to be used in language education. This expansion of artificial intelligence requires the inclusion of AI provisions in the computer science core curriculum. Its implementation should be accompanied in advance by providing schools with appropriate equipment and software, and especially by preparing and supporting teachers.

Below, based on the proposal of the Computer Science Teachers Association (CSTA) (see https://github.com/touretzkyds/ai4k12/wiki and Touretzky et al., 2019), we present the thematic outline of an AI Module for schools in Poland. This proposal is based on five main AI ideas that address the most important aspects of AI and are not too advanced for teachers at this stage of introducing AI to schools. Such a module, supplemented by student achievements, which also defines the scope of teacher preparation and the standards of the equipment at school, should be prepared as soon as possible to begin its piloting in schools.

There are many elements in the following proposal that can be found in the current computer science core curriculum. In many cases, it's a matter of emphasizing appropriate learning objectives, working methods and the applications and devices used, as well as programmable and "intelligent" robots.

1. Perception of the environment

Computers and robots view and perceive the world through the sensors they are equipped with, designed, among other things, to:

- recognize speech or faces,
- recognize objects, decipher and understand surroundings/scenes,
- recognize other forms of communication: sounds, temperature, radiation, etc.

Students should be able to identify the type of sensors (stand-alone and in other devices), their functions, purpose and limitations.

2. Representation, understanding and decision-making

Computer agents,[28] having a representation and model of the environment (world), make decisions based on this, which includes:

- knowledge representations, e.g., in the form of graphical diagrams,
- semantic computer networks that understand our questions,
- searching, including heuristic searches,
- inference algorithms, including, in particular, proving theorems, reasoning and justifications based on rules, optimization, i.e., efficient operations.

Students starting in the 4th grade of elementary school should be able to form a logical reasoning and decision-making scheme, in particular, an object search tree in different contexts of problem situations.

3. Learning

Computers can learn from data. This includes, among other things:

- machine learning, including classifiers, discriminators, function approximations; data science, training sets,
- neural networks as a tool for making inferences based on big data.

Students should be able to train a classifier, in the first two grades train a gesture discriminator; in grades 6–8 – define appropriate functions, training a classifier in the form of a decision tree.

4. Natural interactions

AI aims to create agents that interact naturally with humans, among other things, in:

- understanding natural language,
- conducting dialogue,
- affective computing,
- human-robot interactions.

Students in the first two grades should be able to talk to an agent, and in grades 6–8 – they should be able to create a simple chatbot.

[28] An agent is a computer program, generally an elaborate one, operating in a certain environment of software systems, monitoring its environment and making autonomous decisions to achieve its specified goals of operation.

5. Social impact

Artificial intelligence can impact society in both positive and negative ways, including:

- Ethics, and the following related issues:
  - assessing which applications are desirable and acceptable,
  - the transparency and accountability of AI systems,
  - privacy versus security,
  - who should own or have access to our data, as well as the responsible management of our data;
- the expected effects of AI technology's impact on society, such as:
- robot servants, rescuers, companions,
- economic disruptions, changes in the nature of work,
- the effects of unintended biases.

Starting in grade 6, students should be able to identify and describe the ethical issues raised by AI applications.

Relevant applications, many of which are available in our schools (like robots) and most of which are open access on the web, can be useful in achieving the above learning objectives. Among them are applications for: (1) recognizing and remembering faces, people, (2) recognizing and identifying objects, manipulating objects, such as robots or with the help of robots (e.g., industrial robots), (3) navigating in the field (robots in the classroom, cars, people), (4) automatic text translation (e.g., Google translator), (5) generating speech, speech recognition (bots).

3.2. Selected proposals for lessons

Selected examples of the use of AI in various spheres of human activity are reviewed here. They can become the subject of activities to introduce AI and engage students to actively explore AI's capabilities.

Robots

Robots are today the most popular educational toys, filling classrooms from kindergartens, through early childhood education (grades 1–3), to older grades almost to the end of secondary school. More advanced robot constructions are used and self-built in vocational schools, as an implementation of the provisions of the computer science core curriculum: "The student: [...] designs, creates and tests software that controls a robot or other object on a screen or in reality." The robots used are equipped with a variety of sensors to recognize the environment, operate with sound and lights, and are generally programmable in various languages, such as Scratch, Blockly, Python. More advanced robots, such as humanoids, remain beyond the financial reach of the school.

Computer games

An interesting story for students may be the history of attempts to automate the game of chess, which attracted some of the keenest mathematical minds.[29] Long before the computer age, there were attempts to construct chess automata, and in the late 1940s, Alan Turing and Claude Shannon were interested in chess machines. Turing wrote software for an MADM machine to play a full game of chess, Shannon built a Caissac machine to play chess endings, and in 1956 ran a chess program on one of the first MANIAC I computers. In 1950, Shannon estimated that the size of the search tree in this game is 10120 (the so-called Shannon number), but this does not encourage many amateurs to create computer programs that play chess based on a full exploration of the space of possible situations (so-called brute force).

In the late 1980s, IBM began developing a machine to beat the then chess champion Garry Kasparov. Kasparov won the first game 4:2 (1996), but lost the second duel 3.5:2.5 (1997). However, this was a success for the power of the computational system, as it treated chess as a complex computational problem rather than an artificial intelligence challenge. The machine did not mimic the thought process and had no self-learning function; its power lay in its great computational power (by brute force methods) and its ability to quickly use the huge amount of accumulated data on chess games.

A fair challenge is the computer chess world championship. In the middle of the second decade of this century, the champion was Stockfish 8, which had access to centuries of accumulated chess experience and could analyze 70 million positions per second. However, at the end of 2017, it lost to the AlphaZero program created by Google, which analyzed only 80,000 moves, had no data from other games, but used machine learning to master the game of chess by playing against itself. The AlphaGo program developed by Google-owned DeepMind was highly successful in the game of Go, which is much more difficult than chess, beating top players from Korea and China. It used an algorithm that is a combination of neural network techniques, machine learning and Monte Carlo search. This raises a question and a doubt about the limits of the intelligence of these programs. For example, is AlphaGo smart enough to sit down to play chess with AlphaZero and win? Or at least play checkers and win? What is the intelligence of these programs? Unfortunately, these systems, like most AI systems, are very narrowly specialized and far from representing general AI.[30]

[29] For more details on this, see Sysło (2019).

[30] General AI will be formed, because there are no such systems, intelligent systems able to think and perform tasks independently as efficiently as a human, including tasks with which they were previously unfamiliar.

Without going into the details of how the computer plays, you can offer students to play a game of chess against a computer at www.chess.com/pl. There are many other games available on the Internet that can be recommended to students as material for discussion of how much the computer in these games is exhibiting intelligence.

The Turing test

The Turing test described in subsection 2.1 lived to see a new version today with reversed roles. In Turing Test 2, a computer program engages in a textual dialogue with a human and another computer. The program's task is to distinguish between the human and the computer. A popular version of this test is CAPTCHA (Completely Automated Public Turing Test To Tell Computers and Humans Apart), which students encounter on many websites. Most commonly, it displays a distorted image of random characters, and a person is supposed to type in the characters correctly read from the image on the keyboard. In another version, the solution to a simple equation must be typed in. In doing so, it is expected that the computer is unable to "read" the image or find the solution. However, there is sometimes unfair play by the computer when it "asks" for a hint from a person to whom the request is not directed for the correct entry.

Google Translator

Among the many programs that translate texts into various languages, the most popular at the moment is Google translator at https://translate.google.pl. It is estimated that it is used daily by more than 500 million users speaking more than 100 languages. Previously, this translator was based on phrase-to-phrase translation, and since 2016 it has been using machine learning. It learns constantly from new texts entered for translation: single words, pairs of words, whole sentences. Each language has its own peculiarities, there are different alphabets (like Arabic, Russian, Japanese, Chinese), for example, German has definite articles, and Polish has cases. English is an intermediate language for translations between two other languages, so it can be considered that the most faithful translations are those in which English is one of the languages.

The computer translator is an excellent tool when using a foreign language, not only in the correct use of the language, but also in learning the ability to correct (debug) texts. Students can also use this program when working with source texts in other languages that they do not know.

Using Google translator can be a great opportunity, even a lesson, to make students aware that AI solutions can be imperfect in their intelligence. Every translation should be verified and often corrected. In general, this program has a problem with idioms, not to mention proverbs. It has already learned that "it's raining cats and dogs" in Polish is "it's pouring as if from buckets [*leje jak z cebra*]," but when asked to translate "raining cats and dogs" it gives us [the literal] "rain of cats and dogs" [*deszcz kotów i psów*], without guessing our mistake. Nor does it associate that "east or west home is best" in Polish means "everywhere is good, but home is the best" [*wszędzie dobrze, ale w domu najlepiej*]. However, it learns by accepting user corrections and suggestions. Translations are unlikely to be fully algorithmized, even by neural network methods, as these are sometimes unique. It needs to be trained on the translations of words or larger passages with cultural contexts.

There are many programs available that translate not only printed texts, but also handwriting, websites, spoken words and other forms of communication.

Google Maps

This is another service that uses machine learning. This application and others with similar purposes are the basis for planning and driving vehicles with autonomous driver functionality. We often use such systems to suggest our next moves on the road: go straight or turn right. In addition, they show the course of the entire route, the approximate travel time, some road signs (such as the speed limit). Unfortunately, it has already turned out that complete reliance on such a system in an autonomous car can lead to a fatal accident.

An interesting exercise with this system might be for students to conduct an experiment to verify the parameters of their various routes from home to school by different means of transportation: on foot, walking to pick up a friend, on a bicycle, by streetcar, by bus, by family car.

Art

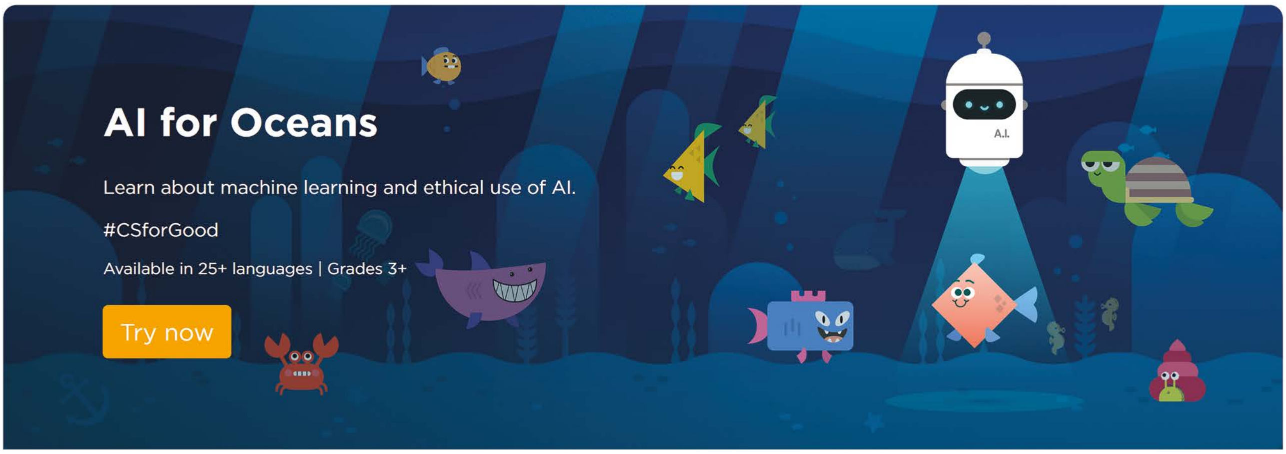
A painting made by a machine learning algorithm, called *Portrait of a Man,* has been circulating in the world. It was displayed for less than $10,000 and sold for $400,000. The portrait was created as a result of machine learning based on data collected from more than 15,000 other portraits. Looking at it from the side, one could compare the process of making this work to the process an artist follows when creating works by traditional methods. The artist also looks at many other works, actual models and patterns, makes many sketches, and thus collects data for his/her work.

However, the traditional artist is accompanied by all the baggage of life experiences, ones of the past and those of the moment of creation. This is alien to the machine. In fact, the work of art is not the painting itself, but the entire process of its creation. The differences between the processes, the traditional one and the one supported by AI, are projected in the final result. According to experts (Hertzmann, 2020), modern technologies such as AI do not create art, they are mainly a tool in the hands of artists. This is because art is a social activity, while AI is still software.

Machine learning

Students can already be partners in creating AI solutions using machine learning. The simplest examples of such possibilities are offered by the code.org environment. This is a collection of puzzles called *Artificial Intelligence for Oceans* https://code.org/oceans. In an interactive game, students teach an AI robot how to distinguish between fish and pollution so that the robot removes trash from the oceans. The puzzles are accompanied by videos from which students learn what AI is, what machine learning is, and what training data is. At the same time, they learn how artificial intelligence can be used to solve real world problems. These puzzles are accessible even to preschoolers. By solving them, children have the opportunity to take the first steps in learning about AI methods and applications.

Figure 1. *AI for Oceans* **https://code.org/oceans**



3.3. AI and computer science (informatics) education

Many of the student activities mentioned in subsection 3.1 appear in computer science education, in which computational thinking is the primary approach to problem solving and project realization. This is another argument for school activities in AI to be closely linked to computer science. Educational practice in computational thinking will be the subject of a book by Sysło (2022). Seymour Papert (1980) wrote about computational thinking with his constructivist ideas well ahead of the possibilities of technology. Returning to this concept in 2006, Jeannette Wing (2022) used the term to describe "the useful attitudes and skills that everyone, not just computer scientists, should try to develop and apply." Thus, the term should not be taken as shorthand for "thinking like a computer scientist". It is now accepted that:

> Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry out. (Wing, 2014)

The most important mental tools in computer thinking are considered to be:

- abstraction – enabling the modeling of the most important features of the problem situation under study, while neglecting secondary features;
- recognition of formulas and patterns – patterns can enable modeling, algorithmization and analysis, and later – the automation of calculations;
- reduction and decomposition of a complex problem into smaller subproblems whose solutions are known or easier to solve;

- algorithmization, i.e., the creation of procedures for decision-making on the basis of properly prepared data;
- generalization, that is, transferring the effects of reasoning to more general, richer situations (Sysło, 2018).

A fundamental role in the processing of large amounts of data, which takes place in machine learning, is played by abstraction, i.e., the omission of secondary features of the data, recognizing patterns in them while adopting an appropriate representation of them for further processing. The initial analysis of the data is facilitated by decomposing it in terms of the features it has. Abstraction and decomposition in machine learning play the role of preparing data for further processing in appropriately built neural networks, which can be considered the algorithm of the entire AI system. The most important feature of a machine learning system, indeed of any learning, is the ability to generalize, making it possible to apply lessons learned to current, generally new situations. In machine learning, these experiences are the result of training, and generalizations are the decisions made by the system for new data.

3.4. Artificial intelligence in the hands of the teacher, in school

Given the ever-increasing presence of AI in our environment, we should define the place of AI in education and its contribution, as well as the role of traditional education in the *environment* filled by AI. It may also be useful to know the benefits of using AI in administering the education process. No less important are ethical issues, such as those relating to the purpose and scope of using the data collected by AI.

Old doubts resurface as to whether this time AI solutions will replace the teacher, if not fully, then to what possible extent? What then about the responsibility for the results of education, the competence of students, their education? Generally speaking, if in many areas AI is aiming to replace or at least displace humans, then education needs to rethink the competencies that humans should have in an environment with AI solutions.

As always, and this is repeated with every new technology or method of education, it is asserted that its goal is to improve the conditions and ways of learning and for students to achieve better results. Teachers, on the other hand, are told that the purpose of the technology is not to replace them. However, teachers are aware that every new technology means new responsibilities, not only relating to the need for further training, but also to daily duties in and out of the classroom. AI will be no exception here, in fact, it seems that it will require much more lesson preparation from teachers. And this doesn't just apply to computer science teachers who will be introducing students to how AI works, but to all teachers when the classes they supervise/teach will be conducted in an environment of AI solutions. There are as yet no large-scale studies showing the benefits of AI-supported learning environments.

The greatest opportunities in AI applications in education are seen in adaptive (machine) learning systems, which adapt teaching and learning methods and materials to the capabilities and needs of each individual learner.[31] In such a system, the external world is represented by three models: pedagogical – which determines the didactic methods of teaching and learning, domain – this is knowledge about the field of education, and learning – containing information about students' activities and progress. Such a system can be used in the classroom, as well as in cases of individual tutors. An example system using learning about fractions is available in the presentation referenced in item 3 in the "Recommended" subsection below this chapter's bibliography. Another popular area for such systems is foreign languages. A personal tutor is usually an open system, in the sense that provides the learner with opportunities for dialogue, questions and discussion, verification of solutions and dynamic assistance. Whenever such a system is used, it learns from data relating to the environment in which it is used.

Adaptive systems have many advantages, mainly for learners – they allow learners to have personalized, flexible and engaging learning. They can also support collaboration, group work, and are great for project-based work. As for teachers, such systems can be a catalyst for changing their role in teaching. However, it requires considerable preparation to use such systems. The teacher should know and understand the role of such a system, know how to interpret the data and results it provides, know how to formulate appropriate questions for the system, and work with the assistant of such a system as an integral part of it (intelligence). At present, the road to such systems in the classroom seems long: creating the system, preparing the teacher, teaching the system through the use of classroom data, and finally classroom activities. This path could be lengthened by the necessary expansion of AI environments in schools, which at this point seems unrealistic, although abandoning the classroom-teaching system and the school will do little to shorten the path. Real progress could be accelerated by the results of predictive studies that would define a roadmap for schools to gradually adopt AI technology.

No less important than the technical and logistical aspects are the ethical issues of using artificial intelligence in education. We may have doubts about the transparency of AI systems, understanding the decisions they make, their predictability, the possibility of auditing them, that is, controlling and supervising their operation. On the teacher's side, on the other hand, is the responsibility for educational outcomes. What if such a system for some reason starts to malfunction due to errors in the "algorithm" or deliberate action? Such cases have already happened. One of the most important problems is also the protection of teachers' and learners' personal data and the right to access and use them. There are many other problems that AI will face in its expansion into the field of education, such as ensuring equal opportunities for all learners, in and out of school.[32]

[31] A similar idea guided the developers of the PLATO system (Sysło, 2022), but it did not have tools such as neural networks, so that it could learn how best to help learners.

[32] A detailed discussion of the opportunities, problems and risks associated with machine learning was presented in a report by Webb et al. (2020) by a group of experts associated with the Technical Committee on Education of the International Federation for Information Processing.

4. Threats and challenges

4.1. Threats

With the increasing impact of AI solutions on the daily lives of individuals, communities and entire societies, the ethical, legal and social issues are becoming more serious. Here we will comment on some media coverage regarding the impact of AI and how it is perceived.

1. On the first page of one of Google's brochures (Grow with Google), you can read that "Google is committed to making sure everyone benefits from the opportunities created by new technology." And on the last page of the brochure we read that "We are always inspired to see what people do when they have access to technology." So Google is interested in watching us (to see what people do) and that inspires it to act (We are always inspired)! Those who are watched are generally unaware of this voyeurism (read – using the data they leave online, not always consciously) and do not know what the data will be used for.

2. One can question whether every AI solution is really a manifestation of intelligence. Is it a bot produced by a person who may not be very intelligent? Who is to judge this? A machine? The mere use of an intelligent tool does not guarantee the same in the final product. And with regard to education – how can the correctness of the methods used by an AI tutor be judged through the students' performance? Or maybe the AI tutor will be judged by the AI tutor inspector?

3. Uber's autonomous car has already killed a pedestrian in Arizona – the on-board system spent too much time analyzing the "object" it "saw" in front of it, instead of stopping immediately. Who is liable for such an accident? The owner (which could be the rental company), the passengers, the designer, or perhaps the programmer?

We will not continue to multiply examples to the detriment of AI. Fortunately, education has well-defined goals, the implementation of which is to point out to the student the benefits of AI in their near and more distant surroundings and the right ways of using it. It is also supposed to draw attention to the ethical and social aspects and risks. AI is expanding, perhaps even more so than in education, in almost every aspect of modern life. One can only hope that students' attitudes formulated at school will direct their interests to the right track in using modern technology, which is increasingly "saturated" with AI solutions, and their human intelligence and sensitivity will prevail.

4.2. Challenges

When using AI solutions, one of the most serious problems is understanding and accepting the decisions made by AI systems. The problem of automating decisions is not entirely new. Even if one party makes decisions based on a fully readable and understandable decision-making model, the other party may have doubts about the validity of the decisions made: why was such a model, such a method of inference used, and not another? There was a loud objection in the US from prospective doctors when they began to be assigned to hospitals using a method based on the technique of stable arrangements.[33] They protested, appealing to purely life arguments – why, after so many years of study and training, is their future decided by some algorithm! It was a situation where both sides fully knew and revealed their preferences, the "algorithm" was also out in the open, but the doctors considered the decisions on their employment socially unfair, without doubting the validity of the approach that both sides, doctors and hospitals, wanted to make the match in such a way as to ensure stable working conditions, that is, the satisfaction of both parties. The algorithm was to blame.

In the above case, it is fairly easy to justify the decision being made. In addition, one can operate within a certain range of solutions, from optimal for hospitals to optimal for candidates. Moreover, an additional quality function of all allocations can be introduced and its coefficients parameterized. These elements of decision-making can still be fully explicit, but the more complex the model, the more difficult it is for the other party to understand and accept it.

AI models and methods cease to be as transparent as those based on simple decision models using optimization methods, even multi-criteria ones. It also becomes more difficult to interfere with these models and convincingly explain how they work. However, additional explanations and interference with the model can serve to save it in the opinion of its users.

4.3. Machine learning

Machine learning is also the subject of research,[34] which points to its theoretical barriers.

In practical terms, the most serious limitation and drawback of machine learning is the lack of transparency in its operation – as users do not have access to an explanation of how decisions are made. Therefore, the biggest challenge today is to enable users of AI systems based on this technology to fully understand how they work, which is essential for full trust. In the case of traditional algorithms, the programmer has full insight into the application code, can explain it and possibly fix a bug or modify the algorithm. In the case of AI algorithms based on neural learning networks, their operator can only have insight into a huge matrix of weights, which, however, does not provide a full explanation of how more or less unexpected decisions occur. Such systems lack a layer that can serve as an explanation of how the whole system works. This is essential in the realm of education, so that teachers aided by such an AI system can explain their decision to students and their parents.

According to the ACM (2017), "Computational models can be biased by errors in data and/or algorithms," with the result that "automated decision-making about

[33] This method is based on a strategy that, accepting the preferences of both parties, assigns doctors to hospitals so that this assignment is stable for both parties, so that they "do not diverge" (stable marriage). The theoretical basis for this method was developed by David Gale and Lloyd Shapley in 1962, for which, fifty years later in 2012, Shapley (Gale had passed away) received the Nobel Prize in Economics for his theory of stable allocations.

[34] In early 2019, it was shown (Ben-David et al., 2019) that solving the problem of estimating the maximum with the use of machine learning is equivalent to the continuum hypothesis in set theory – so it is not possible to tell whether this problem has a solution or not. This is one of the theoretical barriers of machine learning.

individuals can lead to painful discrimination." The most powerful players in the field of AI, such as Facebook, GitHub, Google, IBM are already using solutions to detect and prevent bias and prejudice (AI bias) in AI solutions on the way to ensuring the fairness and equity of such systems (AI fairness) (Johnson, 2018). It is essential that such solutions find their way into AI systems in education as soon as possible, applied on an individual scale (e.g., as a tutor) and globally (in a school setting).

Another challenge in machine learning is dealing with problems relating to data quality. Systems based on machine learning are very sensitive to small changes in training data, can easily replicate errors in the data, and generally cannot resolve disagreements in data on a particular topic from different sources. For this reason, there are very serious concerns about the use of learning systems in areas responsible for law enforcement and security, such as the judiciary, police and military. Equally serious is the ethical problem – systems trained on data with biases (cultural, racial) and tendentious may exhibit these biases and tendencies in use. The authors of a collective compilation of 10 dilemmas relating to the use of AI systems (Denning et al., 2020) emphasize that Asimov's first law applies to most cases: "no matter what action is taken (or not taken), a human will get hurt."

A very serious problem in the sphere of education is the limited portability of AI systems – those developed, that is, trained for one condition (students, teachers, schools) are generally useless for other user groups. A math tutor for John won't understand Mary's math problems; it will have to study with her itself for a long time, although the math will be the same. Similarly with an English tutor. Google translator shows that it is possible to be intelligent in several languages, although it is difficult to judge the style in which the translator speaks to us. The domain scope (school subjects) is fairly easy to code appropriately in an AI system, while methods and personalization are very individual characteristics. Learning them, if at all possible, requires such a system to be very extensively trained. Only general artificial intelligence will perhaps be able to address this.

Summary

Students now come into contact on an almost daily basis with devices whose results of the actions they undertake can be perceived as manifestations of intelligence. This chapter provides arguments in favor of incorporating artificial intelligence into school curricula. The computer science education community proposes that, after taking into account AI's relationship with computers and computing, an appropriate AI module should be included in the scope of computer science education (computer science classes), in addition to being integrated with other subjects. The structure of such a module was taken from the vigorously developed US proposals, but its implementation will require taking into account the current core curriculum in computer science and other subjects. This proposal for curricular solutions is supplemented with examples of environments in which students can already develop familiarity with AI, as well as pay attention to important social aspects relating to the expansion of AI. Areas where solutions using AI could have a significant impact on the work of teachers and on school operations were also pointed out, although AI does not seem likely to threaten the role of teachers in education in the near future. Brief reference is also made to the risks associated with AI and the challenges posed by the use of AI-enabled solutions.

The discussion in this chapter is set in many places against the backdrop of the historical development of AI and its connections to mathematics and computer science – the fields from which it emerged and continues to be associated with. These connections involve both scientific aspects and education, where the expansion of computers is accompanied by ventures to make them smarter devices that assist the teacher and students in their activities leading to better educational outcomes.

Bibliography

ACM (2017). *Statement on Algorithmic Transparency and Accountability*. ACM U.S. Public Policy Council, ACM Europe Policy Committee. https://www.acm.org/articles/bulletins/2017/january/usacm-statement-algorithmic-accountability

AI4K12. https://github.com/touretzkyds/ai4k12/wiki

Ben-David, S., Hrubeš, P., Moran, S., Shpilka, A., Yehudayoff, A. (2019). Learnability can be undecidable. *Nature Machine Intelligence 1*/2019, 44–48.

Denning, P. J., & Denning, D. E. (2020). Dilemmas of Artificial Intelligence. *CACM No. 3*, 63(2020), 22–24.

Feigenbaum, E., & Feldman, J. (Eds.). (1972). *Maszyny matematyczne i myślenie.* PWN.

Harel, D. (1992). *Algorytmika. Rzecz o istocie informatyki*. Wydawnictwo Naukowo-Techniczne.

Hertzmann, A. (2020) Computers do not make art, people do. *CACM 5*, 63. 45–48.

Holmes, W., Bialik, M., Hadel, C. (2021). *Artificial Intelligence in in Education. Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.

Johnson, R.C. (2018). Overcoming AI Bias with AI Fairness. *CACM News*.

Kaplan, J. (2019). *Sztuczna inteligencja*. PWN.

Knox, J. (2020). Artificial intelligence and education in China. *Learning, Media and Technology*. DOI: 10.1080/17439884.2020.1754236

Lane, D. (2021). *Machine Learning for Kids*. San Francisco: No Starch Press [the book is accompanied by the website https://machinelearningforkids.co.uk/].

McCarthy, J., Minsky, M.L., Rochester, N., Shannon, C.E., A proposal for the Dartmouth Summer Project on Artificial Intelligence (1955), http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html

Moursund, D. (2021). *The Future of AI in Our Schools*. http://iae-pedia.org/The_Future_of_AI_in_Our_Schools

Nęcka, E. (2005). *Człowiek – umysł – maszyna*. Znak.

Nęcka, E. (2020). *Pobudzenie intelektu. Zarys formalnej teorii inteligencji*. Universitas.

Papert, S. (1980). *Mindstorms*. Basic Books.

Papert, S. (1993). *The Children's Machine. Rethinking School in the Age of the Computer*. Basic Books.

Prensky, M. (2012). Education Week, October 2012.

Sysło, M. M. (2018). *Jak myśleć komputacyjnie* [Conference materials]. Informatyka w Edukacji, XV, 2018, Nicolaus Copernicus University in Toruń, Poland, pp. 3–14.

Sysło, M. M. (2019). *Inteligencja+* [Conference materials]. Informatyka w Edukacji, XVI, 2019, Nicolaus Copernicus University in Toruń, Poland, pp. 5–17.

Sysło, M. M. (2022). *Myślenie komputacyjne w praktyce edukacyjnej* [Unpubished manuscript]. PWN.

Sztuczna inteligencja. https://www.sztucznainteligencja.org.pl/

Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI? *Proceedings of the AAAI Conference on Artificial Intelligence*, *33*(01), 9795–9799. https://doi.org/10.1609/aaai.v33i01.33019795

Walsh, T. (2018). *To żyje! Sztuczna inteligencja*. PWN.

Webb, M. E., Fluck, A., Magenheim, J. Malyn-Smith, J., Waters, J., Deschênes, M., Zagami, J. (2021). Machine learning for human learners: opportunities, issues, tensions and threats. *Education Tech Research Dev 69*, 2109–2130. https://doi.org/10.1007/s11423-020-09858-2

Wing J., (2014, January 10). Computational thinking benefits society. *Social Issues in Computing*. http://socialissues.cs.toronto.edu/index.html%3Fp=279.html

Wong, G. K. W., Ma, X., Dillenbourg, P., Huan, J. (2020). Broadening Artificial Intelligence Education in K-12: Where to Start? *ACM Inroads 1*, 11(2020), 20–29.

Zimmerman, M. (2018). *Teaching AI. Exploring new frontiers for learning*. ISTE.

Recommended

Selected initiatives relating to artificial intelligence and education are presented here.

Finland has set a very ambitious challenge to teach the basics of artificial intelligence to 1% of its citizens. https://course.elementsofai.com/pl/. Thanks to European funding, this course is available in Polish.

"Basics of Artificial Intelligence" course: https://navoica.pl/courses/course-v1:OPI_PIB_DZI+Basics_SI+Basics_ AI_02/about

Presentation on AI: https://www.youtube.com/watch?v=osqV6AT1Rhw The lecture "Intelligence for the almost novice programmer" by A. Borowiecka and K. Olędzka.

Learning math: https://www.italk2learn.com/ – an open-source intelligent tutoring platform that supports math learning for students aged 5 to 11.

A video on Intel's collaboration with PSNC on AI projects involving teachers and high school students: http://www.bbc.com/storyworks/digitally-enlightened/intel

MIT's Responsible AI for Social Empowerment and Education initiative (M. Resnick) – a description of many educational projects – https://raise.mit.edu

OECD website with recommendations on AI – https://oecd.ai/en/

Extensive blog by Ryszard Tadeusiewicz, dedicated to artificial intelligence: https:// natemat.pl/blogi/ryszardtadeusiewicz/174271,uporzadkowane-wiadomosci-na- temat-sztucznej-inteligencji

Digital education: e-learning, blended learning

Prof. Dariusz Jemielniak*

Introduction

The year 2020 brought huge changes to the world, including to digital education. One of the few positives of this – for most other areas it was catastrophic – turned out to be raising the digital competence level of a very large number of people who moved into remote learning mode.

This is important because the mere availability of tools and technologies never determines actual cultural and behavioral change – decades of minor adaptations are usually needed. Meanwhile, the COVID-19 pandemic forced most people to adapt rapidly to the realities of virtual communication, as well as become familiar with existing digital education tools.

At the same time, the pandemic made us realize how inadequate and imperfect these existing tools are (Almaiah et al., 2020).

In this text, I will look at the legal conditions of digital education and its market environment, in order to then present the possible future of education, including with the use of AI, as well as the near future of digital education development.

The legal framework

Resolution No. 196 of the Council of Ministers of 28 December 2020 on the Policy for the *Development of Artificial Intelligence in Poland from 2020* points out that the development of AI largely depends on what human capital we have at our disposal, and this is related to the education of society, especially in the sciences, and the ability to think creatively. The document emphasizes the vital importance of preparing curricula at all levels of education, including for those already in the workforce and those studying outside the formal framework. One of the goals of the policy formulated in this way is "the high availability in Poland of educational tools, including online, allowing all those wishing to educate themselves in the field of AI to gain knowledge, both theoretical and practical."

Similarly, one of the elements of public policy is the *Integrated Skills Strategy 2030*, adopted by the Council of Ministers in Resolution No. 195/2020 of 28 December 2020. It assumes, among other things, "the comprehensive preparation of those who perform tasks relating to their professional education," which includes the continuous upgrading of skills in accordance with the latest scientific developments. In order for this continuous up-skilling to be possible at all, it is necessary to develop appropriate learning modalities and trajectories, including for persons already engaged in professional work.

Finally, a broad framework for education in this regard is also defined by the *Key Competences for Lifelong Learning – A European Reference Framework*, which is an annex to the Recommendation of the European Parliament and of the Council of 18 December 2006 on key competencies for lifelong learning. While they refer to digital competencies in the broadest sense, it is clear that in today's context they should also apply to current applications, such as AI.

Both the aforementioned policy as well as the development strategy assume that Poland in the long term can be one of the leading countries in terms of setting trends in the development of artificial intelligence. However, for this to happen, education systems need to be adapted to the realities of the 21st century.

In particular, we need to meet the needs of adult education. While the education of children and adolescents is generally structured and standardized, the continuing education of adults is still in its infancy from the point of view of developing uniform rules and typical adult education institutions. This is also particularly important in the context of developing key pro-innovative competencies and promoting the creative potential of working people (Fazlagić, 2021) – as there are many indications that the creative professions may resist automation in the long term.

The Integrated Qualifications System (IQS), in force in Poland and introduced by the Act of 22 December 2015, includes the possibility of integrating market qualifications into the IQS. It also defines ways to validate and raise funds for improving the qualifications of citizens. Similarly, the EU Council Recommendation of 22 May 2017 on the European Qualifications Framework for Lifelong Learning clearly emphasizes the need for flexibility in the qualifications system, as well as its constant adaptation to market conditions.

Regulations should be considered in the context of the global trend: the educational model, in which qualifications are attained over a dozen or so years in order to then draw on this body of knowledge for several decades, is no longer valid. At the same time, we still don't have a clear situation for the formal recognition of qualifications developed through digital education, although the labor market is already handling this problem. It is therefore worth taking a look at the business environment of remote education.

The business environment of asynchronous remote education

Globally worth $4.6 billion a year in 2020, the remote education services market is growing rapidly and, according to current projections, could reach $20 billion as early as 2026. According to other estimates by Global Market Insights, also including, among other things, school platforms, the market is now already worth $250 billion and will grow to a trillion in the coming years. Regardless of the size of the estimate, what is certain is that this rapid growth trend is continuing. Not surprisingly, this is a highly competitive market dominated by large US companies, both in general education (Coursera, edX, Skillshare, Udemy, Udacity, or LinkedIn Learning) and specialized education (DataCamp, Treehouse, Creativelive, MasterClass). This is education delivered primarily asynchronously, i.e., participating individuals watch recorded lectures and

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solve pre-prepared tasks – and even if they are obliged to watch a live lecture or at a certain time, their ability to participate actively is severely limited.

Coursera made its IPO in March 2021 with a valuation of $4.3 billion. That same year, news broke that Harvard and MIT, which jointly developed the edX learning platform, had decided to sell it for $800 million (Shaw, 2021). This move could determine the direction of digital education for decades – because it makes the business model, in which elite universities chose to create high-quality online learning materials and on a not-quite-commercial basis (many courses were free), lose its raison d'etre. This is important because educational platforms with the support of universities were a solution for offering courses that ended in having a formal diploma awarded – under the control of the universities developing the platforms. Today, corporations developing platforms are becoming the main players. They are signing contracts for diploma courses with various universities; for example, Coursera has been offering them with five different universities as early as 2018. Moreover, the model of education as a mission (i.e., education for the good of humanity), which at least rhetorically guides many universities, is giving way to a commercial, purely product-based education model (Volmar, 2021).

This shift of the decision-making center of gravity from universities to platforms will have far-reaching consequences. True, universities still create educational content, but already their distribution is becoming dependent on commercial platforms. While universities such as MIT, Harvard and Stanford, with very strong branding and prestige, can afford to ignore control over distribution channels, because interest in their offerings will be very high anyway, other universities may become increasingly dependent on distributors, who in turn have a vested interest in developing their own educational products. Platforms are already offering many courses with their own certificates – an example is DataCamp, a platform specializing in teaching programming languages. A market valuation of the value of such certificates is difficult to estimate, but interest in certification indicates that at least job seekers find this type of competence certification useful.

At the same time, it is worth noting the huge demand for quality educational offerings available for free or at a low price, as evidenced by the popularity of Khan Academy, a nonprofit development project with several million monthly active users (see https://khanacademyannualreport.org/#a-message-from-sal-why-khan-academy). To some extent, market expectations are also reflected in the business model used by Coursera, for example – offering lectures for free, but charging for certified courses.

These considerations lead to several conclusions for the future. First, the role of the certificate issuer is important, but increasingly, the quality of the education is being validated by universities. Admittedly, this is consistent with the IQS, but it has long-term implications. It causes universities to have little control over added value: they have no control over the distribution chain, and the distributor's own brand is growing in importance. This is especially true of courses that do not lead to master's or bachelor's degrees. In the long term, this may translate into universities losing their dominance/monopoly of the market for MBAs and other forms of postgraduate education. Global giants will be able to offer similar or better quality education, while tailoring their offerings to the individual needs of learners. This trend will intensify once computer translation enables simultaneous translations of sufficiently good quality. This can be expected to happen in the next few years – relatively, when course distributors see that so-called language localization is another important market for them. This is a direct threat to domestic universities pursuing commercial training and study programs.

Second, a consolidation of the players can be expected. Mergers and acquisitions are one of the primary forms of growth in this booming market – and the aforementioned acquisition of edX, or even LinkedIn's purchase of the Lynda platform, are just early signals of the coming wave. Ultimately, it is easy to imagine that there will be only a few dominant solutions left in the digital education platform market.

Third, and perhaps most interestingly, the dominant digital education model can be expected to stabilize in the coming years – due to the market consolidation of the players. Only then will it become clear whether traditional e-learning, in the future aided by AI, or rather blended learning will lead the way. Regardless of the outcome, both solutions will certainly gain a strong market position and together will continue to displace face-to-face learning.

The business environment of synchronous remote education

The previous section of this chapter described the market for the major players in digital education. In fact, the description focused entirely on the MOOC (Massive Open Online Courses) market, i.e., courses offered en masse and almost entirely one-way. While learners via the aforementioned platforms can watch lectures and complete interactive exercises, they cannot actively participate in conversations with the course instructors or with other students. This made sense insofar as this market is now dominant in terms of remote courses and will grow to tens of billions of dollars annually by 2027, according to the Research and Markets 2021 report.

However, the pandemic, as mentioned earlier, has changed the mindset of broad swaths of the audience, and now a large portion of the population is aware of what courses delivered synchronously and with interaction can look like – because that's simply what remote education has mostly looked like around the world (Xie et al., 2021; Onyema et al., 2021).

This market has also undergone dynamic changes and has clear leaders. Google Meet (in conjunction with Google Classroom), Microsoft Teams and Zoom are products that have grown rapidly, but there are also quite a few other players – if only from the corporate video conferencing market, such as Cisco Webex and Bluejeans, or directly from the remote classroom market, such as Big Blue Button, Adobe Connect and Schoology.

It is clear that while before the pandemic these tools were primarily focused on enabling communication, whether in one-on-one or group or even congress meetings, the purely educational segment is now growing strongly. Google is making it easier to combine solutions dedicated to schools with a teleconferencing platform that also includes options for managing questions and answers or simple quizzes. Microsoft and Zoom have significantly developed both the basic classroom platform and numerous additional educational modules.

An important strategic question is whether this way of participating in classes will be acceptable to a wide range of people. The pandemic has shown that it is definitely flawed without proper procedures: students and pupils often join without turning cameras on and do not fully participate in classes. On the other hand, there are also positive examples – with a restrictively required video connection, recreating the experience of classroom participation is getting closer. Admittedly, some things cannot be replaced, but utilizing the synchronous remote learning formula, in turn, allows the use of many tools that cannot be used in traditional education. Looking at the problem from yet another angle, synchronous digital education has shown to some extent what a traditional school can become when augmented reality (AR) becomes widespread. AR undoubtedly has great potential for teaching, as can be seen, for example, in surgical simulation technologies, but we still have to wait for the emergence of platforms that will be massively applicable.

One possible option for the development of digital education, therefore, is to maintain a teaching formula similar to the traditional one, in the sense of teaching in a dialogic way, in small groups and synchronously, and only using modern communication methods. A final option worth considering is the use of blended learning.

Advantages and disadvantages of e-learning and blended learning

The two ways of implementing digital education discussed earlier involved e-learning. In theory, it's easy to imagine why e-learning can work well – after all, especially in its synchronous version, it seems to differ little from traditional schooling, while having many additional advantages. In practice, however, it's important to remember that in education per se, the problem is not access to knowledge per se. After all, knowledge is available for free in libraries, and these days even in Wikipedia (Jemielniak, 2013). The real challenge, on the other hand, is the long-term motivation to systematically expand knowledge, especially in areas that are not exactly the most interesting and natural for the learner.

This is why, as we know from research (Rovai, Ponton et al., 2007), e-learning is only effective when those using it have very strong intrinsic motivation. In traditional learning, the role of the teacher or lecturer is much more to arouse interest and induce mastery of the material than the presentation itself – which is why traditional learning works so well, because physical co-presence strongly facilitates this. The same is true, by the way, of sports – the hardest part is not mastering exercise at all, but forcing oneself to do it regularly – or diets of any kind (Hagger, Chatzisarantis et al., 2006), as well as overcoming addictions. Hence the popularity of programs like AA: humans are social creatures, cooperation and developing habits through interaction with others are natural to them (Jemielniak & Przegalińska, 2020). The formation of a bond with a teacher, the creation of a specific classroom culture and behavioral norms (Koźmiński, Jemielniak et al., 2009) are much easier with the physical presence of others.

This is one of the main reasons why asynchronous e-learning on a mass scale is very difficult in practice: you need a very strong intrinsic motivation to use it. Synchronous e-learning improves the situation, but only partially – because establishing a relationship with the group and the instructor is much more difficult than in a face-to-face classroom meeting.

This is why, after many years of trying and experiencing e-learning, the concept of blended learning was born: implementing part of the learning in a traditional formula, and part using digital education. While the origins of remote learning date back as far as the 19th century, when Pitman Training offered the first distance learning courses, blended learning has primarily emerged in the last 20–30 years.[35]

Of course, this approach also has numerous disadvantages: first of all, it is not suitable for completely remote implementation, and breaking with the need for geographic proximity is one of the significant advantages of e-learning. However, it is an approach that avoids the motivation-related disadvantages typical of e-learning (Nortvig, Petersen et al., 2018), while allowing the introduction of important elements of digital education and, as a cumulative result, even better ones than in traditional learning.

An example of the use of blended learning is the InstaLing platform, in existence since 2013, co-created by the author and used by nearly half a million students each year. InstaLing is a tool that allows teachers to easily assign vocabulary and grammar material for repetition to entire classes – so it is primarily used for foreign languages, although it also has modules for Polish and mathematics. The algorithm adjusts the repetition time of given units of knowledge in such a way as to optimize it with the so-called memorization curve, i.e., not to assign the repetition of words that a person almost certainly still remembers well, but to allocate time for the repetition of words that still cause difficulties or are probably on the verge of being forgotten.

InstaLing and other similar platforms complement traditional learning while introducing an element of digital education that would be impossible without computer technology: complete customization of the trajectory of material repetition. Each student learns a slightly different set of words on a given day – because it depends on how they did on previous days and which words they should be memorizing.

This is a good example showing that the future of digital education, at least in the medium term, is to complement traditional learning rather than trying to replace it. Information technology can indeed perfectly augment the learning experience – both in the classroom (just think of tools like Mentimeter or Kahoot for instant feedback and quizzes) and outside of it, for memorization and homework.

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[35] See https://elearningindustry.com/history-of-blended-learning

However, it can be expected that the acceleration of the pace of digital education will only be fully realized when it harnesses the potential of artificial intelligence.

AI in school education

The example of InstaLing shows how much can be achieved through the use of digital tools, but at the same time, how much more needs to be done. The algorithm for the repetition of material, in line with the state-of-the-art in so-called spaced repetition (Ausubel & Youssef, 1965; Tabibian, Upadhyay et al., 2019), allows the timing of the repetition of a given word to be optimized, but treats each word the same. It is reasonable to suppose that lexical material can be further tailored to individual needs – but this type of dynamic adjustment will already require the use of machine learning.

Individualizing the learning mode at a much more granular level is at the heart of the Squirrel AI system – a leading digital support platform for primary and secondary school students in China. Interestingly, while Squirrel AI is based on a spaced repetition algorithm, aided by machine learning, it also offers synchronous e-learning to increase student motivation (Hao, 2019).

The second area where AI can make a radical technological breakthrough in school education is in the automatic grading of papers. TOEFL tests have been graded in part with the use of machine learning algorithms already for several years (ETS, 2021). With a huge database of graded papers, both written papers and oral statements are able to be initially assessed with a high degree of accuracy.

Finally, the use of artificial intelligence makes it possible to replace expensive tutoring with hands-on learning. In this area, a very interesting new project using machine learning for education is CoPilot, offered by GitHub. CoPilot does not have strictly educational functions, but it prompts for code snippets as they are being written, as well as typical comments and questions relating to the functions used. Since the functionality is very simple for now, it is difficult to assess its long-term usefulness. However, it demonstrates an extremely important direction in the development of digital education using AI: the implementation of the concept of learning by doing, education in action. Instead of theoretical considerations and artificial training examples, which only then can be translated to one's needs, the use of tools such as CoPilot will in the future allow a person to move very quickly from absolute basics to practice – because AI algorithms will suggest correct solutions based on probable context. It is impossible to assess how far this type of solution will be realistically useful, but the idea is very promising.

However, the use of AI in digital education is still hindered by a number of challenges otherwise typical of the development of machine learning in general: incomplete or flawed data sets, a narrow understanding of "education", or problems relating to methods (Perrotta & Selwyn, 2020). Thus, it is difficult to assess today how quickly and to what extent it will spread.

The future of digital education

There is no doubt that the application of artificial intelligence in education will progress. It is also clear that the policy for AI development in Poland must also be based on education and human resource development. In order for the IQS and the *Integrated Skills Strategy 2030* to take advantage of the full potential of new technologies, it is necessary to recognize that digital education platforms, while offering customization at the individual level, thrive best when they can build on standard mass programs. In other words: a platform can brilliantly customize repetition trajectories using AI for an individual, but the material offered on the platform will be the same for millions of male and female students.

From this follows a rather simple conundrum: it is in the interest of Polish education to unify and standardize curricula as much as possible with the curricula of other countries in those subjects for which this is possible – thus, to a large extent the sciences, and to a small extent the humanities. This is primarily because with the use of AI in education, the effect of scale is particularly evident: the use of globally used tools greatly increases their effectiveness and impact capacity.

Therefore, the creation of European core curricula is a unique opportunity to create a market in which it will be profitable to offer advanced educational platforms, which are currently being developed primarily for the US or Chinese market.

At the same time, it is impossible to overlook the serious risks: in view of the advanced development of American and Chinese education systems using AI, an important element of risk will be the acquisition of data on individuals by foreign entities, as well as potentially inferior adaptation to the socio-cultural needs of the European education sector.

Minimizing these risks and capitalizing on opportunities will only become possible if education using AI in Poland is based on technologies that will have a chance to compete in the global market. This will be possible in principle without question at the transnational level. The unification of curricula at the European level offers the possibility of creating a single, large market that will provide a base for them.

Summary

This chapter discusses the basic determinants of the legal framework for AI in education, the current state of synchronous and asynchronous remote learning and their possible not-too-distant future, the advantages and disadvantages of e-learning and blended learning, areas where AI in school education is already active, and conclusions about the opportunities and threats of digital education.

Based on an analysis of current trends, it is prudent to assume that augmented reality (AR) and virtual reality (VR) will soon begin to significantly influence the remote education market, also with the use of AI. The development of projects such as Google's StarLine (Coldewey, 2021), which allows for remote conversations with a 3D view of the interlocutors, as well as the development of AR and VR technologies also strongly suggest that the aforementioned deficiencies of synchronous digital learning will continue to decrease, and the division between traditional learning (in face-to-face settings) and synchronous e-learning will lose its importance.

Asynchronous e-learning will be a growing market, but it's doubtful that it will permanently dominate education. Instead, it will remain an increasingly better way to improve the skills and knowledge of those who are able to effectively motivate themselves.

We can certainly expect all sorts of market reshuffling and promising innovations – interesting times are ahead!

Bibliography

Almaiah, M. A., Al-Khasawneh, A., & Althunibat, A. (2020). Exploring the critical challenges and factors influencing the E-learning system usage during COVID-19 pandemic. *Education and Information Technologies*, *25*, 5261–5280.

Ausubel, D. P., & Youssef, M. (1965). The Effect of Spaced Repetition on Me: Meaningful Retention. *The Journal of General Psychology*, *73*, 147–150.

Coldewey, D. (2021). *Google is making a 3D, life-size video calling booth*. TechCrunch.

ETS (2021). Understanding your TOEFL iBT scores (for test takers). https://www.ets.org/toefl/test-takers/ibt/scores/understanding/

Fazlagić, J. (2021). *Dobre praktyki w zakresie wspierania kreatywności, innowacyjności i samodzielności uczniów szkół ponadpodstawowych*. Ośrodek Rozwoju Edukacji.

Hagger, M. S., Chatzisarantis, N. L. D., Harris, J. (2006). The Process by Which Relative Autonomous Motivation Affects Intentional Behavior: Comparing Effects Across Dieting and Exercise Behaviors. *Motivation and Emotion*, *30*, 306.

Hao, K. (2019). China has started a grand experiment in AI education. It could reshape how the world learns. *MIT Technology Review*, *123*.

Jemielniak, D. (2013). Życie wirtualnych dzikich. Poltext.

Jemielniak, D., & Przegalińska, A. (2020). *Społeczeństwo współpracy*. Wydawnictwo Naukowe Scholar.

Koźmiński, A. K., Jemielniak, D., Latusek, D. (2009). Współczesne spojrzenie na kulturę organizacji. *e-mentor*, *3*, 4–13.

Nortvig, A. M., Petersen, A. K., Balle, S. H. (2018). A Literature Review of the Factors Influencing E Learning and Blended Learning in Relation to Learning Outcome, Student Satisfaction and Engagement. *Electronic Journal of e-Learning*, *16*, 46–55.

Onyema, E. M., Eucheria, N. C., Obafemi, F. A., Sen, S., Atonye, F. G., Sharma, A., Alsayed, A. O. (2020). Impact of Coronavirus pandemic on education. *Journal of Education and Practice*, *11*(13), 108–121.

Perrotta, C., & Selwyn, N. (2020). Deep learning goes to school: toward a relational understanding of AI in education. *Learning, Media and Technology*, *45*, 251–269.

Rovai, A., Ponton, M., Wighting, M., Baker J. (2007). A comparative analysis of student motivation in traditional classroom and e-learning courses. *International Journal on E-learning*, *6*, 413–432.

Shaw, J. (2021). Harvard and MIT to sell edX for $800 million. *Harvard Magazine*. https://www.harvardmagazine.com/2021/06/sale-of-edx

Tabibian, B., Upadhyay, U., De, A., Zarezade, A., Schölkopf, B., Gomez-Rodriguez, M. (2019). Enhancing human learning via spaced repetition optimization. *Proceedings of the National Academy of Sciences of the United States of America*, *116*, 3988–3993.

Volmar, E. (2021). Mission and Money: Unpacking Competition between Hybrid Organizations in the Nascent MOOC Market. *Academy of Management Proceedings*, Vol. 2021, No. 1, p. 10177. Academy of Management.

Xie, X., Siau, K., & Nah, F. F. H. (2020). COVID-19 pandemic – online education in the new normal and the next normal. *Journal of Information Technology Case and Application Research, 22(*3), 175–187.

The social context of media education and artificial intelligence

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Introduction

In this chapter, we address public's perception and understanding of artificial intelligence. In the context of the increasing number of technologies based on artificial intelligence and their growing impact on the everyday life of all people, it seems crucial to recognize the level of public awareness in this regard. In turn, the ability to identify the artifacts of artificial intelligence, understand its mechanisms and interpret the results are an important subject of modern media education. In this article, we would like to present the main themes of selected reports on media education and artificial intelligence, and formulate preliminary conclusions and recommendations based on them.

It is worth noting that the far-reaching impact on how different social groups understand and evaluate artificial intelligence, how they perceive the possibility of using it in their personal and professional lives, and how they evaluate its impact on their lives, is influenced by the media competencies they possess – especially digital ones. These competencies translate, among other things, into the ability to understand phenomena such as the impact of intelligent algorithms on recommendations in various streaming services and social networks, fake news, information bubbles and profiling mechanisms in online marketing.

In a society in which much of the interaction takes place via the Internet, competencies based on an understanding of such phenomena seem essential to critically construct one's picture of reality and share it with others. In this sense, media competence is the foundation for building a cooperative society, understood as a collaborative bottom-up group social structure using technology in building economic, cultural or interpersonal relations (per Jemielniak & Przegalińska, 2020, p. 16).

Artificial intelligence and technology reports from the last two years indicate which competencies meet the call for systemic media education – starting from the first stage of school education (see, for example, DESI – the Digital Economy and Society Index, https://digital-agenda-data.eu/datasets/desi). Valuable information is also provided by the results of the PISA and PIAAC international competency surveys (Burski et al., 2013; Federowicz and Sitek, 2017).

New media are defined as information and communication technologies that include three components: 1) the physical objects or tools that create and expand

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opportunities for communication and exchange, 2) the activities and practices conducted in the design of these devices, and 3) the forms of social organization around these objects and practices (Ptaszek, 2019). In this study, we refer to new media, understood in a context that is not only technological (component 1), but also social (components 2 and 3).

New media researchers pay special attention to the technology of information circulation and acquisition and the analysis of large amounts of data. Therefore, an additional task of media education is to increase society's level of understanding of the technological and economic transformations based on these technologies. Media education will increasingly prepare people of all ages to use everyday tools in the immediate environment, and the media means of communication exchange are primarily digital tools – smartphones, search engines, the Internet of things and cloud computing.

Social perception of AI from the perspective of media education

Over the past two years, there have been several reports showing how the presence of artificial intelligence technologies is perceived in professional and social life in Poland. They show not only whether the participation of AI solutions is noticeable socially, but also whether Poles are ready to reap their benefits. Do we as a society understand what AI is?

Most reports confirm the public's positive attitude toward new technologies. The vast majority of people surveyed have encountered the term artificial intelligence (89.2% of respondents to a survey conducted by the Scientific and Academic Computer Network NASK (Lange et al., 2019). However, only an analysis of responses to specific questions shows that the level of digital competence is what shapes expectations and concerns about the use of AI in everyday life.

Let's pause at two statements:

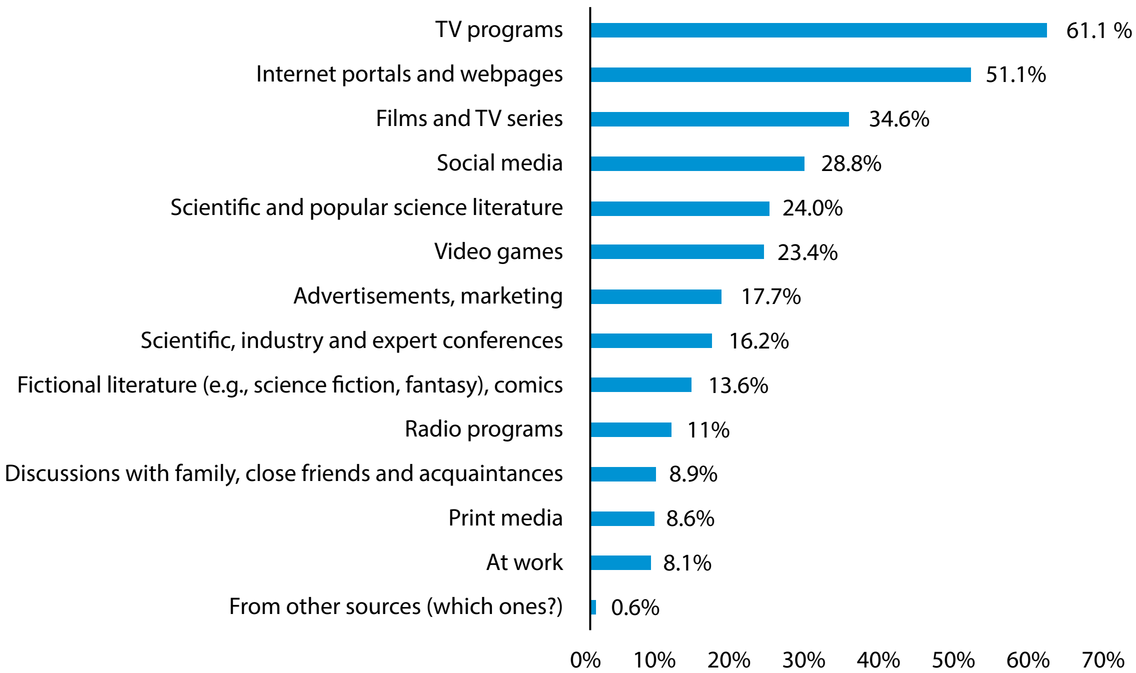
- For most of Polish society (55.8%), the most important element in defining artificial intelligence is the claim that it involves devices and processes in which humans are not involved.
- Half of the respondents believe that artificial intelligence affects their daily lives (Lange et al., 2019).

Misunderstanding and erroneously defining artificial intelligence result in a lack of confidence in new technologies. Respondents believe that AI-based technology will soon be independent of human control (55.9%). Nearly one in four respondents were unable to say whether AI will become independent of human oversight. There are also concerns that the proliferation of AI technology will primarily result in privacy risks. Then the problem of a possible increase in unemployment is raised. And finally, great importance is given to the danger of cyber attacks. In addition, another survey signaled the possibility of a loss of control over various processes in companies (41.8%), as well as the issue of uncontrolled data growth (23.6%) and a possible decrease of trust in institutions (21.8%) (Biczyk et al., 2019).

The above observations show that AI and the way it works create uncertainty among its average users, who often lack the competence to recognize the basic fact that artificial intelligence is created through the creativity of its creators. As Torczyńska (2019) writes, "doubts and fears arise about the unsuitability of humans for most jobs, the use of human bodies, or ignoring the value of human life – fears that stem from ignorance."

We know that Poles build their perceptions of AI and its dangers on messages from the media and pop culture (e.g., science fiction films). It is worth noting where Poles most often encounter the concept of AI, and therefore – at the same time – where they get their knowledge about AI.

Figure 2. Percentage distribution of responses to the question "Where do you most often encounter the term artificial intelligence?" (n=1023)



Source: Lange et al., 2019, p. 13.

It is noteworthy that the chart above lacks a source relating to education – Poles do not get their information about artificial intelligence from school, university, vocational education or hobby courses. Only one in four Poles reaches for scientific or popular science literature. This shows how important and necessary it is to ensure that relevant content is conveyed within media education, as well as to provide opportunities to acquire this knowledge in adulthood (creating opportunities for media education in lifelong learning).

Competencies in AI reports

What competencies do authors of reports on AI pay attention to? First and foremost, well-developed competencies of the future, among which digital and technical competencies are key (Pokojska et al., 2020). But cognitive and social competencies play an equally important role.

We are referring here to the concept of digital competencies, as well as key competencies. These concepts are not clearly defined, and do not have sharply delineated boundaries – in some cases they can be used interchangeably. The literature on the subject proposes at least several perspectives on looking at the implementation of the abovementioned competencies. For the purposes of our article, we will limit ourselves to showing why information about the level of digital or key competencies appears in an article on media education and media competence.

In most approaches, digital competencies include both technical ones (use of digital technologies), as well as the cognitive, emotional and social competencies necessary to use them (Kiss, 2017).

Among the key competencies defined by the European Commission is digital competence, which is described as including:

> "…the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking." (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2018.189.01.0001.01.ENG)

A closer reading of the functioning approaches and concepts close to key competencies shows that media literacy is a cross-cutting category – also linked to social competence, learning skills, etc. (Stęchły & Debowski, 2020).

International studies such as PISA, PIAAC or ICILS show the level of literacy and directly relate this to digital environments (digital literacy, digital reading). Among other things, they tell us whether we are able to search, select and evaluate the reliability of information, and they also show the ability to use ICT. The PISA 2018 survey shows that only 9% of 15-year-olds in OECD countries can distinguish between a description of a factual situation and an opinion, and young people spend an average of 35 hours a week online – 14 hours more than reported in the PISA 2012 survey (OECD, 2021, p. 20). It is worth considering how to tap the potential of today's youth.

Compared to other EU countries, Polish professionals have lower levels of soft competencies: the ability to share knowledge, learning, problem solving, as well as communication and team cooperation skills (Digital Poland Foundation, 2020a). There is no doubt that pressure is increasing to acquire new competencies and skills, with the competencies of career planning and instrumental (tool-using) abilities at the forefront. These will not be new professions, but "sets" of new competencies (Digital Poland Foundation, 2020b). Without these competencies, it will not be possible to take advantage of the vast potential offered by the presence of AI in the economy and public sector. Employees of private companies and public officials, who are implementing and using increasingly large numbers of tools, should understand the opportunities and risks of their use. Without a general knowledge base and the ability to apply this to the specific systems they will be working with on a daily basis, it will become impossible to assess their social impact or internally evaluate the risks (Mileszyk et al., 2019).

Table 6. Types of competencies included in media competence and their description

Type of competence	Description
Play	Ability to experiment with the environment as a form of problem solving
Role playing (*performance*)	Ability to assume alternative identities for the purpose of improvisation and discovery
Simulation	Skill in interpreting and constructing dynamic models (equivalents) of real-world processes
Adaptation	Ability to create media remixes and texts based on existing cultural messages
Multi-task orientation	Ability to "scan" the environment and focus on its individual elements
Distributed cognition	Ability to interact with tools that expand an individual's mental abilities
Collective intelligence	Ability to gather knowledge and compare information with others to achieve common goals
Evaluation	Ability to assess the reliability and credibility of various sources of information
Transmedia navigation	Ability to follow the flow of stories and information within different media modalities
Networking	Ability to seek, synthesize and disseminate information, as well as to exchange information and resources and provide mutual support
Negotiation	Ability to move within different communities, understand and respect diverse perspectives, master and apply alternative norms and rules

Source: Ogonowska, A. (2015). Kompetencje medialne. In Fedorowicz, M., Ratajski, S., *O potrzebie edukacji medialnej*. Warszawa: UNESCO, KRRiTV, p. 106.

Critical thinking in the age of AI

The next category linking today's desired digital or media competencies with artificial intelligence is critical thinking. For the past dozen years or so, it has functioned almost as a code word for a range of competencies (and the training that shapes them) intended to respond to the challenges posed by modernity and ranked among the top skills desired by employers.

Although the first attempts to develop the concept of critical thinking can be dated back to the 1940s – and inspiration can be found in the philosophical literature of centuries past – the current concept of critical thinking developed in the US in its contemporary form in the early 1970s (Wasilewska-Kaminska, 2016). At the time it was a response to the challenges of the so-called "visual era", which began with the 1960 television debate between Kennedy and Nixon. The authors of this concept demonstrated the lack of utility of the tools offered by formal logic for analyzing everyday arguments, including political debates. To this day, the theory of argumentation and the ability to evaluate arguments is at the core of most forms of critical thinking courses, combined with the ability to logically assess the acceptability of conclusions, recognize heuristic tricks or participate in various types of debates.

Over time, the concept of critical thinking evolved into a broad and interdisciplinary field aimed at developing the ability to make independent inferences and understand messages (e.g., cultural texts), independent of authority or cognitive biases. It opposed or was complementary to education aimed at acquiring encyclopedic knowledge, emphasized metacognition and taught how to learn. For this reason, the concept of critical thinking has been developing, on the one hand, in the direction of epistemology in the broadest sense (see Lau, 2011), and on the other – as a practical subject oriented to specific skills, which do not need a particular theoretical foundation.

Related forms of education geared toward the development of criticality and an interdisciplinary set of conceptual tools can be found in various forms in different educational systems – a similar function is served by the theory of knowledge classes of the International Baccalaureate programs (Alchin & Henly, 2014), our native concept of pragmatic logic (Ajdukiewicz, 1964) or... the medieval concept of the *trivium* (Sayers, 1948). Various practical subjects such as digital technology, academic skills, writing workshops and introductions to research methodology also serve similar purposes.

The current challenges we face – relating to the development and increased availability of the Internet, new technologies and new media, and the attention economy – demand new forms of response – similar to those of the 1970s. On the one hand, we need subjects and classes that inform us about the theoretical aspects of new media and technology, on the other – we need to practice skills to better find our place in the surrounding reality. This has been recognized by the authors of the core curriculum (podstawaprogramowa.pl, 2017), who write: "The school is also supposed to prepare them [students] to make informed and responsible choices when using resources available online, to critically analyze information, to navigate safely in the digital domain, including establishing and maintaining mutually respectful relationships with other online users."

Educational reality like few others has to accept numerous concessions and compromises. The era of the Internet, artificial intelligence, new media and the attention economy are phenomena of unprecedented scale and impact. The development of digital competencies and the competencies of the future must proceed in multiple directions and include:

- IT competence to use commonly used application software,

- at least basic programming competence to understand the machines around us that we use each day or that automate basic activities,
- awareness of the operation and perhaps the ability to train AI models, which in addition to basic programming competencies should also involve elements of statistical knowledge,
- social competence and knowledge of how the media work and how to use intelligent algorithms, especially in new media.

These competencies should accompany the development of traditionally understood skills, such as communication proficiency, creativity and team building.

Media education and raising social awareness

The issues raised above reflect the expectations of many sides of the discourse on education. The report summarizing the first meeting of the Digital Sustainability Forum Artificial Intelligence as a component of sustainable economic and social development (2019) identifies two main barriers to developing the desired competencies. First of all, the Polish education system is not directed at developing teamwork, while work on artificial intelligence requires this. Polish education and science are strongly characterized by homogeneity in describing knowledge, while artificial intelligence is interdisciplinary and requires knowledge from many intertwining fields.

Among the priorities identified by the sector of AI-related corporations and companies, as well as academia, are demands for basic education – these institutions propose the introduction of programming classes (e.g., Python language) in primary and secondary schools, as well as AI basics at the secondary school level (Borowiecki and Mieczkowski, 2021). This is because in a society shaped by algorithms, a basic knowledge of their principles of operation and the ability to use them with an awareness of the opportunities and risks they produce is a necessity. Therefore, education – often mentioned, but just as often downplayed – is recognized as a key element in sustainable development (Mileszyk et al., 2019).

At the same time, the field of education, like no other, should be looking for a new opening – the competencies needed to understand and work with algorithms and artificial intelligence are largely the same digital competencies whose development has been called for over many years (Fedorowicz & Ratajski, 2015).

A growing number of researchers and educators are emphasizing the need for media education, as access to modern technologies is not always accompanied by an equally rapid increase in digital competence, not only among children and young people (Tarkowski et al., 2018). Nevertheless, the level of young people's digital competence is increasingly growing. A recent survey of young people's digital behavior shows that the smartphone is the tool they most frequently use to access the Internet (97%). Far in second place is the laptop or computer (56.4%). Young people use social networks on their own, get the information they need for their school work without the help of others, use the Internet to communicate with others, download files or use the Internet to develop their hobbies and interests (74–80% of responses). The problem is the ability to take care of one's health and sense of well-being. One in four adolescents feels overloaded with information. The same number of students report giving up sleep in order to use their smartphones. Smartphone abuse is associated not only with experiencing negative emotions, but also with somatic symptoms. 10% of adolescents participating in the study reported headaches, dizziness, nausea, and occasionally skipping meals due to smartphone abuse (Debski & Bigaj, 2019). It should be mentioned that adolescents are often left alone with new technologies and the challenges associated with them. Participants in the aforementioned study admitted that: 1) their parents have no idea what their children use the Internet and smartphone for (1/3 of students), 2) their parents don't teach them how to use the Internet and smartphone responsibly (60.6%), or 3) they could rarely count on their parents to help them in case something disturbing happens online (26%). In contrast, almost half of the students reported that they help their parents solve problems relating to online use. Recommendations leading to improving the skills of the daily use of the Internet and new technologies within the framework of media education thus apply to all of society, not just the youngest groups. Indeed, they should be appropriately selected into packages addressed to various groups: parents, teachers, students and younger children. Particularly important, according to the authors, is the need for separate recommendations for parents, who, in their view, are rising to the status of being the key people in the digital education of their children, primarily in the period of pre-school and early education (Debski & Bigaj, 2019).

Initial conclusions and recommendations

In the near future, especially after the COVID-19 pandemic, unique in-depth specialized competencies, based, among other things, on the ability to work with artificial intelligence, will begin to play a decisive role. They will enable the development of individual jobs, such as advisors and analysts, who will not only be able to forecast trends and analyze large streams of data (backed by technology), but, above all, will understand the needs of the market and communicate them to their partners and customers accordingly.

As research shows, social skills are also among the competencies of the future, such as the ability to manage people, and emotional intelligence, which can be invaluable in a world of widespread collaboration with algorithm-based systems and artificial intelligence. Finally, the last skill highlighted by the respondents is the ability to "organically" adapt to the structure and operation of the company in the new digital environment (Pokojska et al., 2020). It should be noted that exactly these competencies are the ones that are now being emphasized by media education. The goal is to model skills at three levels: technical – mastering specific skills in the use of modern tools; professional-social – the ability to ensure the prudent use of tools in social, professional and personal contexts; and the level of critical reflection – when an individual's digital activity is the impetus for their creativity and innovation, it allows professional development to be shaped (Ptaszek, 2019).

It is recommended that the public's understanding be deepened on the topic of automated decision-making systems (including AI) and the technologies on which these systems are based. In a society increasingly shaped by algorithms, basic algorithmic literacy is a must.

Summarizing the observations of the reports on the use of tools in AI and the public's reception of new technologies, there are several recurring postulates. Through their implementation, it would be possible to raise public confidence in technological change and increase the participation of various social and professional groups in building new solutions in the economy and public sector.

It is recommended that understanding be increased of AI-enabled technologies, not limiting this to specialized professional groups (e.g., politicians, civil servants, entrepreneurs), but broadly targeting the public (Marczuk et al., 2019).

Ethical awareness and social competence should be raised among AI developers, implementation experts and users. Training on the ethics and regulation of working with large data sets should be part of a broader educational project – an example is Finland's "Elements of AI" course, which is intended to be completed by 1% of Finnish citizens.

There is an urgent need to supplement curricula with issues of developing soft skills such as teamwork, and to emphasize working in diverse and changing project groups.

Employees of public institutions should be provided with training on AI and its practical use in both their professional and private lives.

Ensuring public interest and building understanding around the topic of AI will help build public trust in the technology, which is needed in order for citizens to want to take advantage of innovative solutions and their implementation. At the same time, improving the media competence of people of all ages using increasingly newer tools will allow them to consciously pursue their goals in their chosen field – social, cultural or professional life.

Bibliography

Ajdukiewicz, K. (1964). *Logika pragmatyczna.* PWN.

Alchin, N., & Henly, P. C. (2013). *Theory of Knowledge for the IB Diploma*. Hodder Education.

Biczyk, J., Jamrogiewicz, P., & Malczewski, Ł. (2019). *Czy leci z nami robot? Badanie postrzegania sztucznej inteligencji przez dziennikarzy*. d*fusion communication.

Borowiecki, Ł., & Mieczkowski, P. (2021). *State of Polish AI 2021*. Fundacja Digital Poland.

Burski, J., Chłoń-Domińczak, A., Palczyńska, M., Rynko, M., & Śpiewanowski, P. (2013). *Umiejętności Polaków – wyniki Międzynarodowego Badania Kompetencji Osób Dorosłych (PIAAC)*. Instytut Badań Edukacyjnych.

Dębski, M., & Bigaj, M. (2019). *Młodzi Cyfrowi. Nowe technologie. Relacje. Dobrostan*. Fundacja Dbam o Mój Z@sięg. https://dbamomojzasieg.pl/mlodzi-cyfrowi/

Fedorowicz, M., & Ratajski, S. (2015). *O potrzebie edukacji medialnej w Polsce*. Polski Komitet do spraw UNESCO, Krajowa Rada Radiofonii i Telewizji.

Federowicz, M., & Sitek, M. (Eds.). (2017). *Program Międzynarodowej Oceny Umiejętności Uczniów. Wyniki badania PISA 2015 w Polsce*. Instytut Badań Edukacyjnych.

Fundacja Centrum Cyfrowe, Fundacja Digital Poland, Microsoft (2019). *Sztuczna inteligencja jako element zrównoważonego rozwoju gospodarczo-społecznego*. Fundacja Centrum Cyfrowe, Fundacja Digital Poland, Microsoft.

Fundacja Digital Poland (2020a). *Sztuczna inteligencja w Polsce – Kompetencje ekspertów AI*. Fundacja Digital Poland.

Fundacja Digital Poland (2020b). *Technologia w służbie społeczeństwu. Czy Polacy zostaną społeczeństwem 5.0?* #Tech4Society, II edition. Fundacja Digital Poland.

Kiss, M. (2017). *Digital skills in the EU labour market*. European Parliamentary Research Service.

Lange, R., Ładna, A., Konopczyński, F., & Kowalczyk, M. (2019). *Sztuczna inteligencja w społeczeństwie i gospodarce. Analiza wyników ogólnopolskiego badania opinii polskich internautów*. NASK Państwowy Instytut Badawczy.

Lau, J. (2011). *An Introduction to Critical Thinking and Creativity: Think More, Think Better*. Wiley.

Marczuk, P., Mieczkowski, P., Calini, L., & Paszcza, B. (2019). *Iloraz sztucznej inteligencji* (2nd ed.). Fundacja Digital Poland.

Mileszyk, N., Paszcza, B., & Tarkowski, A. (2019). *AlgoPolska. Zautomatyzowane podejmowanie decyzji w służbie społeczeństwu*. Fundacja Centrum Cyfrowe, Klub Jagielloński.

OECD (2021). 21st-Century Readers: Developing Literacy Skills in a Digital World, PISA. OECD Publishing. https://doi.org/10.1787/a83d84cb-en.

Pokojska, J., Śledziewska, K., & Włoch, R. (2020). *Przyszłość pracy w sektorze finansowym*. Warszawa: Sektorowa Rada ds. Kompetencji Sektora Finansowego; Polish Agency for Enterprise Development PARP.

Ptaszek, G. (2019). *Edukacja medialna 3.0. Krytyczne rozumienie mediów cyfrowych w dobie Big Data i algorytmizacji*. Wydawnictwo Uniwersytetu Jagiellońskiego.

Sayers, D. (1948). The Lost Tools Of Learning. *Hibbert Journal: A Quarterly Review of Religion, Theology, and Philosophy*, *46*(1).

Stęchły, W., & Dębowski, H. (2020). *Descriptive categories for Transversal Key Competencies*. SGH.

Tarkowski, A., Majdecka, E., Penza-Gabler, Z., Sienkiewicz, M., & Stunża, G. D. (2018). *Analiza strategii i działań mających na celu rozwój kompetencji cyfrowych w państwach Unii Europejskiej*. Fundacja Centrum Cyfrowe, Fundacja Digital Poland.

Torczyńska, M. (2019). Sztuczna inteligencja i jej społeczno-kulturowe implikacje w codziennym życiu. *Kultura i Historia*, *36*(2), 106–216.

Wasilewska-Kamińska, E. (2016). *Myślenie krytyczne jako cel kształcenia. Na przykładzie systemów edukacyjnych USA i Kanady*. Wydawnictwa Uniwersytetu Warszawskiego. https://doi.org/10.31338/uw.9788323525639.

Industry

The relationship of artificial intelligence and education – opportunities and threats for the parties of the educational process in the urban context

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Introduction

Both artificial intelligence (AI) and virtual and augmented reality (VR/AR) have great potential to significantly change people's lives. This is widely believed not only by computer scientists, but also by a growing number of people who, listening to the narrative of computer scientists, seek out knowledge gleaned from books or science fiction movies in their search for information and decision-making support. These are desirable activities, since such people, when faced with a decision-making problem, cannot cope satisfactorily with making the decision themselves, or they can cope, but only after having put in a lot of work on the issue, which is not an attractive task for them. Such tasks include education, which, despite its laudable achievements, continues to burden people with work, boring procedures for memorizing unnecessary (as often seems to be the case) information that is difficult for the learner to link into logical sequences. In the following deliberations, we refer to both AI and VR/AR as "phenomena".[36]

Although the aforementioned phenomena are trans-local in scope, the intensification of their functioning[37] is occurring in urban areas. Perhaps they are transient in nature, relating to the emergence of both AI and VR/AR in the context of their implementation and use, nevertheless it seems that cities, for various reasons, have the conditions for the accelerated development of these phenomena.

The authors have delineated the space – created by the overlapping subspaces of a city – of artificial intelligence and VR/AR. It can actively stimulate educational processes. In addition, the authors decided to identify the extent of the impact of this space on education.

However, in order for there to be a point in delving into such considerations, it is necessary to: (1) define the aforementioned concepts, (2) recognize the sense of their separation by formulating assumptions or theses, (3) prove (according to the

[36] The authors' use of the term „phenomenon" is a rhetorical figure, while its justification is an attempt to use the same concept (meaning what is given in sensory cognition) for a wider range of identified and diverse concepts in a situation where this diversity for the narrative is not important from the point of view of its impact on other phenomena (on education).

[37] Speaking of the „intensity" of the phenomenon, the authors mean the quantitative characteristics of the phenomenon, which can be presented in the form of a point, surface or area.

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essence of the theses) their veracity, (4) recognize the interrelationships between these concepts, and (5) recognize the hypothetical impact on education of the scope thus formulated – including attention to opportunities and threats.

In considering the problem outlined in the title of this article, the authors used theses.[38] A thesis is a true rather than a probable sentence, which means that it is, unlike a hypothesis, proven.[39] Theses are formulated sequentially, as the narrative proceeds.

Table 7. Theses of the how the narrative should proceed

Thesis 1	The city is the most popular and advanced educational environment.
Thesis 2	The city as an environment fosters the creation of innovation by establishing objective premises for various dimensions of inter-organizational proximity (including primarily geographic/spatial proximity), thus promoting the creation of emotional, or more broadly, social relationships. In addition, the city as an environment enforces organizational and cognitive proximity in the educational system.
Thesis 3	Augmented reality (VR/AR) is linked to artificial intelligence (AI).
Thesis 4	Augmented reality (VR/AR) is linked to the city (as a phenomenon and material entity).
Thesis 5	Artificial intelligence (AI) is linked to the city (as a phenomenon and material entity).

Source: own elaboration.
Note: all theses cited in this text are from Table 7.

The conceptual proceedings were based on heuristics, understood as the art of detecting new facts and the relationships between them, leading to the knowledge of new truths, or perhaps, as A. M. Turing believed, "the ability to recognize data, which can then be efficiently and effectively used to solve problems" (Firlej-Buzon, 2003, p. 25).

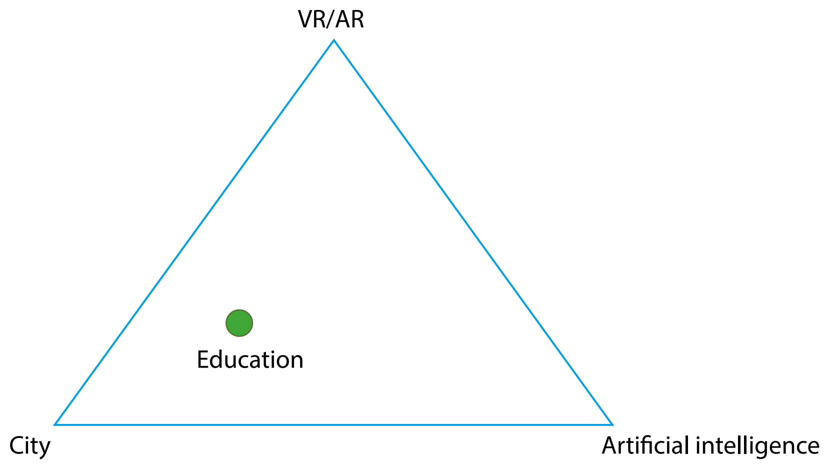
The purpose of this article is to conduct a reflective narrative based on formulated ad hoc theses and to present the areas in which the conditions of space can affect the educational processes.

The space of the considerations

By "the space of the considerations", the authors mean the overlapping phenomena of artificial intelligence (AI), augmented reality (VR/AR) and the city as a structure of interdependent networks (see Filip, 2015, pp. 97–114). In this space, the authors situate education and identify the relationships that exist in the connections between these concepts/phenomena (Fig. 1).

[38] The *Słownika wyrazów obcych* [Dictionary of Foreign Terms] defines thesis (from Greek) as an assertion containing content fundamental to a field, an assumption that someone intends to prove (Kopaliński, 1991).
[39] A thesis is always proven with certain assumptions, on the basis of which a proof is conducted, allowing the thesis to be rejected or accepted, and allowing a thesis statement to be formulated that is relevant to the field in question (Kucinski, 2010, p. 93). The thesis is proven by means of deduction.

Figure 3. Conceptual space of the considerations



Source: own elaboration.

The space thus outlined, as envisioned by the authors, affects the shape of education, understood in a multicontextual way.

The development of graphics processing units (GPUs) at the end of the last century drove the growth of the computer game market, redefined modern computer graphics and revolutionized parallel processing. In recent years, the use of GPUs to process deep learning algorithms has ushered in a new phase in the development of artificial intelligence, with GPUs acting as the brains of computers, robots and autonomous vehicles that can perceive and understand the world. To paraphrase an apocryphal maxim:[40] predicting the future is difficult, especially in a world where the development of breakthrough methods for predicting the shape of proteins is a byproduct of producing computer shooters.

Artificial intelligence is one of the most disruptive[41] technologies of our time (King, 2018, pp. 53–67). Interest in using AI for urban innovation continues to grow. In particular, the development of smart cities – urban locations that, through community, technology and policy, can deliver productivity, innovation, livability, well-being, sustainability, accessibility, good governance and good planning – has increased the demand for AI-based innovation. Some of the most popular technologies in the context of smart cities include, among others: the Internet of things (IoT), autonomous vehicles (AV), big data, 5G, robotics, blockchain, cloud computing, 3D printing, virtual reality (VR), digital twins and artificial intelligence (AI) (Kyriazopoulou, 2015, pp. 14–15). While all of these technologies are crucial to transforming our cities into smarter ones, artificial intelligence combined with these technologies has significant potential to address the urbanization challenges of our time (Rahman, 2017, p. 116).

[40] https://quoteinvestigator.com/2013/10/20/no-predict/. We are talking about a number of various statements about predicting the future, built on the declaration: „Forecasting the future is difficult, especially...".

[41] Disruptive [dysrupcyjny] – characterized by discontinuity, being abrupt, non-linear, difficult to predict, yet significantly affecting daily life/the future (Głomb et al., 2019).

In the defined space of the considerations, a strand of artificial urban intelligence is emerging – where AIs are embodied in urban spaces, infrastructure and technologies that together transform cities into autonomous entities that operate in an unattended manner (Cugurullo, 2020, pp. 2–5). This intelligence can manifest itself through physical artifacts, such as autonomous vehicles, or remain invisible at first glance – though with no less impact. The power of algorithms is perfectly illustrated by an experiment by artist Simon Weckert. It consisted of Weckert pulling a cart loaded with 99 cell phones down a street in downtown Berlin. All the phones had location-based services enabled. As a result, Google Maps began to warn drivers of a major traffic jam on the street Weckert was walking down and suggest alternative routes. Drivers followed the system's prompts suggesting alternative routes to avoid the traffic jam. According to Weckert, the purpose of the experiment was to illustrate how the physical world can be altered through changes in the digital world (Mertala, 2021, p. 7).

Connected to such non-obvious interactions between the real and digital worlds is the concept of urban computing, which refers to the study and application of computing technology in urban areas. As such, it closely relates to urban planning, particularly infrastructure, including transportation, communication and distribution networks. We envision a future in which it is much easier to provide people with what they need and want, including but not limited to education, jobs, health care and personal services of all kinds (access to supermarkets, banking services, etc.). Creating new, broader and easier access to services or places can be hampered by obstacles in getting there. Time spent commuting to school or work could be better spent. Increased travel time could be seen as a serious constraint on the use of service offerings. In addition, when people do not have easy access to preventive health care, the subsequent costs of reversing adverse changes can far exceed those that would have been incurred if appropriate preventive measures had been taken. Lack of easy access to supermarkets with healthy food is strongly correlated with obesity (and thus heart disease, diabetes, etc.) (Kolata, 2012, p. 12). AI technology can greatly improve mobility and thus significantly reduce these and other inefficiencies in the market to make everyday life easier.

The easier it is for people to move around in urban spaces, the more vibrant urban areas will be and the more fruitful will be the social and economic interactions taking place within them. The form of movement is also not indifferent to the health of urban residents (Stutzer & Frey, 2008, pp. 339–366). Soon, as in the case of car navigation, it will be left to an AI-based application to decide which mode of transportation to use (Huiling & Goh 2017, pp. 26–29).

Virtual reality is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with an internal screen and gloves equipped with sensors. Augmented reality, which is defined as the technology of superimposing a computer-generated image over the user's view of the real world, has a similar goal of immersing the user in a virtual environment (Stevenson, 2010). Both systems are immersive technologies with the ability to generate a three-dimensional image that appears to surround the user. They have various features in common, such as providing a computer-generated image and a three-dimensional image or creating a virtual environment. At the same time, each system implies immersion, but with a different intensity – starting with a semi-immersive virtual environment (in the case of augmented reality) and ending with a fully immersive environment (in the case of virtual reality).

For a long time, opinions of researchers in the field have suggested that virtual reality will soon merge with augmented reality (Kaufmann and Papp, 2006, pp. 160–165). Therefore, based on the above, we believe that the future use of a term such as augmented reality (XR – extended reality), which captures the features common to augmented and virtual reality, will be welcomed in the specialist literature (Kwok & Koh, 2021, pp. 1935–1940).

Concluding the discussion in this section, it is worth defining the concept of the city itself. The city as a phenomenon and material entity is defined in various ways, depending on the competence of the definer and the purpose of providing the definition. However, since our attention is focused on the environment of the city conducive to the creation of innovation based on the dimension of spatial proximity (thesis 2),[42] incorporating aspects of human relations (emotional, social) into this dimension, it is worth defining the city in this spatial-social context. This definition was proposed in one of the lesser-known documents in Poland, *The European Charter for the Safeguarding of Human Rights in the City*, adopting the position of the European Charter of Local Autonomy. Paragraph 1.1 of this document reads: "The city is a collective space belonging to all who live in it. These have the right to conditions which allow their own political, social and ecological development but at the same time accepting a commitment to solidarity" (United Cities and Local Governments (UCLG) Committee on Social Inclusion, Participatory Democracy and Human Rights, 2012, p. 10).

In the space thus outlined, the authors situate education, recognizing that it finds its environment of existence within it.

Education in Poland has a long, well-documented history of numerous reforms. Conceptually, they begin in 1551,[43] and have been implemented since 1773.[44] Typically (except for the three-tier model of education introduced by the Commission of National Education) they included: an ideological aspect (theological education, education in the Polish language, germanization and russification, Marxist-Leninist assumptions, education subordinated to and promoting the changing government), adjusting curricula, textbooks, and taking control over the activities of schools and the implementation of established curricula. Thus, it can be concluded that over the course of almost 250 years, education has not gone beyond the confines of these issues. It is puzzling that emerging breakthrough technologies (the transistor, Internet) have not affected its shape. The greatly reduced autonomy of schools (except for universities, which have elements of autonomy) is perpetuated by an expanded regulatory apparatus that favors all forms of control and leads to the cementing of bureaucratic behavior in the organization. This is expressed in an excess of regulations, directives, and it is not uncommon for

[42] The reader's attention is directed to Table 7 of this article each time the formulated theses are referred to.

[43] In 1551 Andrzej Frycz-Modrzewski wrote a work "On the improvement of the Republic", consisting of 5 treatises. One of them, "On School," addressed civic and democratic education.

[44] The Commission on National Education was established In 1773.

executive units to become paralyzed and restricted, resulting in token activities (Bieniok & Rokita, 1984, p. 117). Thus conditioned, the school organization has little freedom to shape its identity.

The proof for thesis 1

The city is the most popular and advanced educational environment. This statement should be considered from two perspectives: (1) the number of facilities and (2) the number of students receiving education.[45] Regarding the first perspective: the number of primary schools (1), there is a misleading impression that the dominant environment for this type of school is the countryside (8675 primary schools versus 5909 located in cities). On the other hand, in terms of the second perspective (2), 1.9 million students attended primary schools in cities in 2019/20, while 1.1 million in rural areas (GUS, 2019, p. 32). The same is true of lower secondary schools (which were in the process of being phased out during the period of the GUS study cited above). In the 2019/20 school year (1), there were 1031 lower secondary schools in urban areas, while 609 in rural areas. In addition, there were 53 primary schools educating adults in urban areas, while there were 2 in rural areas (GUS, 2019, p. 34). In the sector of post-lower-secondary[46] (a) and post-primary[47] (b) schools, the share of such schools (1) located in cities was 90.1%, while in rural areas it was 9.9% (CSO, 2019, p. 35). A derivative of this state is participation in activities that develop interests and talents – as of September 30, 2018, there were 201,600 school circles, clubs and teams conducting extracurricular and voluntary activities in schools for children and adolescents. There were 2,301,900 students participating in such activities (counted as the number of times students attended the many activities offered to develop interests and talents) (GUS, 2019, p. 60). In the proportion derived from both the number and location of educational institutions and learners, we can consider the spatial context (urban – rural) of teaching activity. In the 2018/19 school year, 512,353 teachers were employed in Poland, of which 357,811 (70%) were in urban areas, while 154,542 (30%) were in rural areas (GUS, 2019, p. 200). The presented data sufficiently justify **Thesis 1** formulated in Table 7 and cited at the beginning of this paragraph – the city is the most popular and advanced (in terms of the potential accumulated in urban areas and educational activity) educational environment.

The proof for thesis 2

If we add to the arguments presented in the proof for thesis 1 information about the location of practically 100% of higher education institutions (where teaching processes also occur) in cities, then we can assume that cities are also endowed with the potential to create new trends in teaching, given the massiveness of teaching, as well as proximity[48] (geographic, organizational, cognitive, institutional, cultural or social), conducive in many dimensions to innovation. Boshma and Frenken explain the concept in simple terms – proximity means the similarity of attributes of

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[45] The proof for thesis 1 uses two perspectives: 1 – the number of schools and 2 – the number of students in education. The reference to "1" is always the context – the perspective of the number of schools, while "2" always refers to the number of enrolled students. In addition, a breakdown is presented for post-lower-secondary schools, which are denoted by "a", and post-primary schools, denoted by "b".

[46] (a) general and vocational upper secondary schools and general schools of the arts;

[47] (b) special needs school preparing for work, cycle I sectoral vocational schools and post-secondary schools.

[48] Also known as "inter-organizational proximity".

an organization (Boshma & Frenken, 2009, pp. 120–135). Wojciech Czakon refers to proximity as the similarity of both physical space, emotional and social relations, as well as shared cultural values or similarity of institutional operating conditions (Czakon, 2010, pp. 16–19). Patrycja Klimas, based on an analysis of the literature, points out that despite some inconsistencies, knowledge creation is mainly influenced by geographic proximity – spatial proximity can stimulate knowledge flows, cognitive proximity – having similar knowledge bases, patents or technologies, and organizational proximity. Some researchers have even argued that knowledge and technology diffusion requires organizational proximity (Klimas, 2011, pp. 19–20). Undoubtedly, the aforementioned three dimensions of proximity, whether or not their relevance is increasing these days (e.g., the importance/relevance of the dimension of geographic proximity may be decreasing in view of the existence of a wide range of virtualization solutions, increasingly widely used especially since the lockdowns associated with the COVID-19 pandemic) have a much broader practical significance. Spatial proximity is not neutral (e.g., in the formation of emotional or social relationships), so it can be viewed as a set of underlying dimensions of proximity. Let's look at the education environment described in relative detail (additionally, in the context of cities) – these three dimensions have long existed in the background of cooperation/interaction: facilities (school units), teachers and other personnel related to the functioning of education; relations with educational supervisors (school superintendents), as well as leading authorities.[49] Thus in the city we have not only an accumulation of educational institutions, forming, according to Richard Florida, a resource called "talent". Increasing the density of interpersonal contacts, as a result of the formation of emotional or social relationships, forms the basis of another resource, called "tolerance". Having taken into account Florida's view that the "3 T's – technology, talent and tolerance" are key prerequisites for a city's creative success, and seeking to link a city's success to increasing its creativity, this accumulation of educational institutions seems extremely beneficial in this regard. Admittedly, each of these elements separately is necessary for success, but separately they are not sufficient. Only the implementation of all these elements is capable of generating innovation and stimulating economic growth (Florida, 2011, p. 261). Nevertheless, the arguments cited justify the high probability of innovation in such a perceived city environment.

The city as an environment fosters the creation of innovation by generating an objective premise for various dimensions of proximity (including primarily geographic/spatial), and thus creating emotional or social relationships. The educational system, on the other hand, enforces organizational and cognitive proximity. Thus, **thesis 2** can be considered reasonable.

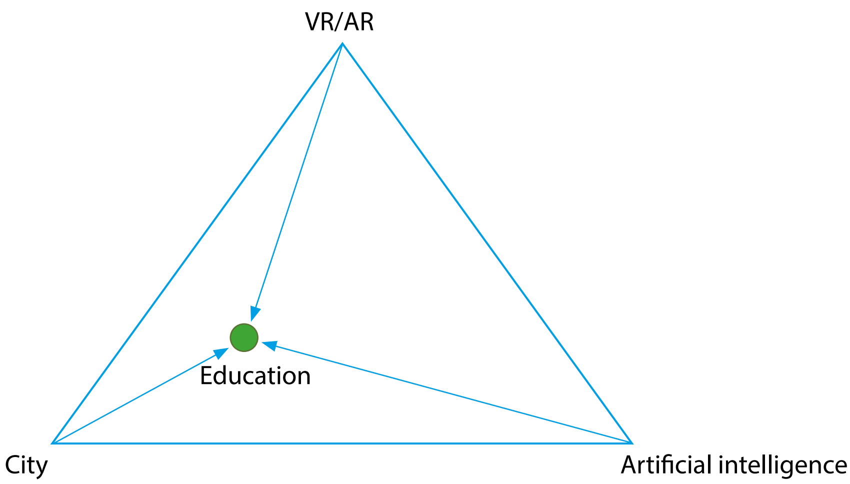
Incidentally – the presence of higher education institutions in cities can also be an impetus for creating innovation in education under certain conditions.

[49] In accordance with Article 10 of the Act of 14 December 2016 – The School Education Act (Journal of laws of 2021, item 1082 with further amendments) – they are: the minister, the local government unit, legal and natural persons responsible for their activities.

The relationships between the phenomena

The phenomena defined above fill the space of the considerations with varying intensity. They can be independent of each other, or interdependent in a certain way (e.g., technologically or regulatorily), and in such a way affect the processes of education. The space of the considerations in this situation is a certain ecosystem, hence it is natural to seek to recognize the relationships that are realized inside such a system (Figure 2).

Figure 4. The relationships between the phenomena



Source: own elaboration.

The proof for thesis 3

Artificial intelligence and augmented reality are increasingly coexisting and even complementing each other in various spheres of life, such as education (Jiang, 2021), fitness (Zhao, 2021), rehabilitation (Riva et al., 2019), art (Lugrin et al., 2006) or mining (Mitra & Saydam, 2014). The diverse spheres mentioned indicate the transversal nature of the occurrence of these technologies in coexistence and even symbiosis – but a review of the literature points to medicine as the sphere where, as of today, development is most dynamic.

As an example, virtual reality simulators used to train surgeons (described by Winkler-Schwartz et al., 2019) track all movements and forces on the simulated surgical instruments and generate huge data sets that can be further analyzed using machine learning algorithms. These algorithms are being developed not only to classify trainees according to surgical knowledge, but primarily to train them on a specific surgical standard. These systems will allow studies to be conducted to further develop the right approach to using this technology in teaching psychomotor skills. Regardless of what the future holds, a clear understanding of surgery, artificial intelligence methodologies and best educational practices will be crucial to the ultimate success of these systems, understood as surgeons achieving higher competence.

As Bastug et al. point out (2017), there are technological limitations to computing power and the bandwidth of wireless data transmission systems, but the development of systems using AI and VR is also limited by privacy issues or environmental aspects (the energy intensity of information processing).

Thus, **thesis 3**, according to which augmented reality (VR/ AR) is linked to artificial intelligence (AI), can be considered reasonable.

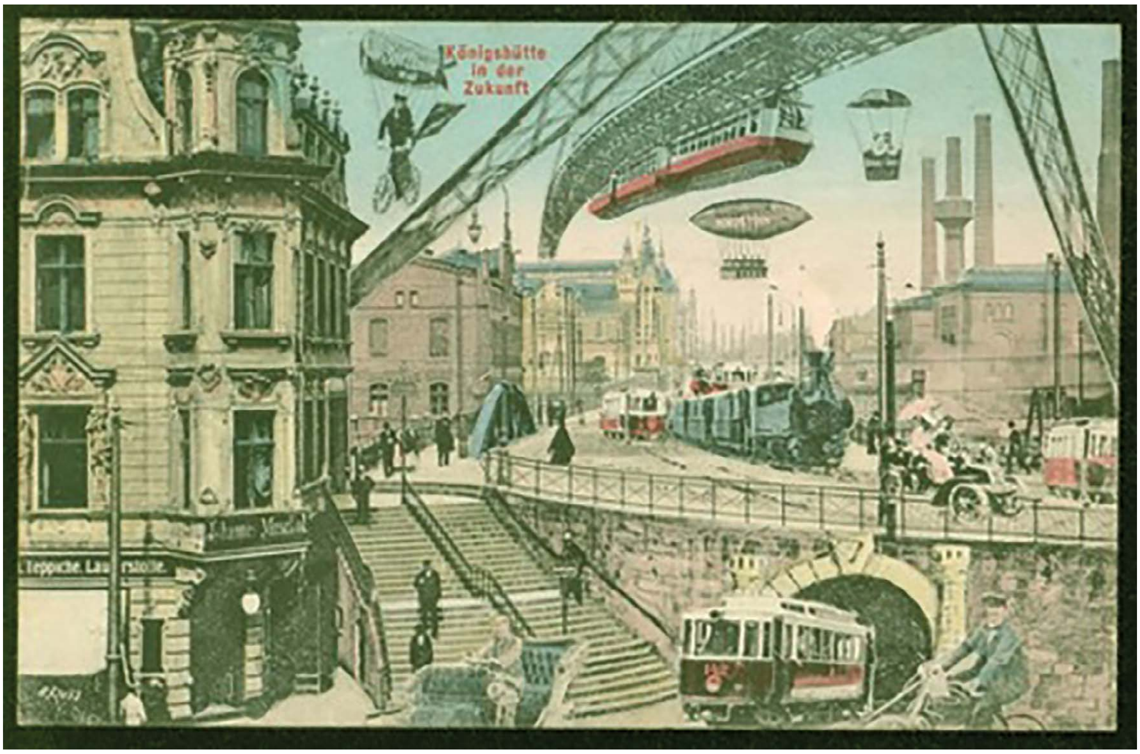
The proof for theses 4 and 5 (*smart city*)

The aforementioned theses (4 and 5) link the city and artificial intelligence (AI) and augmented reality (VR/AR) in a relationship. To this end, it should be assumed that for such a relationship, the city must be properly prepared, in other words – it should have certain attributes, creating an ecosystem for the development of the aforementioned phenomena, combined with benefits for the city. The Internet of things (IoT) in the context of the city usually appears in the stream of discussions about the smart city. What is the "intelligence" of a city? Among the conceptual currents, two can be identified. The first is relatively unified, technological – it emphasizes the possibilities of IoT and the technologies at our disposal. The second trend is less unified and contemplative in nature. A growing number of publications fall within the latter trend, stating that increasing the "smartness" of a city essentially boils down to having the city acquire the ability to "think" (Szołtysek, 2017, p. 288). A smart city is defined as one "…where technologies are interconnected and developed. A place that makes available an operationalized life experience, taking it to a whole new level. It's also a city whose managers have possessed the ability to optimize growth, refine budgets and plan proactively" (U.S. Department of Commerce, 2016, p. 6). A city that is adaptive, proactive and agile, seizing opportunities, decoding and analyzing data and taking advantage of what is being collected today in big data. Typically, such cities are relatively data-intensive with "smart objects capable of sensing, responding to the environment, processing and remembering digital information, as well as transmitting this information to other objects (and thus to their users) via Internet protocols" (Czajkowski & Nowakowski, 2016, p. 28) – i.e., the Internet of things.

In 2018, Szołtysek formulated two smart city paradigms, thus introducing a kind of "intelligence gradation" of cities. He points to the "smart" city and the "thinking" city (Szołtysek, 2018, Vol. 3, pp. 127–156). In his opinion, most contemporary Polish cities tie their plan for the future to the aspiration of becoming a "smart" city. Measures taken in this regard usually focus on the technical side of the project, and the results achieved through instrumentation allow both city authorities, city services of all kinds and other dedicated users to use the information obtained from sensors and all monitoring and recording devices. They thus seek to increase the efficiency (effectiveness, economy or benefit) of these users and the city itself. Such activities are ushering in a new era in the operation of the city – the era of the smart city paradigm. The author used the word "clever" [*spryt*] here, as in Polish it means "the ability to deal with difficult situations in a quick, practical manner" (Szymczak, 1981, p. 307). Decisions based on such information are usually made as before, but are based on faster and more objective (less distorted) source data and a greater range of such data. Gradually moving to the next (higher) levels, in which the range of possibilities to derive information and create intelligent prompts based on it – advisories that are intelligently tailored to the needs of a wide audience – means a gradual paradigm shift toward a thinking city. A thinking person is one "who independently thinks, analyzes and reflects on what one does," "becomes aware of something and focuses attention on it, tries to understand or solve something" (Szymczak, 1981, Vol. 2, p. 236).

IoT has a central place in the conceptual space of the smart city idea, while the smart city is the practical manifestation of municipal functioning in the thinking city paradigm. The thinking city reaches out to three key resources: information and communication technologies, which are the essential instrumentation of IoT; infrastructure, supporting not only the smart functioning of the city, but also having a significant positive impact on IoT development; and finally – creative capital, the only resource that can, on the basis of the previously mentioned resources, innovatively develop the city, as well as any conceptual and implementional achievements, which nourish the development of any organization, group of people or individuals. Contemporary solutions of the "smart" city are embedded in the intersection of these determinants and in their mainstream – including those based on both the idea of augmented reality (VR/AR) and artificial intelligence (AI). As it turns out, the areas where these phenomena are applied in cities is growing, and the reason for this is primarily that concentrated in the city, as in a lens, are all the problems which people face, as individuals and groups, as they conduct their activities, satisfy their needs, and finally use available services. The same is true of the processes of manufacturing, resource development, issues of security, sports, culture, health care or education – this area partially fills the needs of residents, also in terms of services. The city, in implementing its assigned functions, as well as through the economic, environmental and social order it establishes, directs its offerings to residents and the surrounding area. In this way, it creates its competitive advantages, which it further strengthens in constant dialogue with its stakeholders so as to attract new residents and retain existing ones. Moreover, acquiring new residents should be directed especially to those groups that are able to "stimulate" the city into new forms of action to enable it to make a civilizational leap in the hierarchy of cities. Much has been written about this by Richard Florida (2011) or Scott McQuire (2008). McQuire sees the city as a variety of digital networks and electronic media within it, which are beginning to dictate increasingly more to residents, shaping their way of life and ideas about time and space, influencing not only the lives of individuals or groups, but also urban planning or architectural trends. In his ideas, he comes dangerously close to Orwell, Foucalt or Sennet (we are referring to *The Fall of Public Man*). The poignantly and surprisingly accurate future of humanity described half a century ago by Alvin Toffler (in *Future Shock* and *The Third Wave*) is being realized today, and the technical challenges of combining biotechnology and information technology are posing the greatest challenges humanity has ever encountered. This is what Yuval Noah Harari believes (in his book *21 Lessons for the 21st Century*), while Nassim Nicholas Taleb hails the unpredictability of the world vision (in *Antifragile: Things that Gain from Disorder*). Not all predictions made many years ago have come true. Confirmation of these observations can be found in a postcard depicting a vision of the city's future from about 100 years ago (Fig. 3).

Figure 5. A vision of the future of the city of Königshütte (Chorzów, Poland), a postcard from the early 20th century



Source: Own archives.

Since we still believe that dominant numbers of humanity will be living in cities, and that there are no alternatives to the technological, digital environment shaping our lives in every way, it is necessary to consider that cities in their functioning are interdependent and co-dependent on well-being.

Considering the above, it can be concluded that there is justification for both **theses: 4** – augmented reality (VR/AR) is linked to the city **and 5** – artificial intelligence is linked to the city. In both theses, the city is treated as a phenomenon and material entity.

Opportunities and potential limitations for education processes associated with the potential of AI, VR/AR and the city

Opportunities

As Noureddine Elmquaddem (2019) points out, the value of using virtual reality in education and learning partly relates to the fact that this technology can enhance and facilitate learning, information assimilation and decision-making processes while working in stimulating environments. In reality, when we read textual content (for example, in a printed document), our brain interprets everything we read, and this increases our cognitive effort. When using virtual reality, the interpretation process is shortened because there are fewer symbols to interpret, and understanding is more direct. For example, it is easier to understand how a machine works by visualizing how it works than by reading a textual explanation. And when the visualization is in 3D/VR, understanding comes even more easily. Physical access to everything we learn is not possible – VR allows us to access everything we want virtually, as if we were really there. A learner can, for example, explore the moon or the ocean floor, or see what a place looked like in the past. This allows for a better understanding of things and phenomena with less cognitive effort on the part of the learner and lower costs for learning institutions. The learner is more engaged, motivated, open-minded, ready to learn and communicate with others.

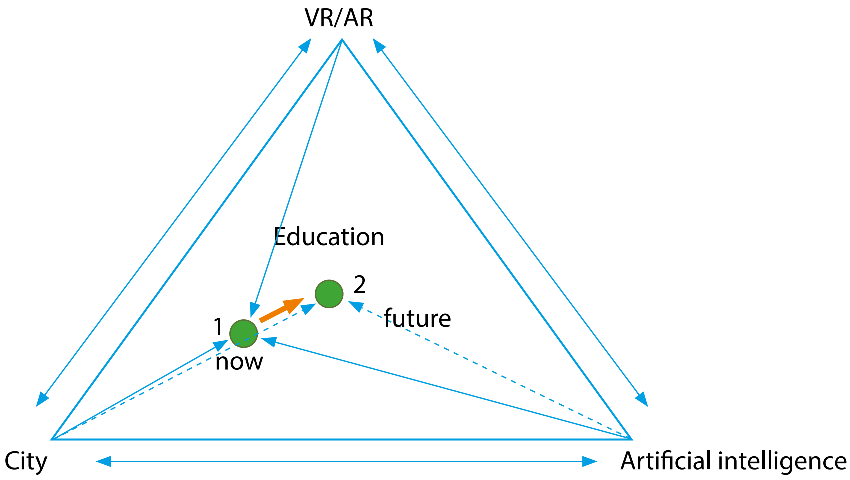
Over the past two decades, numerous studies have demonstrated the strengths of using virtual and augmented reality in teaching (Postawa, 2018). One of their most important strengths is that they change the role of the teacher from a provider of knowledge to a facilitator who helps students explore and learn (Youngblut, 1998). This strongly complements constructivist learning theory. Students feel empowered and engaged because they have control over the learning process (Dede, 2005). They can learn experientially and make progress at their own pace as they explore the virtual environment. It also prevents students from falling behind during a lecture and spending the rest of the class trying to catch up (Jonassen et al., 1999).

In addition, virtual reality can help students learn abstract concepts because they can experience and visualize these concepts in a virtual environment. Unlike the traditional learning process, which usually relies on language, the conceptual and abstract learning environment in virtual reality fosters active learning and helps students understand abstract knowledge (Ray & Deb, 2018). Learners with low spatial orientation especially benefit from virtual reality because visualizations help lower external cognitive load (Lee and Wong, 2014).

According to Kurubacak and Altinpulluk (2017), AR provides numerous educational benefits. For learners, these benefits can be summarized as: enjoyment of activities, reduced cognitive load, increased motivation and interest in activities, increased opportunity to ask questions, more interaction between learners, new opportunities for individual learning, specification of abstract concepts, and increased efficiency of the learning process. For teachers, the benefits lie in contributing to the development of learners' creativity, ensuring the effective participation of students in classes and opportunities to conduct classes at their own pace.

While the links between AI and VR/AR are clear, as they belong to the same technological streams, the links between the city and education are less obvious and require deliberate action for their existence. Today, educational processes are increasingly taking advantage of the opportunities provided by various technologies, including the aforementioned AI, VR/AR. Advancements in this area are increasing with the influx of new teaching staff, brought up in a digital environment, and under the influence of growing investments in securing equipment, which accelerated rapidly with the advent of the COVID-19 pandemic. The implementation of education using distance learning methods and techniques was the impetus for taking action, moving the education process from "1" to a forward-looking remodeling of it ("2") towards increasing its participation in AI and VR/AR (Fig. 4).

Figure 6. Changing dimensions of AI and VR/AR in the future education process



Source: own elaboration.

The effectiveness of such a transformation can be conditioned by a number of factors, but the framework of this study assumes certain self-constraints. Therefore, the authors propose a look at the determinants in the matrix presented in Figure 5. Considering AI, VR/AR as objectively existing elements in varying degrees of advancement, the relationship of the city and education can be considered in four dimensions (2 each characterizing education and the city, respectively) and filled with activities. These activities should be activated and deliberately formed in the city environment to place education in the space of the considerations that better utilizes the potential of AI, VR/AR. For the sake of clarity, it should be pointed out that the position of "2" can be located anywhere in the space, with the understanding that each time the role of the components defining the space of the considerations is increased or decreased, a change in the quality[50] of education will result accordingly.

[50] Quality, including the quality of education, is, counterintuitively, a complex and understated phenomenon (cf. Mizerek, 2012, p. 19). Recognizing that it is exceptionally accurate to view quality in the contexts of excellence, educational outcomes, audit-review results, mission, culture or transformation, in our approach, this quality is treated cross-sectionally as additional opportunities created by the city, AI, VR/AR in terms of excellence.

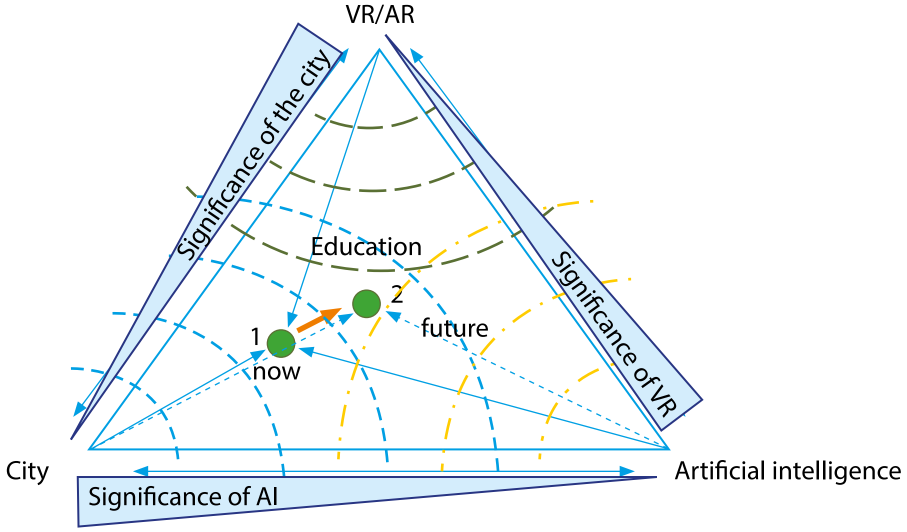
Figure 7. Matrix of the determinants of change in the quality of education in the "education – city" system

EDUCATION	Formal dimension	Conceptual dimension
Conceptual dimension	Shaping the potential of educational units, including upgrading qualifications and molding the competencies of the teaching staff as well as improving cooperation with stakeholders	Using the city's resources to enhance the attractiveness of the education process, including both the technical and technological aspects, as well as those relating to history, culture, anthropology, and identity
Formal dimension	The organization of the educational system and supervision by the superintendent of education, implementation of the tasks of the founding authority, the leading authority	Shaping the educational system from the point of view of multiplying the benefits of inter-organizational proximity and innovation
		CITY

Source: own elaboration.

The farther education is located from the angles of the triangle in the space of the considerations, the greater is the intensity of the phenomenon, or the significance of its presence in the education process (Fig. 6).

Figure 8. The intensity of phenomena in the space of the considerations



Source: own elaboration.

In their considerations, the authors focus their attention on the second quadrant of the matrix, i.e., the conceptual dimensions of both education and city functioning. In it, they find calls for the intensive use in educational processes of the city's resources – technical and technological (attributes of the smart city, AI, VR/AR), the history of the city as a phenomenon and the city as a material entity, culture (including the place of the city and its inhabitants in the history of the region, state, continent, etc., as well as in the context of urban legends), the identity of residents and more broadly – social groups, as well as in the context of anthropology, which seems to be particularly relevant to the functioning of cities. Access to these areas should be made available through the technologies we are discussing here, and this channel should be "embedded" in the processes of education, taking place both in the school building and in the various spaces of the city. The purpose of such measures is to offer a new quality of education, facilitating and organizing the understanding of curricular content, through which this content should become more attractive and acquire the attribute of usefulness so absent in the modern learning process. Incorporating elements of the space of the considerations into the educational process will allow the learning process to be individualized in the context of adapting it to students' perceptual abilities, as well as providing the curricular content with the specificity of the city in which education is conducted. These proposals seem innovative in the context of their potential mass use.

Limitations

As with any technological advancement, virtual reality is a tool that must be used properly to be effective. Despite the great promise of virtual reality and the advantages described above, there are some limitations that need to be considered when integrating virtual reality into educational settings (Boyles, 2017).

For many years, the main obstacles to using virtual reality in education have been the cost and computing power required to create realistic environments (Merchant et al., 2014). In addition, some virtual reality systems were difficult to use (Youngblut, 1998), and the equipment the user had to carry was bulky and had limited immersiveness (Ray & Deb, 2016). Fortunately, advances in mobile device technology have reduced the size of VR devices (Wu et al., 2013) and the introduction of solutions such as Google Cardboard and Oculus Quest have made virtual reality extremely affordable

Another obstacle to the use of virtual reality are the complaints reported by its users. Selected participants in virtual reality studies have experienced nausea, symptoms of motion sickness or minor headaches while using the devices (Kinateder et al., 2014). Up to 10–20% of users in one study reported such complaints (Hussein & Nätterdal, 2015). Technological advances over the past decade have resolved some of the causes of the problems, but there is still a portion of the population complaining of "cyber-nausea" (Caserman et al., 2021).

Another limitation is the issue of mastering the use of virtual reality. Students and teachers need additional time to learn how to use VR devices. For example, improperly adjusted head-mounted displays can result in blurred images and text (Hussein & Nätterdal, 2015), and the additional cognitive load of learning to navigate and explore in a virtual world requires teachers to spend time – their own and students' – learning how to use the devices (Wu et al., 2013). In addition to using the tools, teachers or administrators must acquire or build virtual worlds or simulations for their classrooms. Since most teachers do not have the time or technical skills to create their own virtual reality applications, third parties will likely be needed to create and maintain these programs and develop content. With this in mind, it is also important that the programs used can be easily modified, customized or updated by instructors for specific classes and students (Kerawalla et al., 2006).

It is important to remember that virtual reality technology does not diminish the importance of lesson planning or the role of the teacher in classroom instruction. Although the role of a teacher equipped with virtual reality tools is usually limited to being a coach and mentor (Zhang, 2013), teacher guidance is still crucial when using VR systems (Lee et al., 2010). In addition, there must be clear educational goals as well as those that support virtual reality (Choi et al., 2016; Baker et al., 2009). In some cases, virtual reality is not the best method to achieve the learning objective (Pantelidis, 2010), so the curriculum should be reviewed to determine where virtual reality can help and where other teaching methods are more appropriate.

It is also worth noting that teaching a topic in virtual reality may take more time than with traditional methods (Wu et al., 2013). If virtual reality tools are difficult to use, this may discourage teachers from taking advantage of them in their classrooms (Choi, 2016). Additionally, since many teachers may not have been exposed to the possibilities or applications of virtual reality in the classroom, it is important to find a form of professional education that makes teachers feel comfortable using the technology in their classrooms and explore the new possibilities that VR opens up.

Summary

The issues considered about the future of education, implemented in the urban environment in the face of new challenges and opportunities created by the development of AI and VR/AR, allow a number of reflections and conclusions to be made, which also take into account the surprising resistance of the education system to change. Thus:

1. AI and VR/AR technologies have disruptive potential and will significantly affect the reality around us, both in the context of the city as well as in the context of education.

2. Taking into account that AI and VR/AR technologies and the city are interrelated, and that the city is the most popular and advanced educational environment, it can be assumed that the innovative climate of the city and the inter-organizational proximity of educational units provide the opportunity for a qualitative change in the education system of the future.

3. The creative combination of the identified characteristics (in terms of usability) of AI and VR/AR technologies and the city aims to offer a new quality of education, facilitating and organizing the understanding of curricular

content. As a result, this content should become more attractive, acquire the attribute of usability, and complement the educational process with elements of the space of the considerations. This will make it possible to individualize the educational process in the context of adapting it to students' perceptual abilities, as well as to make the curricular content specific to the city. Such an outcome is part of a positive scenario for the development of the space of the considerations.

4. If the dark scenarios of strong artificial general intelligence (AGI) do not materialize, the development trajectory will depend largely on the awareness and cooperation of stakeholders for a controlled transition from the conceptual to formal dimensions of the city and education. Should this be lacking, we are in danger of having urban spaces or the education process dominated by unsustainable (in the sense of the Sustainable Development Goals) solutions, such as self-driving cars for urban mobility.

5. Just as we did not live to see flying bicycles, which are, however, materializing in another form (e.g., drones), some of the considerations for future education will never materialize, or there will be solutions that we cannot foresee today.

6. The authors hope that the coming technological change will be accompanied by a fundamental transformation of the Polish education system towards the development of curiosity, openness to the world and people, and cooperation.

Regardless of the trajectory of the mutual development of cities, education and technology, any use of technology as a tool to restrict freedoms of expression, access to knowledge and the promotion of disinformation is a force that significantly impedes the development of the space of the considerations.

Bibliography

Ab-Rahman, A., Hamid, U. Z., & Chin, T.A. (2017). Emerging technologies with disruptive effects: A review. *PERINTIS eJournal, 7*(2), 111–128.

Baker, S. C., Wentz, R. K., & Woods, M. M. (2009). Using virtual worlds in education: Second Life® as an educational tool. *Teaching of Psychology, 36*(1), 59–64.

Bastug, E., Bennis, M., Médard, M., & Debbah, M. (2017). Toward interconnected virtual reality: Opportunities, challenges, and enablers. *IEEE Communications Magazine, 55*(6), 110–117.

Bieniok, H., & Rokita, J. (1984). *Struktura organizacji przedsiębiorstwa*. Państwowe Wydawnictwo Ekonomiczne.

Boschma, R. A., & Frenken K. (2009). The Spatial Evolution of Innovation Networks: a Proximity Perspective. In R. A. Boschma, R. Martin (Eds). *The handbook of evolutionary economic geography*. Edward Elgar.

Boyles, B. (2017). *Virtual Reality and Augmented Reality in Education* [Master Teacher Program paper, Center For Teaching Excellence, United States Military Academy].

Caserman, P., Garcia-Agundez, A., Zerban, A. G., & Göbel, S. (2021). Cybersickness in current-generation virtual reality head-mounted displays: systematic review and outlook. *Virtual Reality, 25,* 1–18.

Choi, D. H., Dailey-Hebert, A., & Estes, J. S. (Eds.). (2016). *Emerging tools and applications of virtual reality in education*. Information Science Reference.

Cugurullo, F. (2020). Urban artificial intelligence: From automation to autonomy in the smart city. *Frontiers in Sustainable Cities*, *2*, 38.

Czajkowski, R., & Nowakowski, W. (2016). IoT jako naturalna ewolucja Internetu. *Elektronika 4,* 28–32.

Czakon, W. (2010). Hipoteza bliskości. *Przegląd Organizacji 9*, 16–20.

Dede, C. (2005). Planning for neomillennial learning styles. *Educause Quarterly, 28*(1), 7–12.

Elmqaddem, N. (2019). Augmented reality and virtual reality in education. Myth or reality? *International Journal of Emerging Technologies in Learning, 14*(3), 234–242.

Filip, A. J. (2015). Miasto jako struktura sieci współzależnych, Studia Ekonomiczne. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach 217*, 97–114.

Firlej-Buzon, A. (2003) Heurystyka – geneza oraz współczesne zastosowania. *Zagadnienia informacji naukowej, 1,* 23–37.

Florida, R. (2011). *The rise of creative class and how it's transforming work, leisure, community and everyday life*. Basic Books.

Głomb, K., Jakubowski, M., Krawczyk, A., Kulisiewicz, T., Nowakowski, Z., Złotnicki, A., & Gajderowicz, T. (2019). *Kompetencje przyszłości w czasach cyfrowej dysrupcji. Studium wyzwań dla Polski w perspektywie roku 2030*. Instytut Badań Rynku, Konsumpcji i Koniunktur.

Główny Urząd Statystyczny (2019). *Oświata i wychowanie w roku szkolnym 2018/19.* Główny Urząd Statystyczny, Urząd Statystyczny w Gdańsku.

Huiling, E., & Goh, B. (2017). AI, Robotics and Mobility as a Service: the Case of Singapore. Field Actions Science Reports. *The Journal of Field Actions* (Special Issue 17), 26–29.

Jiang, L. (2021). Virtual Reality Action Interactive Teaching Artificial Intelligence Education System. *Complexity 2021*(3), 1–11.

Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning with technology: a constructivist perspective*. Merrill.

Kaufmann, H., & Papp, M. (2006). *Learning objects for education with augmented reality.* Proceedings of EDEN, International Media Systems. Vienna University of Technology.

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). Making it real: exploring the potential of augmented reality for teaching primary school science. *Virtual Reality, 10*(3), 163–174.

Kinateder, M., Ronchi, E., Nilsson, D., Kobes, M., Müller, M., Pauli, P., & Mühlberger, A. (2014). *Virtual reality for fire evacuation research*. 2014 Federated Conference on Computer Science and Information Systems (pp. 313–321). FedCSIS.

King, B.A., Hammond and T., Harrington, J. (2017). Disruptive technology: Economic consequences of artificial intelligence and the robotics revolution. *J. Strateg. Innov. Sustain 12*, 53–67.

Klimas, P. (2011). Wymiary bliskości w sieciach innowacji. *Przegląd Organizacji, 4,* 16–20.

Kolata, G. (2012, April 18). Studies question the pairing of food deserts and obesity. *New York Times*. https://www.nytimes.com/2012/04/18/health/research/pairing-of-food-deserts-and-obesity-challenged-in-studies.html

Kopaliński, W. (1991). *Słownik wyrazów obcych i zwrotów obcojęzycznych*. Wiedza Powszechna.

Kuciński, K. (2010). *Metodologia nauk ekonomicznych: dylematy i wyzwania*. Difin.

Kurubacak, G., & Altinpulluk, H. (Eds.). (2017). *Mobile technologies and augmented reality in open education*. IGI Global.

Kwok, A. O., & Koh, S. G. (2021). COVID-19 and extended reality (XR). *Current Issues in Tourism, 24*(14), 1935–1940.

Kyriazopoulou, C. (2015). Smart city technologies and architectures: A literature review. Proceedings of the 2015 International Conference on Smart Cities and Green ICT Systems, Lisbon, Portugal, 20–22 May 2015 (1–12).

Lee, E. A. L., & Wong, K. W. (2014). Learning with desktop virtual reality: Low spatial ability learners are more positively affected. *Computers & Education, 79*, 49–58.

Lugrin, J., Cavazza, M., Palmer, M., Crooks, S. (2006). Artificial intelligence-mediated interaction in virtual reality art. *IEEE intelligent systems, 21*(5), 54–62.

McQuire, S. (2008). *The Media City. Media, architecture and urban space*. Sage Publications Ltd.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40.

Mertala, P. (2021). The pedagogy of multiliteracies as a code breaker: A suggestion for a transversal approach to computing education in basic education. *British Journal of Educational Technology, 52*(6), 2227–2241.

Mitra, R., & Saydam, S. (2014). Can artificial intelligence and fuzzy logic be integrated into virtual reality applications in mining? *Journal of the Southern African Institute of Mining and Metallurgy, 114*(12), 1009–1016.

Mizerek, H. (2012). Jakość edukacji. Dyskursy, które wybrzmiały, milcząc. In G. Mazurkiewicz (Ed). *Jakość edukacji. Różnorodne perspektywy*. Wydawnictwo Uniwersytetu Jagiellońskiego.

Pantelidis, V. S. (2010). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education, 2*(1–2), 59–70.

Postawa, A. (2018). *Rzeczywistość rozszerzona w nauczaniu i uczeniu się. Komunikacja a zmiana społeczna*. Instytut Pedagogiki Uniwersytetu Wrocławskiego.

Puryear, J. S., & Lamb, K. N. (2020) Defining Creativity: How Far Have We Come Since Plucker, Beghetto, and Dow? *Creativity Research Journal, 32*(3), 206–214, DOI: 10.1080/10400419.2020.1821552

Ray, A. B., & Deb, S. (2016). Smartphone Based Virtual Reality Systems in Classroom Teaching – A Study on the Effects of Learning Outcome. *2016 IEEE Eighth International Conference on Technology for Education (T4E)*, 2016, pp. 68–71, doi: 10.1109/T4E.2016.022

Riva, G., Wiederhold, B. K., Di Lernia, D., Chirico, A., Riva, E. F. M., Mantovani, F., & Gaggioli, A. (2019). Virtual reality meets artificial intelligence: The emergence of advanced digital therapeutics and digital biomarkers. *Annual Review of CyberTherapy and Telemedicine 17*, 3–7.

Stevenson, A. (Ed.). (2010). *Oxford Dictionary of English*. Oxford University Press.

Szołtysek, J. (2017). Logistyka miasta wobec postulatów zwiększania „inteligencji" smart city. In R. Matwiejczuk & I. Pisz (Eds.). *Logistyka w naukach o zarządzaniu. Part I*. Wydawnictwo Społecznej Akademii Nauk.

Szołtysek, J. (2018). Miasto w dobie Internet of Things. In Ł. Sułkowski & D. Kaczorowska-Spychalska (Eds.). *Internet of Things. Nowy paradygmat rynku*. Difin.

Szymczak, M. (1981). *Słownik języka polskiego.* PWN.

UCLG Committee on Social Inclusion, Participatory Democracy and Human Rights (2012). *The European Charter for the Safeguarding of Humans Rights in the City.* United Cities and Local Governments.

U.S. Department of Commerce. (2016). Export Opportunities. *Smart Cities, Regions & Communities, Vol.1*, 276.

Winkler-Schwartz, A., Bissonnette, V., Mirchi, N., Ponnudurai, N., Yilmaz, R., Ledwos, N., & Del Maestro, R. F. (2019). Artificial intelligence in medical education: best practices using machine learning to assess surgical expertise in virtual reality simulation. *Journal of Surgical Education, 76*(6), 1681–1690.

Wu, H. K., Lee, S. W. Y., Chang, H. Y. and Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62*, 41–49.

Youngblut, C. (1998). *Educational uses of virtual reality technology*. Institute for Defence Analysis.

Zhang, H. (2013). Pedagogical challenges of spoken English learning in the Second Life virtual world: A case study. *British Journal of Educational Technology, 44*(2), 243–254.

Zhang, L. & Sternberg, R. J. (2011). Revisiting the Investment Theory of Creativity. *Creativity Research Journal, 23*(3), 229–238, DOI: 10.1080/10400419.2011.595974

Zhao, C. (2021). Application of Virtual Reality and Artificial Intelligence Technology in Fitness Clubs. *Mathematical Problems in Engineering*, Volume 2021, (1–10). Hindawi. https://doi.org/10.1155/2021/2446413

Services

The role of education – the need to develop digital competence. The cybersecurity perspective

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Introduction

Matching education to market demand is particularly important in the case of niche skills – a good example of this is competence in cybersecurity, where the market, both Polish and global, faces a shortage of workers.

As indicated by research conducted by the HRK portal (a Polish company specializing in HR consulting) together with HackerU (an Israeli provider of IT security training and services):

> The demand for cybersecurity job candidates is currently very high (...). In Poland, there are about 7 unfilled vacancies per candidate (...). It is estimated that we have about 17,500 unfilled positions in Poland. If the current trend continues, this number will increase with each year. This means that even people without experience will have a chance to enter this attractive market (Gajewski & Zbudniewek, 2021, p. 4).

Accordingly, the "demand" for educational services in security management is very high. Hence, it is crucial to propose solutions whose results will be achievable in the short term, rather than the longer term, which is characteristic of formal education, e.g., 3 years for undergraduate studies or a total of 5 years when adding a master's degree. The dynamics of the cybersecurity market are such that about 50% of the content becomes obsolete within 2 years, hence education in this area must be designed in short learning loops that allow both the rapid acquisition of new competencies by learners, as well as the rapid "unlearning" of what the learner has learned.

A solution currently being discussed and introduced in the European Higher Education Area (EHEA) may be "micro-credentials". In Poland, the discussion on micro-credentials has also begun, in particular, it is worth referring to the expert publication by Stęchły and Nowakowski (2021).

The purpose of this chapter is to present micro-credentials as a solution recognized in formal education for the more effective training of people in digital competencies, and in particular, competencies in the area of cybersecurity.

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This chapter is divided into the following subsections:

1. Micro-credentials – the current status of the work in Poland and the EHEA
2. Characteristics of digital competencies with particular emphasis on cybersecurity competencies
3. Micro-credentials as a response to educational needs in the field of cybersecurity
4. The Integrated Qualifications System (IQS) and micro-credentials

As a result of Cezary Piekarski's work in the financial sector, the observations presented here will be based to a large extent on the author's experience in this sector. However, the phenomena described in this chapter do not only apply to the financial sector – they are universal in nature, hence the data will be more general and mostly apply to the labor market.

This chapter is mainly based on expert reports and data available on the Internet. Cybersecurity and IT competencies in general are subject to continuous and dynamic development, so one can assume that the current scientific literature on the subject has not kept up with these changes. Micro-credentials, which will be presented extensively in this chapter, are also a new phenomenon, not yet described extensively in the scientific literature on education.

The authors do not focus too much on artificial intelligence, however, it also is an extremely dynamic phenomenon that has been described in detail in other chapters here. Undoubtedly, artificial intelligence is closely related to competence in the area of cybersecurity, as it is becoming the foundation of cybersecurity management, where the algorithms that "attack" measure themselves against the algorithms that "defend" an organization, and humans are becoming the experts who oversee the operation of the algorithms. At the same time, the increasing use of artificial intelligence in education makes it possible to better tailor educational processes to the individual characteristics of learners, so despite not focusing on the concept of "artificial intelligence" itself in this chapter, it will be taken into account when formulating recommendations and conclusions.

Micro-credentials – its current status in Poland and the EHEA

Intensive work is currently underway in the European Higher Education Area to integrate micro-credentials into formal education, i.e., education that is universally recognized and is encompassed by the European Qualifications Framework.

The European Commission's proposed definition of micro-qualifications or micro-credentials is presented in Table 8.

Table 8. Definition of a micro-credential

Original definition in English:	Translation into Polish (own work):
A micro-credential is a proof of the learning outcomes that a learner has acquired following a short learning experience. These learning outcomes have been assessed against transparent standards. The proof is contained in a certified document that lists the name of the holder, the achieved learning outcomes, the assessment method, the awarding body and, where applicable, the qualifications framework level and the credits gained. Micro-credentials are owned by the learner, can be shared, are portable and may be combined into larger credentials or qualifications. They are underpinned by quality assurance following agreed standards.	Mikrokwalifikacja jest dowodem uzyskania efektów uczenia się przez ucznia po krótkiej nauce. Te efekty uczenia się zostały zweryfikowane na podstawie przejrzystych standardów. Jest to poświadczony dokument, który zawiera nazwisko posiadacza, osiągnięte efekty uczenia się, metody oceniania, dane instytucji przyznającej mikrokwalifikację oraz, jeśli jest to potrzebne, poziom ram kwalifikacji i zdobyte punkty. Osoba, która zdobyła mikrokwalifikacje, może je okazywać, przenosić i łączyć w większe pakiety lub kwalifikacje. Ich jakość zapewniają określone standardy.

Source: European Commission, 2020, p. 10.

Analyzing the above definition, it is worth noting the following key features of a micro-credential:

- micro-credentials are embodied in a specific credential/evidence – this could be, for example, a certificate of the learner's achievement of specific learning outcomes,
- micro-credentials cover a short period of time, so acquiring their learning outcomes takes a shorter period of time than, for example, in the case of a bachelor's or master's degree,
- the certificate (evidence) contains the elements indicated in the definition, described in language that allows it to be assigned to a specific level of the qualifications framework,
- the certificate (evidence) is universally recognizable, which means that it can, among other things, be part of formal study programs,
- the learning outcomes indicated in the certificate (evidence) are attested to by an external quality assurance institution.

In practice, micro-credentials can include any course or training offered not only by universities, but also by various types of private entities. In order to avoid chaos in this area, European projects are discussing the quality assurance of both the micro-credentials themselves, as well as the "certification" of micro-credential awarding bodies.

The characteristics of digital competencies with particular emphasis on cybersecurity competencies

The most relevant document in Europe on competencies for learning is Council Recommendation of 22 May 2018 on key competences for lifelong learning. The document distinguishes eight competencies:

1. Literacy competence,
2. Multilingual competence,
3. Mathematical competence and competence in science, technology and engineering,
4. Digital competence,
5. Personal, social and learning to learn competence,
6. Citizenship competence,
7. Entrepreneurship competence,
8. Cultural awareness and expression competence (Recommendation OJ C 189, 4.6.2018, pp. 7–8.

Cybersecurity is part of digital competence. The following table presents the detailed provisions of the above-mentioned document on digital competence.

Table 9. Digital competence as a key competence in lifelong learning

Digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking.
Essential knowledge, skills and attitudes related to this competence
Individuals should understand how digital technologies can support communication, creativity and innovation, and be aware of their opportunities, limitations, effects and risks. They should understand the general principles, mechanisms and logic underlying evolving digital technologies and know the basic function and use of different devices, software, and networks. Individuals should take a critical approach to the validity, reliability and impact of information and data made available by digital means and be aware of the legal and ethical principles involved in engaging with digital technologies.
Individuals should be able to use digital technologies to support their active citizenship and social inclusion, collaboration with others, and creativity towards personal, social or commercial goals. Skills include the ability to use, access, filter, evaluate, create, program and share digital content. Individuals should be able to manage and protect information, content, data, and digital identities, as well as recognise and effectively engage with software, devices, artificial intelligence or robots.

Engagement with digital technologies and content requires a reflective and critical, yet curious, open-minded and forward-looking attitude to their evolution. It also requires an ethical, safe and responsible approach to the use of these tools.

Source: European Council, Recommendation OJ C 189, 4.6.2018, pp. 9–10.

Also worth noting is a European study on the impact of artificial intelligence on education. This publication presents future competencies relating to artificial intelligence along with an estimate of the probability of their sustainability.

Table 10. Areas of competence and the probability of their disruption in the future

Skill cluster	Description	Probability of disruption
Technicians	High on technical skills	Moderate
Crafters	Medium in technical skills, low in management skills	Very high
Doers	Emphasis on basic skills	High
Solvers	Emphasis on management skills and critical thinking	Minimal
Facilitators	Emphasis on emotional skills	Moderate
Providers	High in analytical skills	Low

Source: Tuomi, 2018, p. 24.

Cybersecurity competence issues are one of the key areas of analysis and activity of the European Union Agency for Cybersecurity (ENISA). It is an organization that aims to achieve a high common level of cybersecurity across the European Union by actively supporting its Member States, institutions, bodies, offices and agencies in improving cybersecurity (De Zan & Di Franco, 2019, p. 1). One of ENISA's activities is to develop a database of formal cybersecurity study programs in European Economic Area countries and Switzerland. The database is intended to become the main reference point for all European citizens who want to improve their cybersecurity knowledge and skills by completing higher education (De Zan & Di Franco, 2019, p. 3).

ENISA has made a number of recommendations to support cybersecurity education. These are presented in Table 11.

Table 11. ENISA's recommendations for cybersecurity education

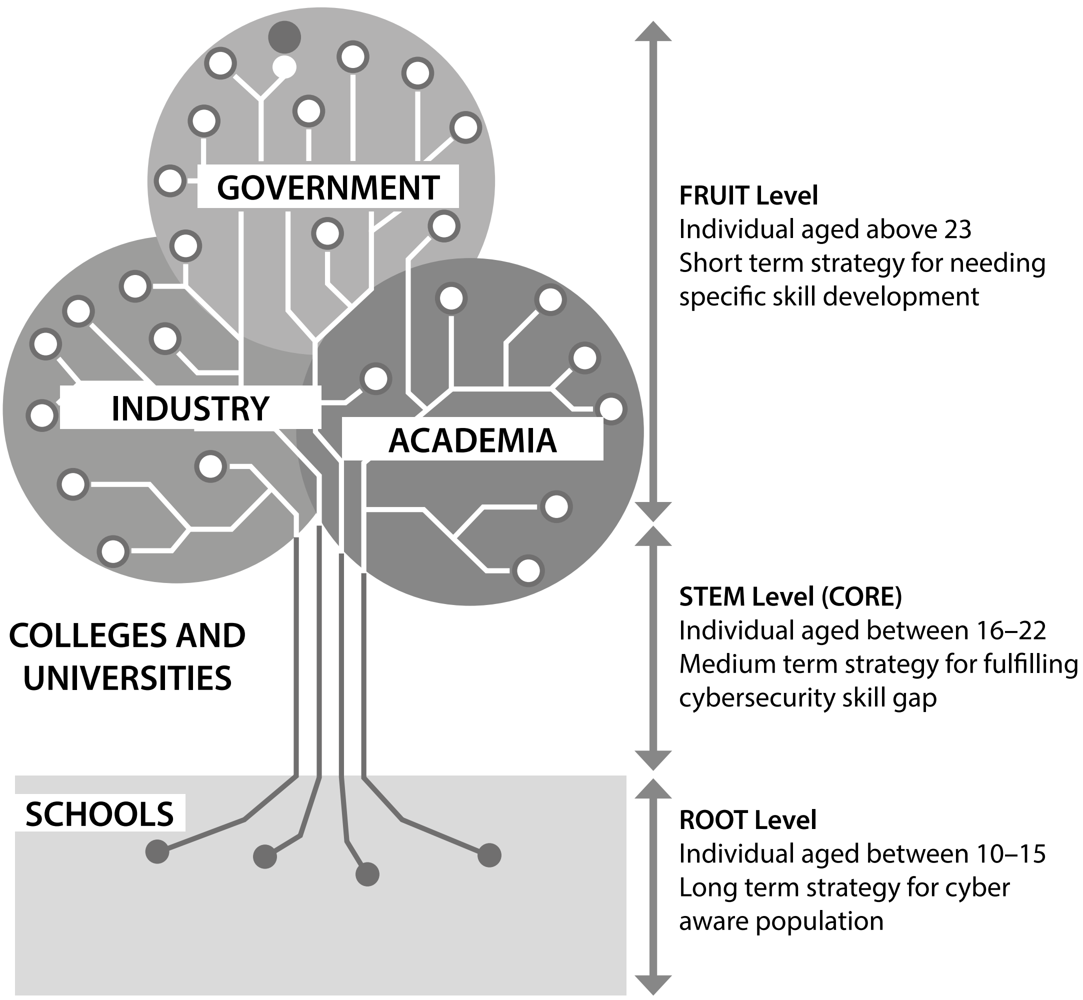
1. The impact of the certification* of cybersecurity degrees on the CSSS [cybersecurity skills shortage]. A rigorous and systematic analysis of the implementation and outcomes of already established national certification can give insights into potential best practices, which can be implemented in other national contexts, after careful consideration of the characteristics of local education systems and labour markets. For example, impact evaluations could compare certified cybersecurity degrees with non-certified degrees and measure: ▪ to what extent students improve their cybersecurity knowledge and skills; ▪ to what extent certified degrees attract students before enrolling are only marginally interested in cybersecurity as a career opportunity; ▪ the percentage of students landing a cybersecurity job, and the job's role, sector, seniority and wage level; ▪ the time that students take to find a job after graduation; ▪ the level of satisfaction of employers with graduates from certified cybersecurity programmes; ▪ the level of satisfaction of educators with partnership with the industry; ▪ the level of satisfaction of students with the degree; ▪ other specific outcomes that certified programmes might produce, for example inclusion levels of less represented segments of the population or increased collaboration with national cyber ecosystems.
2. The uptake and promotion of ENISA's Cybersecurity Higher Education Database. The Database will be a useful instrument for citizens only if it includes most, if not all, relevant cybersecurity degrees in Europe. If the Database achieves this objective, it will also enable further analysis of the evolving status of cybersecurity education in the EU. It will be in the best interest of higher education institutions to proactively add their cybersecurity degrees to the database, as this will be another way their educational offer can be further promoted and publicised.
3. The nature and characteristics of the CSSS in the EU. This report aggregated the available data to gain a better understanding of the CSSS, but also noted the lack of granular and essential information on the shortage in the EU, especially in comparison with information available in other countries. As the design of policies to mitigate the shortage should be preceded by a detailed analysis of the problem, there are still too many gaps in our knowledge of the EU CSSS that should be filled.
4. Policy interventions are most effective in increasing the pipeline of professionals. To make sure the shortage is addressed for what it is (a quantitative as well as a qualitative issue), policy measures should ensure that more professionals come through the pipeline. Policies such as degree certification most probably help to increase the quality of knowledge and skills, but it is unclear to what extent they induce more people to join the sector. There are other policies that have been deployed to increase career interest in cybersecurity, such as competitions, challenges, career awareness campaigns and retraining programmes for professionals already in the workforce.
5. Design of a comprehensive cybersecurity workforce development strategy. The design of a comprehensive cybersecurity workforce development strategy that goes beyond policies targeting only the education and training system. Instead, it should promote an active role for employers in developing a national cybersecurity workforce.
**According to ENISA, "certification of cybersecurity degrees" refers to formal education confirmed with, e.g., a bachelor's or master's diploma (commentary: Jakub Brdulak)*

Source: De Zan & Di Franco, 2019, pp. 30–32.

A rather simple and well-illustrated logic for cybersecurity education was proposed by ENISA in a report on identifying key success factors for organizing national cybersecurity competitions and presenting a picture of the current situation in EU partner countries (see Figure 7).

The graphic is based on the metaphor of a tree symbolizing cybersecurity education planned in the long, medium and short term. In order to achieve results in this area (fruits), it is necessary to first create security awareness among children. The next step is to provide opportunities for adolescents and students to acquire skills (competencies), especially first cycle degree students. The third step is to continuously develop the skills of adults in this area. Micro-credentials are primarily for adults, so they fit very well into this logic. They make it possible to implement short-term strategies oriented toward the narrow and precise delivery of missing qualifications. Micro-credentials in particular can play an important role here.

Figure 9. Model of organizing cybersecurity education



Source: De Zan and Yamin, 2021, p. 44.

Micro-credentials as a response to cybersecurity educational needs

Micro-credentials are also recognized by employers and treated as a certain opportunity in reducing competence gaps in not only academic, but also vocational education.

The Association of European Chambers of Commerce and Industry Association is conducting an analysis of the micro-credentials initiative and formulated the following expectations that should be fulfilled with their introduction:

> We expect the initiative of micro-credentials to create a voluntary framework that aims to support rather than excessively regulate the growing offer of short courses. To be successful, the framework must be founded on **four guiding principles that will make the micro-credentials framework useful to both businesses and learners and contribute to the performance of labour markets**.
>
> 1. The framework must first and foremost promote **courses that are relevant to labour market needs**. […]
>
> 2. **Micro-credentials cannot undermine present formal qualifications in vocational education**. […]
>
> 3. **A submission to the European micro-credentials framework must be a provider's [learning institution's] voluntary choice**. […]
>
> 4. **Finally, the framework's goal should be to strengthen the trust and transparency of the training opportunities** (Eurochambres, 2021, p. 8).

At the same time, the Association of European Chambers of Commerce and Industry makes it clear that micro-credentials can be the answer to rapidly replenishing the skills of workers in those sectors where skills shortages exist, including cybersecurity.

The problem with the shortage of cybersecurity personnel is not just on the education side. Excessive expectations on the part of employers, particularly with regard to the experience of job candidates, is also a problem. As Fortinet – a multinational U.S. corporation that develops and sells ICT security software, devices and services – writes on the aleBank.co.uk website:

> One of the biggest problems when recruiting a security specialist is the expectations of company management regarding the candidate's competence and experience. As a rule, they far exceed what can be achieved in a 5, 7 or even 10-year career. What's more, narrowing down job opportunities to only those who meet certain experience and seniority requirements often excludes the most talented and gifted graduates. Meanwhile, they are usually the ones who are eager to learn and curious about the possibilities of working in the cybersecurity field (Fortinet, 2020).

The authors believe that increasing the required experience of a job candidate is a response to the lack of tools and information giving the recruiter confidence that a candidate has the described learning outcomes, i.e., knowledge, skills and social competence, in cybersecurity.

The IQS and micro-credentials

The Integrated Qualifications System (IQS) was introduced in Poland by the Act of 22 December 2015 on the Integrated Qualifications System. The Act defines the IQS (Article 2.25) as:

> […] a separate part of the National Qualifications System, which is governed by the standards specified in the Act on describing qualifications and assigning Polish Qualifications Framework levels to qualifications, the principles of including qualifications in the Integrated Qualifications System and registering them in the Integrated Qualifications Register, as well as the principles and standards of certifying qualifications and of ensuring the quality of awarding qualifications.

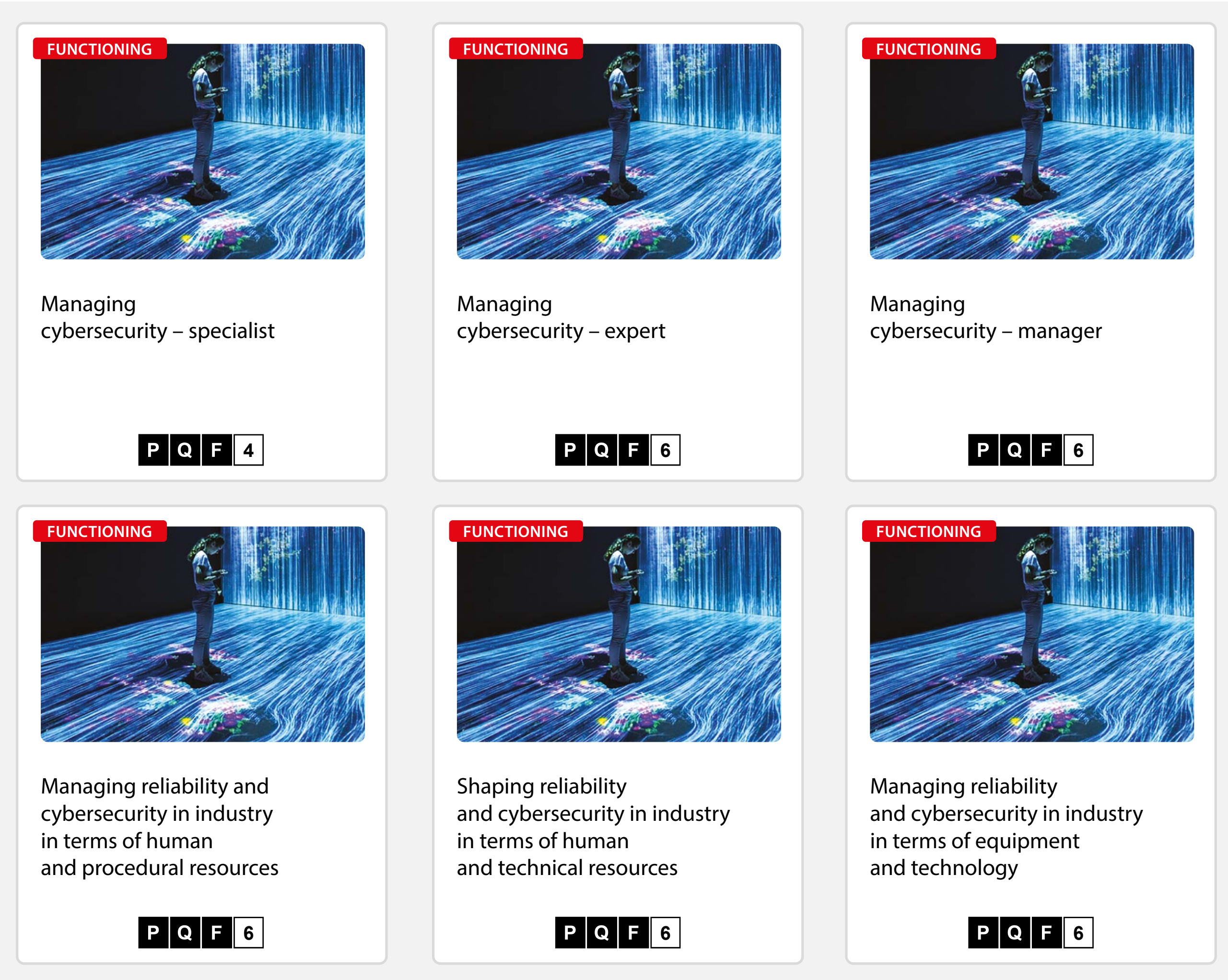
This law also introduced the Polish Qualifications Framework, on which formal education is based. All detailed information in this regard is available both in the aforementioned law, as well as on the portal about qualifications and the IQS: kwalifikacje.edu.pl operated by the Educational Research Institute.

The IQS is intended to support employers in "more easily recognizing the value of a potential employee, and [to support] employees in presenting their competences in a credible manner" (IBE, 2021). The IQS organizes qualifications in a single register where they are included and presented.

It is worth noting that the idea of "common" registers is close to both the database of formal cybersecurity degree programs in the countries of the European Economic Area and Switzerland proposed by ENISA (as presented in the earlier subsection *Characterization of digital competencies with special emphasis on cybersecurity competencies*) and the idea of micro-credentials, which are also to be catalogued in a central register. Thus, it is worth considering whether all these activities could be synergistic. So couldn't the IQS, micro-credentials and the data base of, for example, ENISA, be one entity or be based on the same mechanisms?

Currently (March 2022), the Integrated Qualifications Register (IQR), which is a component of the IQS, includes six qualifications in the field of cybersecurity, as shown below.

Figure 10. Cybersecurity qualifications included in the IQR



From the Integrated Qualifications Register (IQR), https://kwalifikacje.gov.pl/k#undefined (accessed March 30, 2022).

The number of qualifications in the register is growing dynamically. Each qualification in the register has elements that the European micro-credentials data base should contain in the future, such as the European Qualifications Framework level (here we have the Polish Qualifications Framework level, which is referenced to the European framework) or the learning outcomes. Thus, it seems that it should be possible to link qualifications found in the IQR with corresponding micro-qualifications. For example, in order to attain the "Managing reliability and cybersecurity in industry in terms of human and procedural resources" micro-credential, the completion of relevant postgraduate studies or courses offered by the companies (suppliers) listed in the register should be required.

Summary

The aim of the chapter was to present micro-credentials as a solution recognized in formal education to provide more effective training of people in digital competencies, and particularly in the area of cybersecurity.

According to the authors, micro-credentials are a solution that can reduce market gaps due to the lack of workers skilled in digital competencies, including cybersecurity. Micro-credentials introduced into degree programs, especially formal programs – at the undergraduate and graduate levels – can increase the flexibility of studies. Qualifications in digital competence are a prerequisite for the greater and more informed use of artificial intelligence. Thus, making education more flexible, realized through micro-credentials, can foster a better education that is more aligned with labor market expectations.

A major challenge for the systemic solutions outlined in this article is the issue of quality assurance both at the level of the qualifications found in the IQR, as well as at the level of micro-qualifications/micro-credentials (see, for example, Szostakowska and Szczurek, 2020). The amount of data to be included in these registers and their diversity virtually preclude the use of any highly centralized mechanisms. There is currently an ongoing discussion in Europe on how to make these data reliable. As experience based on quality assurance in the higher education sector shows, administrative solutions do not automatically lead to the absence of so-called "predatory" universities, whose business model is based on printing diplomas (Brdulak, 2021). Hence, perhaps solutions based on bottom-up content generation will be sought, somewhat in the logic of crowdfunding solutions or Wiki-type content management models.

At the same time, the shortage of employees with cybersecurity competencies generates the question of how to shape these competencies. To what extent do systemic solutions help this process, and to what extent are they bureaucratic measures that do not generate value for the community? The answer to this question requires in-depth research.

Undoubtedly, European funds for the creation of common qualifications registers are currently flowing in a large stream. It is likely that funds will soon be released for the implementation of micro-credentials in European countries – in the first instance, those belonging to the European Union, and perhaps more broadly, to the European Higher Education Area. What is important, according to the authors, is that entities (professional associations, chambers of commerce and companies) representing a given field, such as cybersecurity, recognize these initiatives so that their results actually translate into solutions to economic problems as much as possible. At this point, the economic problem for all of Europe, not just Poland, is the lack of employees with cybersecurity qualifications. Micro-credentials may be a certain solution, but only on the condition that the whole process relating to the IQS and micro-credentials is undertaken in close dialogue with its stakeholders, in particular with employers and teaching institutions. The result of all these processes and systemic initiatives, such as micro-credentials and the IQS, is to be an employee with the competencies needed in the market. Today's shortages show that the effectiveness of these processes is not yet at the right level.

Bibliography

Act of 22 December 2015 on the Integrated Qualifications System (Journal of Laws of 2020, item 226).

Association of European Chambers of Commerce and Industry. (2021). EUROCHAMBRES input for public consultations on the micro-credentials framework and the initiative for individual learning accounts. https://www.eurochambres.eu/publication/eurochambres-input-for-public-consultations-on-the-micro-credentials-framework-and-the-initiative-for-individual-learning-accounts/

Brdulak, J. (2021). *Jakość w szkolnictwie wyższym. Zapewnianie czy iluzja?* Oficyna Wydawnicza SGH (in print).

Council Recommendation of 22 May 2018 on key competencies for lifelong learning (2018/C 189/01).

De Zan, T., & Di Franco, F. (2019). *Cybersecurity Skills Development in the EU. The certification of cybersecurity degrees and ENISA's Higher Education Database*. European Agency for Cybersecurity (ENISA).

De Zan, T., & Yamin, M. (2021). *Towards a common ECSC Roadmap. Success factors for the implementation of national cybersecurity competitions*. A. Belmonte & F. Di Franco (Eds.). European Agency for Cybersecurity (ENISA).

European Commission (2020). *A European Approach To Micro-Credentials*. *Output of the Micro-Credentials Higher Education Consultation Group*. https://education.ec.europa.eu/sites/default/files/document-library-docs/european-approachmicro-credentials-higher-education-consultation-group-output-final-report.pdf

Gajewski, M., & Zbudniewek, M. (2021). *Cybersecurity. Raport o rynku pracy w Polsce*. HRK, HackerU.

Instytut Badań Edukacyjnych (n.d.). *Czym jest ZSK?* https://kwalifikacje.edu.pl/czym-jest-zsk/

Integrated Qualifications Register. https://kwalifikacje.gov.pl/

Fortinet (2020). *Aż 68% firm ma problemy z zatrudnianiem ekspertów ds. cyberbezpieczeństwa*. https://alebank.pl/az-68-firm-ma-problemy-z-zatrudnianiem-ekspertow-ds-cyberbezpieczenstwa/ ?id=347307&cat id=28090

Recommendation OJ C 189, 4.6.2018. *On key competences for lifelong learning*. Council of the European Union.

Stęchły, W., & Nowakowski, M. (2021). Szanse i zagrożenia związane z nowymi rodzajami poświadczania umiejętności. Microcredentials, open badges, ECVET oraz osiągnięcia w ZSK. Material prepared for the *Foundation for the Development of the Education System* (FRSE), Warsaw.

Szostakowska, M., & Szczurek, A. (2020). Ewaluacja procesu wsparcia Podmiotów Zewnętrznego Zapewniania Jakości w systemie ZSK. Ośrodek Ewaluacji Sp. z o.o.

Tuomi, I. (2018). *The Impact of Artificial Intelligence on Learning, Teaching, and Education. Policies for the future*. M. Cabrera, R. Vuorikari, & Y. Punie (Eds.). EUR 29442 EN. Publications Office of the European Union. DOI: 10.2760/12297

The artificial intelligence (AI) revolution in healthcare

Ligia Kornowska, M.D.*

Introduction

The term "artificial intelligence (AI) in health care" will evoke the following vision to the average patient: a robot, instead of a human, talks, diagnoses and treats the patient. It has the competence to conduct a history, physical examination and subject examination. If we are dealing with a computer, not a robot, then once the patient's health information is added to the system, AI is able to offer a holistic[51] approach to the patient and a holistic diagnostic and therapeutic process. It is also colloquially believed that in using artificial intelligence, many of the activities and processes previously performed by the doctor, including the provision of feedback to the patient on his or her health status, will be performed by AI. However, these are misconceptions.

For those who have basic digital competence and a certain level of knowledge about the digitalization of health care, but are not innovation specialists, the phrase "AI in health" mainly brings to mind advanced algorithms that are commonly used in medicine. Every doctor, nurse and paramedic knows that – especially in acute health situations such as sudden cardiac arrest – one should not only use the latest medical standards, but precisely the procedural algorithms. When asked at industry conferences about artificial intelligence in Polish hospitals, these people reply that "after all, it has been used for years." But the above assumptions are also not true. Knowledge of artificial intelligence in the healthcare system stands at an average – if not minimal – level.

In order to describe what AI is in the healthcare system, we first need to know what AI is. Of the several definitions proposed by the European Commission, one of them reads, "Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals" (European Commission, 2018, p. 1). According to the author, this definition is one of the most flexible, although it contains the error of *ignotum per ignotum*, since we define *intelligence* as exhibiting *intelligent* behavior.

Instead, the PWN Dictionary of the Polish Language defines the term artificial intelligence as "a branch of computer science that studies the rules governing human mental behavior and creates programs or computer systems

[51] When talking about a holistic approach to the patient, it should be considered an "all-encompassing" approach, which includes considering not only the main symptom or ailment, but also take into account external factors such as lifestyle and living conditions, as well as internal factors, including emotions, thoughts and experiences. The holistic approach works well, e.g., in the case of chronically ill people, as not only are the symptoms treated, but also their deeper cause. So, in a holistic approach to the patient, all aspects relating to the onset of the disease are important.

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that simulate human thinking" (Dictionary of the Polish Language, n.d.). This definition is closest to the understanding of AI presented by one of its first creators, Alan Turing (Homer & Selman, 2001). However, an understanding of artificial intelligence as "pretending to be human" has been challenged on several occasions, including by John Seare in a well-known thought experiment called the "Chinese Room" (Searle, 1980), and such a definition is now being abandoned.

In addition, mention should be made of the growing popularity of developing the abbreviation AI as augmented intelligence instead of artificial intelligence. The concept of augmented intelligence helps us understand that real AI is not opposed to "natural" intelligence, but only helps enrich it with a way of processing ("thinking") that is not natural to humans.

All this shows how difficult it is to find a suitable definition for AI. In addition, due to the continuous development of artificial intelligence, giving it a rigid definition risks quickly becoming obsolete.

For the purposes of discussing AI in health, the author suggests assuming that AI is complex mathematical algorithms having the ability to continuously self-improve through learning.

However, the term "AI in health" does not include a single, all-knowing AI algorithm that can answer every medical question, in every medical specialty. There is no single broad AI algorithm that can be applied to all diagnostic and treatment problems. Instead, we have several hundred algorithms, each tailored to one specific diagnostic or treatment activity. In addition, a single algorithm may not be able to evaluate even a single diagnostic test in its entirety – for example, we know of algorithms for evaluating MRI (magnetic resonance imaging) or CT (computerized tomography) scans of the head that only detect a few conditions. This means that a doctor's follow-up remains essential.

Certification of AI algorithms

The previous paragraphs provide an obvious answer to the very frequently asked question, "Will artificial intelligence replace doctors?" AI, like any of the other medical advances, will not replace doctors, but it can significantly improve the efficiency, quality and safety of patient treatment. We are standing at the threshold of the AI revolution – not only in medicine, but in every sector of the economy.

By 2020, there were more than 450 certified medical AI algorithms in operation worldwide, with a steady exponential growth in the solutions available in the market since 2015 (Muehlematter, 2021).

Classifying AI algorithms by medical specialties, it should be assumed that the undisputed leader is radiology. Recognizing shades of gray in diagnostic images and determining which lesions are pathological and which are physiological has proven to be the best current area for exploiting the potential of artificial intelligence.

In addition to radiology, AI algorithms are widely used in cardiology, neurology, but also in molecular genetics, anesthesiology or dentistry (Muehlematter, 2021).

All medical devices used on patients must be certified to be approved for marketing in health care – from gloves and diapers to defibrillators and implantable devices, as well as artificial intelligence algorithms. The European certification system is based on the CE certificate of compliance, while in the United States, the U.S. Food and Drug Administration (FDA) has a system of acceptance of medical devices. Every medical device must go through a certification process, the complexity of which depends on many different factors. Elements such as the invasiveness of the medical device, its impact on the life or health of the patient, or the risks associated with its use, among others, affect the class of medical device and the requirements that it must meet.

Artificial intelligence, in order to obtain the certification needed for use in the medical market, must demonstrate performance equal to or superior to that of existing technologies, also understood as the effectiveness of dedicated medical personnel assessment. In many cases, AI algorithms have been proven to be more effective in evaluating tests than doctors. For example, one algorithm for evaluating mammography exams, developed by a major technology company, showed a reduction of 5.7% and 1.2% (US and UK) in false positives and 9.4% and 2.7% in false negatives. In the study, the AI system outperformed all six participating radiologists. In some cases, a mammogram must be evaluated by two independent radiologists. It has been proven that using the above algorithm reduces the workload of the second radiologist by 88% without reducing the accuracy of the diagnosis (McKinney et al., 2020).

AI not only diagnoses, but also provides treatment in ways that humans cannot. In July 2021, a study was published that involved placing a subdural implant in a person with anarthria (a speech disorder involving the inability to produce articulate sounds) and decoding the subject's thoughts using artificial intelligence. Computational models developed on the basis of deep learning and natural language processing (NLP) algorithms were used for this. It was possible to decode the subject's cortical activity in real time at a rate of 15 words per minute and an accuracy of about 75% (Moses et al., 2021).

Another study showed that an AI algorithm can diagnose anemia on the basis of a non-invasive test such as an electrocardiogram (EKG, used to assess heart activity). Until today, it has not been possible to diagnose this systemic condition based on an EKG test – doctors need the results of a blood test to make such a diagnosis (Kwon et al., 2020).

Artificial intelligence algorithms not only support the diagnostic and treatment decisions ultimately made by a medical professional. There are already registered algorithms in the world that diagnose on their own, without a doctor's stamp of approval. Such an example is the algorithm for evaluating diabetic retinopathy based on an examination of the eye fundus (diabetic retinopathy is a condition that often occurs in people with diabetes and can lead to blindness). The algorithm was registered in the United States as early as 2018. It is still on the market today, and within three years many other similar algorithms for the fundus examination have been created.

Current status of using AI in Poland's healthcare system

A survey was conducted at Poland's largest "AI in Health" conference in June 2021, in which 93% of respondents said AI algorithms should be widely used in Polish healthcare (AI in Health Conference, 2021). Established professors of medicine are beginning to repeat the phrase that soon "not using technologies such as AI will be a medical mistake" (Kawecki, 2021). AI is revolutionizing Polish medicine – and it's doing so right now.

The "Top Disruptors in Healthcare 2021" report, the only report to inventory Poland's medtech sector, ranked about 380 innovative medical start-ups, 115 of which are described in the report. Nearly 50% of them are involved in artificial intelligence in health (Kornowska et al., 2021), illustrating the popularity of AI among innovations developed in Poland's healthcare sector. According to the report, as many as 62% of medical start-up founders say they are financed by their own funds. This was the most frequently selected answer in the question about funding sources. If we consider global spending on AI, it becomes clear that Poland is not the only country lacking investments in AI-based solutions – Europe is unfortunately lagging far behind Asia and the United States. In 2016, Europe spent €3.2 billion on artificial intelligence development (in later years the amount increased by €1.5 billion), Asia spent €6.5 billion, and the United States €12 billion (Zubașcu, 2020).

At the same time, the author notes the growing interest in AI from the private and public sectors of the Polish healthcare ecosystem. The National Centre for Research and Development (NCBiR) has established a special program to subsidize, among others, projects based on artificial intelligence in health (National Centre for Research and Development, 2021a). At the beginning of the COVID-19 pandemic, the NCBiR financed at least several projects involving the use of artificial intelligence through a funding round intended for single-disease hospitals working on innovative solutions to combat COVID-19 (National Centre for Research and Development, 2021b).

The Ministry of Health collaborated with the Polish start-up Infermedica, which offers AI solutions in health, to develop a patient questionnaire for assessing the risk of coronavirus infection (National Research and Development Centre (2021b). Meanwhile, the Ministry of Digital Affairs and the National Health Fund (NFZ) together with the start-up Yosh.AI developed AI algorithms in the form of a chatbot called "coronavirus info" that answered the most frequently asked questions about COVID-19 while waiting on the telephone to talk with an NFZ consultant (Szafrańska, 2020).

At the beginning of 2021, the Council of Ministers adopted the document *Policy for the Development of Artificial Intelligence in Poland from 2020*, abbreviated as the AI Policy, which sets strategic goals for the development of artificial intelligence. One of the recommendations of the AI Policy was to establish sector working groups at the Prime Minister's Office. A group working on healthcare was established in the second quarter of 2021 and operates under the name GRAI for Health – Working Group on Artificial Intelligence, Health Section (Republic of Poland Official Website, n.d.). In addition, the directions of the digitalization of Poland's healthcare are outlined in the strategic document prepared by the Centre for eHealth in 2020, *e-Health Strategy for 2021–2026*. One of its five main chapters addresses the issues of artificial intelligence and big data. The strategy is awaiting official adoption by the Ministry of Health.

At the same time, the private sector is taking note of the artificial intelligence revolution happening in medicine and is taking steps towards self-regulation. Three years ago, the "AI in Health Coalition" was founded – the first organization in Poland to bring together key healthcare stakeholders interested in the development of AI in medicine. The Coalition now has more than 30 members, bringing together the most important technology and pharmaceutical companies, universities, patient organizations and start-ups, which, through a number of projects, are working for the effective and safe implementation of AI in health in Poland.[52]

The importance of AI training for medical personnel

All of the information presented above indicates very clearly that the AI revolution in health is happening right now. Due to the great importance of this revolution, it is absolutely crucial that medical personnel are educated and aware of what artificial intelligence is – what benefits, but also what risks its use can bring to the diagnostic and treatment process. Each year of delay in developing digital competence and knowledge of new technologies in medicine among medical professionals carries the risk of underutilizing AI in cases where algorithms significantly improve the effectiveness of diagnosis and treatment, but also of using untested AI algorithms in an uncontrolled or incompatible manner.

Certified AI algorithms should guarantee a certain sensitivity and specificity. However, for a number of reasons, the process of certifying AI as a medical device may be ill-suited to new technologies. It is noteworthy that, for example, of the AI algorithms mentioned earlier for assessing the presence of diabetic retinopathy based on a fundus examination, only a few have an assessment performance equal to or higher than that of medical personnel (Lee et al., 2020). This clearly indicates that we should approach the new technologies implemented in the healthcare sector with special caution. It is crucial to prepare medical professionals to critically evaluate artificial intelligence algorithms.

Any AI algorithm must have proven clinical value even if the final decision is made by a physician. This is especially important in light of a recent study in which radiologists were given a suggestion of a diagnosis when evaluating an imaging study. Some of the radiologists were told that the suggestion came from another radiologist, while others were told that it was a diagnosis made by AI, although in fact all the diagnoses came from physicians. There are two important findings from the study: first, the more experienced radiologists judged the accuracy of the suggested diagnosis worse if they were informed that it came from AI. Less experienced physicians were not biased against AI. Second, suggested diagnoses had

[52] For more information, see https://aiwzdrowiu.pl/

a very high impact on the final diagnosis, even if the suggestion was wrong, and this impact was also significant for physicians who rated the accuracy of the suggestion as low. The study was based on only 8 cases, for which almost 300 doctors were involved in the evaluation. This shows that even if the AI algorithm does not make the final diagnostic and treatment decision on its own, it has a significant impact on the decision made by the physician.

Using AI algorithms to support medical decisions is a whole new kind of "consultation". Typically, when doctors are in doubt when evaluating a particular test, they first try to evaluate it themselves, then consult with other medical specialists. They also have the opportunity to discuss the advice received from other specialists. With AI, doctors will most likely receive a suggestion before analyzing the case themselves, and will not have full information about why the AI algorithm evaluated a particular test the way it did. When implementing AI in healthcare, we need to be sure that medical personnel are aware of the impact of the suggested diagnosis provided by the AI algorithm, and that they are able to be critical of the presented results.

The role of digital competence in today's medical education

In a world where digital advances are occurring month by month and new information technologies are constantly changing more branches of medicine, a medical university student should be taught how to find their way in medicine 2.0. In reality, the education system has not kept up with the digital needs of young medical students. According to the report *Future Health Index 2020* (Future Health Index, 2020), based on responses from nearly 3,000 medical professionals under the age of 40, as many as one-third of respondents are unable to use digital medical data to make decisions about patient care, and 31% of respondents feel overwhelmed by the amount of digital medical data. At the same time, 72% of respondents believe that the implementation of new technologies is important to their work, and when choosing a workplace, 88% are guided by access to state-of-the-art equipment and technologies used at the medical facility. Nearly 60% indicate the usefulness of training in the use of new technologies. This is certainly a response to the insufficient training in digital competence during medical studies.

It is difficult to find classes on the use of new technologies in healthcare in the curricula of medical faculties (Poznan University of Medical Sciences, 2020; Nicolaus Copernicus University in Torun, n.d.). Neither will we find such classes in the framework program of practical classes for medical and medical-dental faculties dated August 28, 2017 (Ministry of Health, 2017). In practice, medical students, future doctors, are rarely educated in such basic issues as the use of hospital IT systems or other e-health solutions, let alone such advanced technologies as the use of artificial intelligence for diagnostic and therapeutic purposes, or, for example, the use of virtual and augmented reality headsets during the therapeutic process.

The reality is as follows: young medical students, having completed their formal education, are not adequately equipped with digital competencies. Those interested in innovation take further training on their own, and for the basic skills needed to practice the profession – such as maintaining electronic medical records or issuing e-prescriptions or e-referrals – they learn on the job. As a result, first contact with technologies such as artificial intelligence may arouse the distrust, resistance and reluctance of staff to accept such changes. However, it can also cause enthusiasm and a desire to uncritically implement new solutions without proper validation. Both scenarios are highly unfavorable – one blocks the development of medicine, the other puts the patient's life and health at risk.

The gap in education is also noted by professional chambers. Three years ago, the District Medical Chamber in Warsaw scheduled several hours of workshops on the use of artificial intelligence in health at a training course for young medical graduates. Doctors were taught by computer scientists presenting the IBM Watson solution on how to use AI in clinical practice, but also what to watch out for. This is just one example of the many educational activities of professional chambers – but they can't completely fill the gap in pre-graduate education.

Proposed directions of change for Polish healthcare in the area of AI

Any change, especially in healthcare, must be conducted with an appropriate amount of caution and safety. All stakeholders affected by a change should be properly educated and understand both the opportunities and risks of specific transformations. This should also be the case in healthcare – medical personnel, executives and patients – all should have the right level of digital competence to increase the safety of the revolution taking place in medicine today.

Both the public and private sides are showing interest in the topic of artificial intelligence in health care. The Ministry of Health, the Ministry of Digital Affairs and the National Health Fund are collaborating with start-ups working in the field of AI, while the National Centre for Research and Development has set up a program to subsidize projects based on artificial intelligence. The importance of the public sector to invest in the future that is artificial intelligence is also evidenced by the actions of the Council of Ministers, which in early 2021 adopted the document *Policy for the Development of Artificial Intelligence in Poland from 2020*, setting strategic goals for the development of this field. Another document on AI and big data is the e-Health Strategy, pending official adoption by the Ministry of Health. In the private sector, one of the main organizations working on artificial intelligence and bringing together key healthcare stakeholders interested in its development in medicine is the AI in Health Coalition, which is already actively involved in shaping the future of AI in Poland.

The main problem oscillating around artificial intelligence in the health sector is insufficient knowledge of its capabilities and application, or misconceptions about how AI will affect the sector. The task of artificial intelligence is not to replace medical personnel and make decisions on patient treatment on its own, but to assist doctors in their daily work. It has been shown that the use of AI can significantly improve efficiency, quality and patient safety, as AI diagnoses and treats in ways that are often not available to humans – or are available, but use much more labor and time. AI algorithms are already being used extensively in radiology, cardiology, neurology, molecular genetics, anesthesiology or dentistry. AI's ability to continuously self-improve through learning offers an unlimited number of possibilities in which it will be able to be used. Polish medical start-ups also recognize this potential.

Artificial intelligence faces a number of challenges, which undoubtedly pose a barrier limiting its use in the healthcare sector. Although doctors recognize the changes in the use of new technologies, a significant number of them are still biased, as evidenced by the study in which experienced radiologists judged the accuracy of a suggested diagnosis worse if they were told that it came from AI – even though the diagnosis actually came from another radiologist. Meanwhile, in a world where digital advances are occurring every day, understanding and using new technologies is crucial to the development of medicine. An important breakthrough would be the appearance of subjects on the use of new technologies in health care in the medical school curriculum – even if only as electives. In order to prepare for the adoption and application of AI in healthcare, in practice, it is necessary not only to have objective knowledge of it, but also to understand the advantages, opportunities and risks it entails. Artificial intelligence is beginning to function in the health sector now, but it is up to us to decide whether and how we use it.

In Poland, we witnessed the rapid transformation that accompanied the COVID-19 pandemic. From month to month, the target model for delivering medical services changed from inpatient visits to telemedicine visits. Medical providers often did not have the right equipment to take advantage of all the benefits of telemedicine, and the buzzword "telemedicine" was often simply "teleadvice". Medical personnel would certainly appreciate clear guidelines on how to find their way in the new digital medicine. Patients, on the other hand, should be instructed on exactly what "telemedicine" is.

Given this experience, we should act right away to increase digital competence in healthcare. We can't wait for the next healthcare shakeup to implement the next technological innovations. In particular, we need to make sure that we equip our medical staff with the knowledge of how to safely and effectively implement e-health in Poland. It is absolutely essential to update the curricula of medical specialists with classes on information technology and digital health. Those who educate medical professionals in e-health should include practicing physicians who use modern tools when providing health services, as well as IT specialists who would explain the basics of how each type of technology works. It is important to focus on the practical element – medical personnel need to understand what the solution is, how to use it in clinical practice and what its limitations are, as well as how to validate it in practice. A very important part of the job will be the ability to collaborate with various team members, including IT specialists, statisticians or data science people. Classes incorporating interdepartmental cooperation should be included in the curriculum. It's also worth considering interdisciplinary faculties that would enable the future doctor and computer scientist to work together on specific projects. Such classes would certainly increase the number of innovative medical startups and teach young students how to collaborate with each other on product development early in their careers.

Development in all sectors is exponential, and the frequency of new innovations that revolutionize the existing way of doing things will increase. Let's prepare for the coming and current changes – and invest in education.

Bibliography

AI w zdrowiu (n.d.). https://aiwzdrowiu.pl/

Digital Diagnostics (n.d.). https://www.digitaldiagnostics.com/about/digital-diagnostics/

Document 52018DC0237. (2018). Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic And Social Committee and The Committee of The Regions. Artificial Intelligence for Europe. European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A237%3AFIN

Future Health Index (2020). Era możliwości. Nowe pokolenie akceleratorem zmian w opiece zdrowotnej (zbiór danych). https://www.philips.com/c-dam/corporate/newscenter/global/future-health-index/report-pages/experience-transformation/2020/future-health-index-2020-poland-report-in-polish.pdf

Homer S., & Selman, A. L. (2001). *Computability and Complexity Theory*. Springer Science & Business Media.

Kawecki, M. (2021). Informatyk i lekarz wspólnie na sali? Nieskorzystanie z technologii będzie błędem medycznym [Podcast]. *Komputer Świat*. https://www.komputerswiat.pl/artykuly/redakcyjne/informatyk-i-lekarz-wspolnie-na-sali-nieskorzystanie-z-technologii-bedzie-bledem/ed6ndq8

Kornowska, L. (2021). Podsumowanie Konferencji „AI w zdrowiu". Polska Federacja Szpitali. http://www.pfsz.org/2021/07/09/podsumowanie-konferencji-ai-w- zdrowiu/

Kornowska, L. et al. (2021). *Top Disruptors in Healthcare* (Report). Medexpert Ligia Kornowska.

Kwon, J. M. et al. (2020). A deep learning algorithm to detect anaemia with ECGs: a retrospective, multicentre study. *The Lancet*. https://www.thelancet. com/journals/landig/article/PIIS2589-7500(20)30108-4/fulltext

Lee, A. Y. et al. (2020). Multicenter, Head-to-Head, Real-World Validation Study of Seven Automated Artificial Intelligence Diabetic Retinopathy Screening Systems. *American Diabetes Association*. https://care.diabetesjournals.org/content/early/2021/01/01/dc20-1877

McKinney, S. M., Sieniek, M., & Shetty, S. (2020). International evaluation of an AI system for breast cancer screening. *Nature*. https://www.nature.com/articles/s41586-019-1799-6

Ministry of Health (2017). Rozporządzenie Ministra Zdrowia z dnia 28 sierpnia 2017 r. w sprawie ramowego programu zajęć praktycznych dla kierunku lekarskiego i lekarsko-dentystycznego. https://sip.lex.pl/akty-prawne/dzu-dziennik-ustaw/ramowy-program-zajec-praktycznych-dla-kierunku-lekarskiego-ilekarsko-18630453

Moses, D. A. et al. (2021). Neuroprosthesis for Decoding Speech in a Paralyzed Person with Anarthria. *The New England Journal of Medicine*. https://www. nejm.org/doi/full/10.1056/NEJMoa2027540

Muehlematter, U. J. et al. (2021). Approval of artificial intelligence and machine learning-based medical devices in the USA and Europe (2015–20): a comparative analysis. *Health Policy*. https://www.thelancet.com/pdfs/journals/landig/PIIS2589-7500

Narodowe Centrum Badań i Rozwoju (2021a). Infostrateg (II Konkurs). https://www.gov.pl/web/ncbr/infostrateg-ii-konkurs

Narodowe Centrum Badań i Rozwoju (2021b). *Wyniki oceny pozytywnej naboru wniosków złożonych w ramach przedsięwzięcia Wsparcie Szpitali Jednoimiennych z 2020 r.* https://archiwum.ncbr.gov.pl/programy/programy-krajowe/wsparcieszpitalijednoimiennych/aktualnosci/aktualnosci-szczegoly/news/wyniki-oceny-pozytywnej-naboru-wnioskow-zlozonych-w-ramach-przedsiewziecia-wsparcie-szpitali-jednoim/

Republic of Poland, official website (n.d.). *Grupa Robocza ds. Sztucznej Inteligencji (GRAI)*. https://www.gov.pl/web/cyfryzacja/ grupa-robocza-ds-sztucznej-inteligencji-grai

Searle, J. (1980). *Minds, Brains and Programs*. Cambridge University Press.

Słownik języka polskiego (n.d.), termin "sztuczna inteligencja". https://sjp.pwn.pl/szukaj/sztuczna-inteligencja.html

Szafrańska, M. (2020). Sztuczna inteligencja wspiera walkę z koronawirusem. Polski start-up dostarczył rozwiązanie dla NFZ i rusza w świat. *Forbes*. https://www.forbes.pl/biznes/yoshai-automatyczny-asystent-dla-nfzsztuczna-inteligencja-w-walce-z-koronawirusem/8pzp1ps

Uniwersytet Medyczny w Łodzi (n.d.). Rekrutacja (Zbiór danych i program nauczania). https://rekrutacja.umed.lodz.pl/pliki/Lekarski.pdf

Uniwersytet Medyczny w Poznaniu (2020). Harmonogram roku akademickiego 2020/2021 (Zbiór danych i program nauczania). https://wl.ump.edu.pl/informacje-wydzialowe/dla-jednostek-dydaktycznych

Uniwersytet Mikołaja Kopernika w Toruniu (n.d.). Wykaz umiejętności absolwenta kierunku lekarskiego (Zbiór danych i program nauczania). https://

www.wl.cm.umk.pl/student/lekarski-studia-jednolite-magisterskie/wykaz-umiejetnosci-absolwenta-kierunku-lekarskiego/

Zubașcu, F. (2020). Commission adds AI research 'lighthouse' to innovation priorities amid budget wrangle. *Science Business.* https://sciencebusiness.net/news/commission-adds-ai-research-lighthouse-innovation-priorities-amid-budget-wrangle

Using artificial intelligence in elderly care. New digital competencies in geriatrics

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Introduction

The surge in artificial intelligence experienced in the past two decades, initiated back in the 1940s, is a direct result of advances in computer science and its disciplines, as well as the associated access to large amounts of data that can be obtained in real time and rapidly transmitted over any distance. The facilitation of access to large data sets is occurring in virtually every field of science, but it is crucial in the development of medicine, where information about a patient's baseline condition and any changes occurring in it are the basis for deciding whether to start, continue or change therapy. The progress that has been made in this field is illustrated by data showing that the percentage of US hospitals with an electronic medical record system has increased from less than 10% in 2008 to more than 75% in 2015 (Adler-Milstein, 2015). The potential of collecting and analyzing medical data has been highlighted by the UK's National Health Service (NHS), which announced a long-term 2019–2024 plan to have medical data transferred via electronic systems by all healthcare providers (NHS, 2019). In Poland, as of April 1, 2021, there is a legal obligation for software providers to ensure that data contained in electronic medical records can be exchanged via the Medical Information System within the P1 System (Act of 28 April 2011 on the Healthcare Information System).

An important role in the availability of medical data is also played by the growing market for private-use devices that collect medical data, allowing it to be analyzed and used in remote health assessment. This includes such common tools as smartphones, as well as wearable and other devices gaining popularity.

In 2018, Apple released the PHR (personal health record) platform, a technological standard for transferring medical data coming to the company's devices, allowing apps developed for iOS to easily transfer health data to electronic medical record systems. This means that applications collecting medical data will be able to share data collected by private application tools directly to systems operated by medical personnel, with the user's consent.

The changes described above provide an opportunity to develop cutting-edge technologies based on artificial intelligence, which can: ultimately improve the effectiveness of healthcare, be data-driven decision support for medical personnel, increase patient awareness and involvement in therapy, and lead to the automation of many processes performed by humans today. At the same time, the healthcare systems of developed countries are facing the challenges of a worsening shortage of medical personnel, increasing demand for specialized healthcare services and their

*AIDA Diagnostics

rising costs, ensuring equal access to treatment for people living outside urban areas who require long-term and special care or have a low income status.

An important factor influencing the challenges enumerated above is the process of demographic change, which in the EU-28 will result in an increase in the share of people over 65 years of age from 19.7% in 2018 to 28.5% in 2050, translating into 48.1 million more residents in this age group (Eurostat, 2020). The effect of these changes will be an increased demand for healthcare services for the elderly, which will force the development of technologies to enable their effective delivery.

These facts prompt an in-depth reflection on the possibilities and implications of using artificial intelligence in the inevitable transformation of the care system for the elderly. What are the health challenges behind the rapidly advancing demographic changes? Will solutions using artificial intelligence help us answer them? If so, in which areas will they be most effective? In addition to the expected benefits, can we identify the risks of their widespread adoption? What will the process of adapting to technological changes in the lives of the elderly look like, and what measures should be taken to enable them to realize their full potential?

The aim of this chapter is to review the use of artificial intelligence in the care of the elderly on the basis of experience to date, as well as to identify the opportunities and risks associated with it. The chapter will describe the challenges to which the development of artificial intelligence must respond and identify the technological areas where its role is crucial in meeting the demands of a changing world. This will be followed by an overview of the technologies currently on the market, taking into account future developments, as well as an indication of the risks associated with their use. Special attention will be paid to the risk of the lack of competent medical personnel and patients in the use of modern technologies using artificial intelligence, as well as proposed ways to reduce this.

Challenges in the transformation of elderly care systems

Of the fifty countries in the world with the largest share of people 65+ in the population, as many as half belong to the European Union, and the projected number of people requiring long-term care in the EU-27 will grow from 19.5 million in 2016 to 23.6 million in 2030 and 30.5 million in 2050 (European Commission, 2021). At the same time, it is important to note that long-term care, defined as long-term professional nursing and rehabilitation, as well as the continuation of drug treatment and dietary management in the home setting, does not exhaust the healthcare access needs of the elderly. Available studies indicate that a significantly higher proportion of patients in the 65+ age group in acute care services correlates with higher rates of hospitalization and the risk of adverse events compared to patients in younger age groups (Aminzadech, 2002; Fayyaz, 2013; Fuchs, 2019).

In the Ageing Europe report by Eurostat (2020), statistics illustrate the challenges that will be associated with an aging population. The most significant of these in terms of directions for the application of artificial intelligence in care for the elderly are as follows:

- A healthy life for the elderly

  Increasing life expectancy means greater exposure to experiencing serious illness and disability. In the EU-27 in 2018, women aged 65 lived a healthy life for an average of 10 years of remaining life expectancy, a value that would be comparable for men, where it was 9.8 years. Unfortunately, large disparities within this indicator can be seen among EU countries to the disadvantage of former Eastern Bloc countries (in Poland, 8.8 years for women and 8.2 years for men), and aging societies will require special measures to keep it at its current level

- The independence of the elderly

  With aging, the ability of the elderly to function independently declines. Among those over 75, as many as 23.2% had difficulty doing daily shopping, 14.3% had difficulty bathing and showering, and 13.8% reported problems preparing meals.

- Access to healthcare

  The elderly (over 65 years of age) in the EU-27 will face greater difficulties in accessing medical services than the adult population (defined as those over 16). In 2018, the cost of medical services and waiting times were the two main issues leading to unmet medical needs.

These data raise a number of questions about the shape of future healthcare for the elderly and the appropriate technological directions to address the challenges described.

Is it possible to reduce the burden of healthcare by predicting those at risk of deterioration and implementing preventive measures? How can data be obtained for such actions and how can this need for action be effectively communicated by medical personnel, caregivers and patients?

Which telemedicine solutions can be used and how can they be used effectively to stay in touch with patients who have difficulty accessing medical services and to provide personalized support for their treatment?

How can families and professional caregivers be supported in caring for those who require ongoing assistance in coping with their disabilities? Can digital care in the 21st century take people out of the process? If so, what will be its purpose – controlling adherence to medical recommendations or mental support?

The answers to these questions will be part of the process of developing technological solutions in the field of elderly care, and we will likely be seeing a string of successes and failures both in the scientific and business fields in the coming years. The direction of these changes is reflected in the innovations that have been introduced to date to the general public, which are increasingly having a clear impact on the lives of older people and the work of healthcare professionals.

Areas for applying AI in elderly care

A report prepared by the European Commission, *The Silver Economy*, leaves no illusions about the impact of the aging populations of member states on their functioning in the coming decade. The silver economy is defined as the sum of all economic activity that serves the needs of people aged 50 and older. This includes products and services purchased by them directly, as well as the economic activity that generates this spending. It is worth noting that already in 2015, the silver economy market generated spending of 4.2 trillion euros of GDP (28.8% of EU GDP) and supported 78 million jobs (35.3% of EU employment). By 2025, the silver economy's consumption is expected to grow by about 5% per year, to 5.7 trillion euros; spending to 6.4 trillion euros in GDP (31.5%) and jobs to 88 million (37.7%). Healthcare services account for a larger share of the spending structure of the over-50s compared to younger people, as well as spending on recreation, culture and household goods (European Commission, 2018).

Although the report provides a broad perspective of the challenges and opportunities associated with the observed demographic changes in terms of their impact on the economy, virtually every section of the report refers to the health sector as a key stage on which the response to the processes taking place will define the success or failure of EU countries' policies. The report's authors point out the following concluding recommendations to stakeholders (including the EC):

1. Support the technological and digital revolution in the health sector,
2. Promote healthy aging across the European Union,
3. Support the development of solutions to improve the mobility of older people,
4. Promote the active participation of older people in the labor market,
5. Support innovative products and services aimed at increasing the independence of older people.

Artificial intelligence (AI) can play a significant role in the development of solutions to address all of these recommendations, and its application within the framework of the recommendations listed in points 1, 2 and 5 will have a direct impact on the transformation of geriatric care.

Relating to the general recommendations, *The Silver Economy* report also presents a set of ten case studies on specific solution areas for older adults identified in a multi-stage stakeholder consultation process. Of these, at least three are a promising field for reviewing current and future opportunities for artificial intelligence applications:

- The development of a market for mHealth tools to monitor, among other things, neurological, cardiovascular and sleep symptoms for disease prevention, faster diagnosis, as well as better selection of medications and identification of the potential adverse events they may cause.

- The development of the robotics market to create assistants for the elderly, capable of interacting in complex ways with the user; such solutions will alleviate the shortage of caregivers in the labor market.
- The development of integrated applications and solutions enabling advanced data analysis to promote healthy and active lifestyles, including wearable devices, personalized nutrition solutions and preventive medicine solutions.

Examples of using AI in elderly care

There are at least several types of solutions already on the market that fit the descriptions outlined above. In order to systematize the discussion, three categories of solutions using artificial intelligence will be presented: Internet of things solutions, care robots, and mobile applications used in healthcare. However, it should be emphasized that this division is arbitrary, as modern solutions are often based on a combination of such categories. The role of artificial intelligence in supporting the clinical decisions of geriatric care professionals will be discussed separately.

Mobile applications used in healthcare (mHealth)

With the proliferation of smartphones, mobile applications have become part of our daily lives, and the area of healthcare seems to be the one where technological advances will be most welcome.

In applications developed for the elderly, of course, limitations in access and competence relating to the use of modern technology in daily life become relevant. People in the 65+ age group are less likely to use mobile health apps compared to younger people (Carroll, 2017), but it can be predicted that as the baby boomer generation continues to age, this situation will change (Berenguer, 2017). Rasche et al. (2018), studying the use of health apps among the elderly in Germany, identified barriers relevant to their use: a lack of trust of trust in this form of healthcare support, concerns about protecting sensitive data, and fear of an incorrect diagnosis made with the help of the app. Mobile health apps were used by 16.5% of respondents, compared to 37.5% using any mobile apps and 46% not using any apps.

Despite these challenges, mobile apps to support elderly healthcare are already an important element on the digital gerontechnology solutions map.

Berauk et al. (2017) conducted a review of scientific publications describing the use of health mobile apps for the elderly and identified two primary areas of their functionality: apps to support general geriatric care and apps targeted to patients with specific diseases. In this and other review papers, the most common examples of use include apps that support the maintenance of a healthy diet, physical activity, quality sleep and adherence to medical recommendations, as well as assisting in the control and treatment of elderly patients with diabetes, cognitive impairment, as well as cancer patients and those receiving palliative care (Changizi, 2017; Joe, 2013).

Such applications use artificial intelligence solutions to analyze collected data and personalize recommendations for lifestyle changes, predict the onset or progression of disease, and detect and inform caregivers and medical staff of the need to take action to modify therapy (Khan, 2020).

An example of a model mobile application for the elderly is Altoida. The solution is based on a precision neurology platform that collects and analyzes data from a dedicated application with medical device status. The app, using augmented reality, allows users to participate in a virtual version of a game of hide-and-seek: users navigate computer-generated objects in their physical space, and artificial intelligence identifies mistakes made to analyze spatial reasoning, motor skills, and executive functions of the brain. The solution makes it possible to assess the risk of the progression of Alzheimer's disease over the next 12 months, which can be crucial for therapeutic decisions and care for those at risk of developing the disease. In 2021, Altoida received Breakthrough Device Designation, a program created by the FDA to accelerate the development, evaluation and review of breakthrough technologies while maintaining regulatory standards for pre-market approval and marketing authorization.

Another example of the use of artificial intelligence in mobile apps developed to support elderly care is the FibriCheck app. It enables the diagnosis of heart rhythm disorders using an optical signal from a non-medical device, such as a smartphone. FibriCheck uses the smartphone's camera to detect heartbeats and then, through the use of artificial intelligence, is able to perform an accurate analysis of its rhythm to detect atrial fibrillation. The timely detection of such a disorder is particularly important due to the higher risk of ischemic stroke and gives the patient a chance to implement effective therapy. FibriCheck received European Class IIa medical device certification in 2016, and was also approved by the FDA in 2018.

The mobile apps presented are just the tip of the iceberg when it comes to the potential for introducing this form of new technology into elderly care. Many of the apps with the potential to help maintain better health will not require long and complex research. Examples include apps that monitor physical activity or support healthy eating. It can even be considered that commonly used communication and social activity apps also fall into the group of solutions that support or facilitate elderly care. However, there is no doubt that due to the necessary involvement of the end user, the most successful applications within this area will be those that are tailored to the requirements and adapted to the preferences of older people.

Internet of things (IoT) solutions in elderly care

A related group of applications are IoT solutions, the premise of which is to provide an elderly person with devices that collect data on his or her current condition: from wristbands, to sensors placed on everyday objects, simple testing devices like blood pressure monitors, to specialized ones like spirometers. All are equipped with a wireless connection to the Internet that allows them to transmit data on an ongoing basis to servers where the data is analyzed – in many solutions by artificial intelligence. The results of the analysis make it possible to alert an action to be taken (e.g., taking medication, drinking fluids), transmit information about a dangerous event (e.g., a fall) directly to the caregiver or, in an application dedicated to the solution, display conclusions that can be analyzed by medical personnel.

It is easy to predict that the use of IoT solutions is strongly dependent on the amount of data collected about the user. It would be intuitive to assume that the more devices a solution has, the more complete the data collected will be and will provide better insight into the patient's health. To some extent, this is true, and there are indeed sets of IoT devices designed to enable a patient to perform a set of basic tests. However, this requires familiarization with the operation of many tools, which can make it difficult for patients to use.

On the other hand, a lot of health information can be provided by seemingly simple wearable devices like wristbands. This type of solution is a wristband from CarePredict, which, collecting daily data, analyzes it using artificial intelligence to create a unique profile of the user's daily activities. It then monitors them to detect anomalies that could indicate a problem: from an increased risk of falling, to a urinary tract infection, to the onset of a depressive episode.

Polish products, such as SiDLY and AioCare, are also worth noting as examples of IoT solutions used in elderly care. SiDLY is a wristband that functions in conjunction with a mobile app and telecare platform, so it offers not only real-time health information, but also direct assistance from qualified personnel in the event of an accident. AioCare, on the other hand, is a personal system for monitoring and treating lung diseases. A key part of the system is an IoT device that a patient can use at home to perform spirometry – a respiratory test that measures lung volume and airflow during different phases of the respiratory cycle. The results of the test are sent to the patient's special mobile app and shared via a web platform with the treating physician. AioCare makes it possible for patients of different age groups to control diseases such as asthma, interstitial lung disease or chronic obstructive pulmonary disease. For the elderly, chronic obstructive pulmonary disease in particular is important, which affects 14.2% of people over the age of 65 (Hanania, 2010). It is interesting to note that the device uses artificial intelligence, among other things, to detect coughing during the examination, thus enabling a reduction in errors associated with the diagnostic process itself.

The above examples do not fully exhaust the areas of applying IoT solutions in elderly care. Tun et al. (2021) identified eleven domains in which, in addition to those described, Internet of things solutions supporting the prevention, diagnosis and treatment of mental health disorders or assisting in rehabilitation processes have an important role.

Care robots

In 2014, about 17.4% of all people aged 75 or older in the EU-28 reported having used home care services during the past 12 months. This was more common for women than for men (20% vs. 13.5%) (Eurostat, 2020). Access to home care will be one of the challenges facing the aging population – on the one hand, by the growing number of people in need of such assistance, and on the other, by the insufficient number of qualified personnel. Support in meeting this challenge may be care robots, whose functionalities include ensuring compliance with medical recommendations, supporting rehabilitation processes or assisting with daily activities. Perhaps their most spectacular function is their communication system, often based on conversational artificial intelligence solutions, which were described in detail by Prof. Aleksandra Przegalińska in the opening article of this publication. Robots, in addition to being equipped with a speech understanding system, can obtain data with the help of the ICT tools described earlier. They are often equipped with cameras and even touch sensors that enable a variety of interactions. The application of artificial intelligence in this type of solution not only implies enabling the recognition and analysis of human speech, but also refers to classifying the collected information and analyzing it in order to take personalized actions.

An interesting example is the current ElliQ care robot from Intuition Robotics, which, in addition to its role as an assistant to the human caregiver, is presented as a companion for the elderly – responding to changes in mood, remembering and learning their interests and taking care of their well-being. ElliQ's creators base their product on artificial intelligence solutions, which are designed to mimic empathy and thus provide the impression of a personalized relationship and experience to the caregiver. Thus, ElliQ can conduct conversations, physical training or meditation sessions, and even play games with users to increase intellectual agility.

It's also worth noting the solutions being developed under Horizon 2020, the largest research and innovation program in the history of the European Union. Robots built by multidisciplinary, international teams: RAMCIP (Robotic Assistant for MCI Patients at home) and CARESSES (Culture – Aware Robots and Environmental Sensor Systems for Elderly Support) are promising examples of developing innovations that meet previously diagnosed needs.

The aim of the RAMCIP project was to research and develop a care robot to help elderly people with mild cognitive impairment or dementia. Gerłowska et al. (2018) evaluated the clinical application of the robot, which worked with eighteen patients in a neurology department. Tasks during the tests included detecting falls, helping with simple daily activities, and assisting with proper medication intake. The results of the prototype were promising: the robot achieved high acceptance and positive social impact while maintaining usability, and most of the subjects expressed a desire to work with the final version of the robot.

The CARESSES project, on the other hand, used the commercially available Pepper robot to explore the application of artificial intelligence in personalized communication in terms of cultural patterns and thereby deliver care tailored to the recipient (Bruno, 2019).

The RAMCIP and CARESSES projects, although not achieving spectacular commercial success to date, appear to be relevant to the development of robot use in elderly care. Particular emphasis has been placed in both on research, resulting in a number of conference presentations and publications. This seems particularly relevant given the reports of Abdi et al. (2018), who reviewed scientific papers aimed at confirming the clinical relevance of using care robots.

Despite noting positive findings, the authors point out methodological flaws affecting the reliability of the results.

The use of artificial intelligence to support clinical decisions

The presented overview of modern technologies using artificial intelligence, although integrally related to therapeutic decision-making by medical personnel in the care of the elderly, does not include a number of solutions intended for direct use by healthcare workers. With the development of artificial intelligence, it is becoming clearer that future work in healthcare will involve collaboration between humans and machines with capabilities beyond those of humans.

The use of the ability to analyze large data sets, mentioned in the introduction, provides the opportunity for modern therapy to apply artificial intelligence in therapeutic decision-making, the support of which will improve the quality of care and enable its personalization on an unprecedented scale.

Today, the application of artificial intelligence in imaging analysis and diagnosis is already a widely used standard, and the ACR Data Science Institute AI Central's database has more than 100 solutions in diagnostic imaging approved by the FDA for use in clinical settings. Machine vision technology makes it possible to learn from imaging datasets, which can be used both to directly indicate the presence of pathology and to assist in the interpretation of radiological images. Among the many companies developing this type of solution, it is worth noting Zebra Medical Vision, a start-up whose successful development has been seen over the past few years. It has developed several diagnostic solutions based on deep learning, which have been made available on the Philips IntelliSpace AI Workflow Suite platform.

The increased availability of data from electronic medical records is resulting in an acceleration of the application of artificial intelligence in medicine beyond the field of radiology as well. With the help of machine learning – a subdiscipline of artificial intelligence that uses advanced statistical techniques – it is possible to enable computer programs to independently make predictions about a patient's condition and suggest therapeutic decisions that take into account treatment outcomes in patients with similar clinical profiles (Ho, 2020). Choudhury et al. (2020) analyzed scientific publications on the application of machine learning in geriatric care, identifying 35 research papers in which cognitive disorders, eye disease, asthma or atherosclerosis, among others, were targeted for diagnosis and therapy support. Although the conclusions noted the limitations of the studies analyzed, especially regarding the quality of the datasets used for the learning of artificial intelligence, it can be expected that this type of solution will become a widely used healthcare tool in the future.

Given the above, can we expect artificial intelligence to replace medical personnel in making therapeutic decisions? This does not seem likely to happen in the near future due to the many risks accompanying the use of artificial intelligence in medicine. Artificial intelligence, however, will become an important tool for supporting medical processes. Its solutions offer the possibility of developing advanced clinical decision support systems, the use of which will improve the global level of healthcare (Sutton, 2020).

The risks of using artificial intelligence in elderly care

The application of artificial intelligence in elderly care, in addition to its benefits, will also involve risks, which, due to the dynamic development of the technology, may change in form and risk level. As the impact of artificial intelligence on medicine increases, new risks are being identified and grouped by their specificity (Gerke, 2020). Table 12 indicates categories and examples of risks, along with their description and proposed mitigation. Risks relating to limited digital competence are described in a separate subsection.

Table 12. Review of the risks of using artificial intelligence in geriatrics

Risk	Description	Ways of limiting the risk
Risks relating to transparency		
Limited validation in scientific research	The lack of guidance and limited experience with research methodologies for the application of artificial intelligence and the identification of relevant endpoints may affect the level of scientific evidence and consequently reduce the confidence of healthcare professionals in the solutions or prevent their introduction to the market.	Multidisciplinary collaboration in research design, use of Good Clinical Practice (GCP) standards and consultation in GCP's new technology working groups.
Inability to reproduce the functions and results on actual data sets	Limited data sets (in terms of quality and quantity) can lead to artificial intelligence solutions that present satisfactory results on a specifically transformed and interpreted data set, which will not reflect the tool's performance on real data (Kiener, 2020).	Develop a uniform standard for pre-processing of medical data, create standardized anonymized databases in open access taking into account their specificity.
Ethical risks		
Depersonalization	Because artificial intelligence uses large data sets, there is a risk of under-representing the needs of people with very specific health issues; it can affect decisions and treatment, leading to varying degrees of error in the treatment process (Safdar, 2020).	Provide supervision of qualified personnel for solutions using artificial intelligence in healthcare. Develop digital competencies that allow professionals to identify errors resulting from generalizing unique patient cases.

Table 12. Review of the risks of using artificial intelligence in geriatrics (cont.)

Dehumanization	The use of artificial intelligence in elderly care can lead to a deterioration in the quality of interpersonal relationships and consequently worsen the quality of life of end users (Sharkey, 2010).	Educating the elderly and their caregivers about the proper role of artificial intelligence in caregiving, while developing interpersonal relationships and communicating the risks of their deterioration as a result of technology.
Disciplining	Artificial intelligence-based solutions require constant access to patient data, and collecting this data means that health monitoring tools must be used continuously. This raises concerns about coercion and the use of power over the elderly, limiting their freedom in exchange for safety (Manzeschke, 2016).	Develop solutions using artificial intelligence in cooperation with end users and after taking into account their comments on how they want to use them. Introduce user satisfaction assessments as an equal measure of the effectiveness of using the technology in determining continued use.
Legal risks		
The use of artificial intelligence in medicine raises a number of legal risks, the presentation of which could be the subject of a separate paper. One of the most widely discussed and emotionally charged is the issue of liability for the therapeutic decision made, if it was made with the support of artificial intelligence. In the case of a doctor's use of a tool that has been properly tested and approved for use, it is difficult to determine liability for a medical error arising from the use of AI assistance. Even if we consider that artificial intelligence will always play a supporting role for the doctor (which seems a very conservative approach), and that the final therapeutic decision must be made autonomously by a human being, doubts arise regarding ultimate liability, for example, in the case of a doctor's non-culpable error in an AI-based solution (Raveesh, 2016; Gerke, 2020). This raises the need to update existing legislation, as well as to develop a strategy for introducing regulations to respond to the challenges of emerging legal risks.		

Source: own elaboration.

Digital competencies in geriatrics

One of the risks associated with the use of modern technologies and artificial intelligence in geriatric care will also be the lack of competence of medical staff, patients and their caregivers to use them in an informed manner. The changes taking place, not only in the type of tools used in care, but also in the processes involved in care, carry the risk of the inappropriate use of new technologies, resistance to active participation in modern forms of care, and, perhaps most dangerously, participation in the healthcare system with a sense of alienation and misunderstanding of how it works. Therefore, competence in the use of modern technology needs to be further developed, especially among older patients of current and future generations, as well as awareness of the basic concepts of artificial intelligence, so that as the term becomes more common, knowledge of its advantages, disadvantages, potential benefits and limitations will grow.

Education about the type of therapeutic intervention being undertaken is one way to improve patient compliance with conventional therapies (Roter, 1998; Taibanguay, 2019). To be effective, therapies using modern technology will also require patient understanding. Meanwhile, as many as 44% of people aged 65–74 living in the EU-27 had never used a computer by 2017. This rate varies considerably from country to country: from 5% in Iceland, Sweden and Norway, to 78% in Greece (Eurostat, 2020). The development of technological competence is thus becoming a key aspect of the transformation of geriatric care in the future, and will have an impact on the effectiveness of the solutions used.

The European Commission's Digital Education Roadmap 2021–2027 details three key priorities for action:

1. To make better use of digital technology in teaching and learning,

2. To develop digital competencies and skills appropriate to the era of digital transformation,

3. To improve education through better data analysis and forecasting.

Priority 2 emphasizes the importance of acquiring digital skills from a young age and the continuation of this process throughout life (European Commission, 2020).

The planned activities will certainly help to adapt future generations of older people to the use of modern technologies, but from the point of view of the success of the transformation of geriatric care in the coming decade, it is particularly important to expand the competencies of the current generation of older people, who, for natural reasons, have not had the opportunity to develop them to the same extent as younger generations.

For this reason, of great importance are the efforts of, among others, AGE Platform Europe – a European network of nonprofit organizations focused on articulating and addressing the needs of people over 50. In its public consultation for the digital education action plan, AGE recommends a number of activities to involve older people in the planned activities:

1. To take into account the expansion of digital access for people facing barriers in this area, among others, by organizing open digital access points in public institutions and care facilities,

2. To support formal and informal digital education not only by providing access to technology, but also by building the capacity and skills of adult education staff,

3. To support activities familiarizing digitally excluded people with online learning opportunities,

4. To pay more attention to digital safety education for the elderly,

5. To adjust formal education opportunities to meet the needs of older learners, with consideration given to increasing accessibility for those living in rural areas,

6. To provide mechanisms for the public funding of projects that take into account the above recommendations (AGE Platform Europe, 2020).

The assumptions of these recommendations are already being met today through initiatives such as DIGITOL, Mobile Age, FAITh – educational programs for older people in the field of digital skills, which are funded by EU funds. AGE calls for increasing the availability of such initiatives at EU and national levels.

It can be anticipated that a clash with technology, which is to some extent autonomous in drawing conclusions and suggesting appropriate actions, may raise suspicions among medical professionals about the source and mechanism by which it creates results. Increasing trust in artificial intelligence by ensuring that it is transparent in its operation, as well as robust in the process of testing its effectiveness, may be important for medical personnel to work with AI-based solutions (Asan, 2020).

An important topic in the coming years will be the methods by which such trust is built. It is particularly important to establish good practices for informing and learning how to use particular AI solutions, and to determine who should be responsible for implementing them. It seems natural that a provider of AI-based solutions should provide training for users on how to use the solution in practice, as well as provide support in the day-to-day use of the technology. Perhaps the functioning model of medical departments operating within the structures of pharmaceutical companies and providing resources relating to education and support for healthcare professionals will also become the standard in companies offering digital solutions based on artificial intelligence.

The presence of external consultants ready to assist medical personnel with particular AI solutions may prove insufficient or too burdensome in the daily work of users. However, it is conceivable that a suitable approach would be to train, within medical teams, advanced users (power users) who, by taking extra time to understand and use a given solution, would become experts within the team's work and provide assistance when doubts and questions arise. How wide a range of knowledge such a user should acquire remains an open question. Should we strive for the presence of power users within specific artificial intelligence solutions, whose competencies would be developed within an unchanged team structure, or will it become necessary to delegate an employee or group of employees to support a given organization in various areas of AI application? Such a strategy would incur additional costs and require the development of accommodating business models.

Building confidence in AI among healthcare professionals, regardless of the type of measures taken, will be ineffective if it does not go hand in hand with education on modern technologies. The importance of educating medical personnel about AI was described in detail by Ligia Kornowska in the article preceding this text.

Summary

Progressive demographic changes will force the healthcare system to introduce modern technologies in which artificial intelligence will play a leading role. This will be an opportunity to meet the challenges behind the consequences of changing the standard profile of the patient and his or her needs, as well as the economic and social consequences that follow in parallel. The aim of applying artificial intelligence to the care of the elderly should be, on the one hand, to extend a healthy life expectancy and, on the other hand, to improve the availability and quality of healthcare services for those in need of treatment. High death rates from cardiovascular and oncological diseases, comorbidities and their negative impact on the quality of life, limited access to health services, especially for residents of rural areas, and the long-term care needs of the elderly are among the many important issues where artificial intelligence could prove to be a key agent of change.

In responding to these challenges, however, caution should be exercised in setting goals based solely on therapeutic effectiveness and economic indicators. In introducing AI-based solutions in geriatrics, special attention should be paid to the needs of patients and healthcare professionals who, being end users, have the right to participate in setting the goals of care and ways to achieve them. This will help avoid the situation of inadequate solutions to the needs of the recipients, take into account relevant medical aspects, and gain acceptance and trust in modern solutions from medical personnel.

It is also crucial to take steps toward developing the technological competence of recipients of AI-based solutions, including medical staff. Equally important is to ensure ethical standards, without which artificial intelligence in medicine can become an exclusionary factor and lead to negative health and social consequences, not only from the perspective of the individual, but of the entire healthcare system.

New technologies based on artificial intelligence are becoming increasingly more common in our lives, even though sometimes we don't even notice it. In the near future, they will also be an indispensable part of the lives of the elderly, affecting an important and increasingly long part of everyone's life. Whether, in retrospect, we will be able to consider the field of elderly care as a success story in the application of artificial intelligence will depend in large part on the attentiveness, determination and ability to cooperate of experts in various fields.

Bibliography

Abdi, J., Al-Hindawi, A., Ng, T., & Vizcaychipi, M. P. (2018). Scoping review on the use of socially assistive robot technology in elderly care. *BMJ Open*, *8*(2), e018815. ACR Data Science Institute AI Central. https://aicentral.acrdsi.org/

Act of 28 April 2011 on the Healthcare Information System (Journal of Laws of 2011, No. 113, item. 657 with later amendments).

Adler-Milstein, J., DesRoches, C. M., Kralovec, P., Foster, G., Worzala, C., Charles, D., Searcy, T., & Jha, A. K. (2015). Electronic Health Record Adoption In US Hospitals: Progress Continues, But Challenges Persist. *Health Affairs (Project Hope)*, *34*(12), 2174–2180.

AGE Platform Europe (2020). AGE input to the consultation: Digital Education Action Plan. https://www.age-platform.eu/sites/default/files/AGE_paper_on_Digital_Education_Action_Plan_2020-V2.pdf

Aminzadeh, F., & Dalziel, W. B. (2002). Older adults in the emergency department: a systematic review of patterns of use, adverse outcomes, and effectiveness of interventions. *Annals of Emergency Medicine*, *39*(3), 238–247.

Asan, O., Bayrak, A. E., & Choudhury, A. (2020). Artificial Intelligence and Human Trust in Healthcare: Focus on Clinicians. *Journal of Medical Internet Research, 22*(6), e15154.

Berauk, A., V. L., Murugiah, M. K., Soh, Y. C., Chuan Sheng, Y., Wong, T. W., & Ming, L. C. (2018). Mobile Health Applications for Caring of Older People: Review and Comparison. *Therapeutic Innovation & Regulatory Science*, *52*(3), 374–382.

Berenguer, A., Goncalves J., Hosio, S., Ferreira, D., Anagnostopoulos, T., & Kostakos, V. (2017). Are smartphones ubiquitous? An in-depth survey of smartphone adoption by seniors. *IEEE Consum Electron Mag, 6*(1):104–110.

Bruno, B., Recchiuto, C. T., Papadopoulos, I., Saffiotti, A., Kouloglioti, C., Menicatti, R., Mastrogiovanni, F., Zaccaria, R., & Sgorbissa, A. (2019). Knowledge Representation for Culturally Competent Personal Robots: Requirements, Design Principles, Implementation, and Assessment. *International Journal of Social Robotics, 11*, 515–538.

Carroll, J. K., Moorhead, A., Bond, R., LeBlanc, W. G., Petrella, R. J., & Fiscella, K. (2017). Who Uses Mobile Phone Health Apps and Does Use Matter? A Secondary Data Analytics Approach. *J Med Internet Res*, *19*(4):e125.

Changizi, M., & Kaveh, M. H. (2017). Effectiveness of the mHealth technology in improvement of healthy behaviors in an elderly population – a systematic review. *mHealth*, *3*, 51.

Choudhury, A., Renjilian, E., & Asan, O. (2020). Use of machine learning in geriatric clinical care for chronic diseases: a systematic literature review. *JAMIA Open*, *3*(3), 459–471.

European Commission European Commission, Directorate-General for Communications Networks, Content and Technology, Worthington, H., Simmonds, P., Farla, K., et al. (2018). *The silver economy: final report*. Publications Office of the European Union. https://data.europa.eu/doi/10.2759/685036

European Commission COM(2020) 624 final. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. *Digital Education Action Plan 2021–2027: Resettling education and training for the digital age.* Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/c8eef67f-0346-11eb-a511-01aa75ed71a1/language-en/format-PDF/source-272998351

European Commission, Directorate-General for Communication (2021). *Green paper on ageing*. Publications Office of the European Union. https://data.europa.eu/doi/10.2775/785789

Eurostat (2020). Ageing Europe. DOI: 10.2785/628105

Fayyaz, J., Khursheed, M., Umer Mir, M., & Khan, U. (2013). Pattern of emergency department visits by elderly patients: study from a tertiary care hospital, Karachi. *BMC Geriatrics*, *13*, 83.

Fuchs, C., Çelik, B., Brouns, S., Kaymak, U., & Haak, H. R. (2019). No age thresholds in the emergency department: A retrospective cohort study on age differences. *PLOS One*, *14*(1), e0210743.

Gerke, S., Minssen, T., & Cohen, G. (2020). Ethical and legal challenges of artificial intelligence-driven healthcare. *Artificial Intelligence in Healthcare*, *2020*, 295–336.

Gerłowska, J., Skrobas, U., Grabowska-Aleksandrowicz, K., Korchut, A., Szklener, S., Szczęśniak-Stańczyk, D., Tzovaras, D., & Rejdak, K. (2018). Assessment of Perceived Attractiveness, Usability, and Societal Impact of a Multimodal Robotic Assistant for Aging Patients With Memory Impairments. *Frontiers in Neurology*, *9*, 392.

Hanania, N. A., Sharma, G., & Sharafkhaneh, A. (2010). COPD in the elderly patient. *Seminars in Respiratory and Critical Care Medicine*, *31*(5), 596–606.

Ho, A. (2020). Are we ready for artificial intelligence health monitoring in elder care? *BMC Geriatrics, 2*0(1), 358.

Joe, J., & Demiris, G. (2013). Older adults and mobile phones for health: a review. *Journal of Biomedical Informatics*, *46*(5), 947–954.

Khan, Z. F., & Alotaibi, S. R. (2020). Applications of Artificial Intelligence and Big Data Analytics in m-Health: A Healthcare System Perspective. *Journal of Healthcare Engineering*, *2020*, 8894694.

Kiener, M. (2020). Artificial intelligence in medicine and the disclosure of risks [published online ahead of print]. *AI Soc*., 2020, 1–9.

Manzeschke, A., Assadi, G., & Viehöver, W. (2016). The Role of Big Data in Ambient Assisted Living. *International Review of Information Ethics, 24*.

National Health Service (2019). The NHS long term plan.

Rasche, P., Wille, M., Bröhl, C., Theis, S., Schäfer, K., Knobe, M., & Mertens, A. (2018). Prevalence of Health App Use Among Older Adults in Germany: National Survey. *JMIR mHealth and uHealth*, *6*(1), e26.

Raveesh, B. N., Nayak, R. B., & Kumbar, S. F. (2016). Preventing medico-legal issues in clinical practice. *Annals of Indian Academy of Neurology*, *19*(Suppl 1), S15–S20.

Roter, D. L., Hall, J. A., Merisca, R., Nordstrom, B., Cretin, D., & Svarstad, B. (1998). Effectiveness of interventions to improve patient compliance: a meta-analysis. *Medical Care, 36*(8), 1138–1161.

Safdar, N. M., Banja, J. D., & Meltzer, C. C. (2020). Ethical considerations in artificial intelligence. *European Journal of Radiology*, *122*, 108768.

Sharkey, A.J., & Sharkey, N.E. (2010). Granny and the robots: ethical issues in robot care for the elderly. *Ethics and Information Technology, 14*, 27–40.

Sutton, R. T., Pincock, D., Baumgart, D. C., Sadowski, D. C., Fedorak, R. N., & Kroeker, K. I. (2020). An overview of clinical decision support systems: benefits, risks, and strategies for success. *npj Digit. Med. 3*(17). https://doi.org/10.1038/s41746-020-0221-y

Taibanguay, N., Chaiamnuay, S., Asavatanabodee, P., & Narongroeknawin, P. (2019). Effect of patient education on medication adherence of patients with rheumatoid arthritis: a randomized controlled trial. *Patient Preference and Adherence, 13*, 119–129.

Tun, S., Madanian, S., & Mirza, F. (2021). Internet of things (IoT) applications for elderly care: a reflective review. *Aging Clinical and Experimental Research*, *33*(4), 855–867.

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Glossary

21st century skills – a set of postulates addressed to the education system, directed at developing specific skills linked to the needs of society and the labor market in the 21st century. The term 21st century skills also serves to clearly emphasize the need to reform education systems so that they move away from the model of education developed in the 19th and 20th centuries.

algorithm – a finite sequence of clearly defined steps necessary to perform a certain type of task or achieve a goal; a course of action leading to the solution of a problem. The branch of computer science involving the design and analysis of algorithms is algorithmics.

Source: https://encyklopedia.pwn.pl/szukaj/algorytm.html

artificial creativity – a term derived from the concept of artificial intelligence. The rationale for its existence is derived from the degree to which we distinguish between the concepts of intelligence and creativity. Many psychological concepts consider creativity an autonomous or semi-autonomous entity to intelligence. Accordingly, future research on artificial intelligence will lead to a shift to a discipline called artificial creativity.

Source: Prof. Jan Fazlagić.

augmented reality (AR) – a system that combines the real world with a computer-generated world. Typically, a camera image is used on which 3D graphics generated in real time are superimposed. There are also augmented reality applications supporting only audio (like the RjDj app for the iPhone). For example, an AR user can use semi-transparent glasses to observe life going on in city streets, as well as computer-generated elements superimposed on the real world.

Source: https://pl.wikipedia.org/wiki/Rzeczywisto%C5%9B%C4%87_rozszerzona

automated (algorythmic, robot) journalism – automated journalism refers to the generation of textual materials, information, articles, reports by computer programs, data processing algorithms, text generators based on NLP models. Computer programs and algorithms interpret, organize and present data in a way that is readable to the audience. Typically, the process involves an algorithm that scans large amounts of supplied data, selects from a catalog of pre-programmed structures of informational material, organizes key issues and inserts specific data or organizes a narrative structure (automated storytelling), such as names, places, amounts, rankings, statistics and other numerical data. Combined with text-based voice synthesis techniques and image creation of humanoid characters, text generation techniques create automated and robotic forms of audiovisual journalism.

Automated journalism is sometimes seen as an opportunity to free journalists from routine, repetitive job duties, allowing them more time to perform complex tasks. It also allows for increased efficiency and lower costs, reducing the financial burden that many editorial offices face. However, automated journalism is also seen as a threat to news quality as well as to journalists' livelihoods.

Source: Graefe A. (2016). Guide to Automated Journalism. Columbia Journalism Review. https://www. cjr.org/tow_center_reports/guide_to_automated_journalism.php

big data is a term that refers to large, variable and diverse data sets, the processing and analysis of which is difficult, but at the same time valuable because it can lead to new knowledge. The concept of a large data set is relative and means a situation where the set cannot be processed using commonly available methods. Depending on the industry and the complexity of the algorithm, this can mean terabytes or petabytes in size, but in other applications it will already be megabytes or gigabytes. Big data has applications wherever large amounts of digital data are accompanied by the need to acquire new information or knowledge. At the same time, the use of large data sets for analysis means that there is no need to limit oneself to smaller sets determined by different sampling methods, which eliminates the errors associated with them.

Source: https://pl.wikipedia.org/wiki/Big_data

blended learning – a mixed (integrated, hybrid) method of education, combining traditional methods of learning (direct contact with the instructor) with activities conducted remotely via computer (mobile learning). The ratio of the various elements is selected depending on the course content, students' needs and preferences of the instructor.

Source: https://pl.wikipedia.org/wiki/Blended_learning

CE Certificate of Conformity / Declaration of Conformity – is a document issued by the manufacturer of a product or its authorized representative, constituting a legally binding promise stating that the product conforms to the essential requirements of relevant European Union directives. Before the manufacturer issues a declaration of conformity, the products should be subjected to a conformity assessment procedure and, if required by separate regulations, obtain the appropriate certificates. The CE label is placed by the manufacturer on those products having a declaration of conformity.

Source: https://pl.wikipedia.org/wiki/Deklaracja_zgodności

clinical decision support systems – software designed to improve healthcare delivery by supporting medical decisions through the analysis of clinical knowledge, patient information and other health data. Depending on their type, such systems can use conditional instructions based on expert knowledge as well as artificial intelligence.

Sources: 1. Osheroff, J. A., Teich, J. M., Levick, D., Saldana, L., Velasco, F. T., Sittig, D. F., Rogers, K. M., & Jenders, R. A. (2012). *Improving Outcomes with Clinical Decision Support: An Implementer's Guide* (2nd ed.). HIMSS Publishing. https://doi.org/10.4324/9780367806125

2. Deo, R. C. (2015). Machine Learning in Medicine. *Circulation*. 2015 Nov. 17, *132*(20), 1920–1930. doi: 10.1161/CIRCULATIONAHA.115.001593. PMID: 26572668; PMCID: PMC5831252

collaborative artificial intelligence – a subfield of artificial intelligence that deals with how multiple agents can work together to solve problems. It closely relates to game theory and multi-agent systems.

Sources: 1. Shoham, Y. & Leyton-Brown, K. *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*.

2. Russell, S. & Norvig, P. *Artificial Intelligence: A Modern Approach*.

computer-managed instruction (CMI) – the use of computer technology to organize and manage curricula for pupils and students; it allows one to build testing applications, track test scores and monitor student progress.

Source: https://pl.wikipedia.org/wiki/CMI

critical thinking – an attitude expressed as a willingness to consider in a thoughtful manner the problems and issues that fall within the scope of an individual's experience, knowledge of logical methods of reasoning and inquiry, and a certain proficiency in applying these methods.

Source: Glaser, E. M. (1941). *An Experiment in the Development of Critical Thinking*. Teacher's College, Columbia University.

According to Prof. Dr. Jan Fazlagić, the ability to think critically is now considered one of the most desirable international competencies. High critical thinking ability is useful for employees working on AI solutions.

data science – is an interdisciplinary field that uses scientific methods, processes, algorithms and systems to extract insights from a wide range of structured and unstructured data. Data science is associated with data mining, machine learning and big data analysis. Data science uses statistics, data analysis, machine learning, domain knowledge and related methods to understand and analyze data.

Source: https://pl.wikipedia.org/wiki/Danologia

data journalism – known in English-language literature as data journalism or data-driven journalism (DDJ) – a method of journalism and reporting that involves analyzing and filtering large data sets to create or enrich news, journalistic, editorial and other forms of journalism. The approach is based on older practices, most notably computer-assisted reporting (CAR) journalism, which was mainly used for decades in the US. Other terms for partly similar approaches include "precision journalism," a term coined in Philipp Meyer's book of that title, first published in 1972. The importance and possibilities of data-driven journalism are increasing due to the growth of information resources and databases, which are available both freely on the Web and through a growing number of specialized commercial services and databases.

Source: DataJournalism.com

deep learning – a subcategory of machine learning involving the creation of neural networks to improve voice recognition and natural language processing. It is also applied in bioinformatics and drug design.

Source: https://pl.wikipedia.org/wiki/Deep_learning

digital competencies – competencies that enable the conscious and responsible use of digital technologies, acquiring skills that pertain to them for use at work and as part of social functioning. These competencies include not only the ability to use information, data, communication and media, but also knowledge of the principles of security and intellectual property law, among others.

Source: Council Recommendation of 22 May 2018 on key competences for lifelong learning (2018/C 189/01)

education system – a group of institutions, organizations and other legal and natural persons involved in the education and upbringing of children, adolescents and adults. Public and non-public entities are in the education system. The education system has intertwining formal and informal structures. The key role in the education system is played by the state, which performs the vast majority of activities for the functioning of the system.

e-learning – teaching or training using information technology. It includes supporting the teaching process with personal computers, smartphones and tablets (m-learning), and the Internet. It allows students to complete a course, training or even studies without being physically present in a classroom. It also supplements the traditional teaching process, and is a component of blended learning.

Source: https://pl.wikipedia.org/wiki/E-learning

field (domain) of creativity – a concept based on the assumption that no one is creative in a general sense and, therefore, most people have distinguished certain specializations in which they have been performing at an average level for years. This concept should not be equated with the theory of multiple intelligences, which does not have a strong theoretical basis, although it is very popular in the world of practitioners.

Source: Prof. Jan Fazlagić.

gerontechnology – technological solutions for older adults to support independent living and strengthen their social activities to keep them in good health, comfort and safety. Defined as implementing the idea of successful aging and supporting older people in areas such as daily life, communication, health, safety, mobility and leisure.

Source: Mendes, D., Fonseca, C., Lopes, M. J., Garcia-Alonso, J. & Murillo, J. M. (2020). *Exploring the role of ICTs in healthy aging*.

Internet of things (IoT) – a system of interconnected computers, mechanical devices and objects that have so-called unique identifiers (UIDs, special codes made up of numbers, letters and characters, assigned to each unit in the system) and the ability to transmit data over the network without human intervention. However, humans can interact with IoT devices, for example, to configure them, pass on instructions or access data. Importantly, an object in the Internet of things does not have to be an inanimate object, it can also be a human with a heart monitoring implant or a dog with an implanted chip.

Source: https://www.sztucznainteligencja.org.pl/slownik/

key competencies – competencies necessary for self-realization and personal development, making the individual an active citizen, able to interact in society and take up gainful employment. These competencies combine knowledge, practical skills and social attitudes appropriate to the situation.

Source: *Key Competences for Lifelong Learning – A European Reference Framework*, annex to the Recommendation of the European Parliament and of the Council of 18 December 2006 on Key Competences for Lifelong Learning, published in the Official Journal of the European Union of 30 December 2006/L394.

language transformer – a type of artificial intelligence whose job is to transform one natural language into another. Transformers are commonly used in machine translation and natural language processing applications.

Sources: 1. Bird, S., Klein, E., & Loper, E. *Natural Language Processing with Python*.

2. Manning, C. D. & Schütze, H. *Foundations of Statistical Natural Language Processing*.

learning style – characteristics of the process of consolidation, as well as changing the state of knowledge and skills. Teaching style closely relates to learning style. The concept of learning styles is very popular among educational practitioners, however, there are no scientific research results proving a positive relationship between a teacher's use of the concept of "learning styles" and students' learning outcomes.

Source: Prof. Jan Fazlagić.

LLL Glossary – In early 2022, the LLLGlossary, namely the Review of Lifelong Learning Terminology was published by the Lifelong Learning Platform. The publication was prepared in consultation with members of the LLLP group and organisations such as CEDEFOP, ASEM-LLL and UNESCO as part of a project supported by the European Commission.

The publication may be downloaded from: https://lllplatform.eu/lll/wp-content/uploads/2022/12/LLLGlossary.pdf

media education – education that enables people to understand the mass media used in society (including the printed word, graphics, sound, still and moving images delivered by any technology) and to acquire the skills for using them to communicate with others.

Source: Recommendations Addressed to the United Nations Educational Scientific and Cultural Organization UNESCO, UNESCO, Paris 1999, pp. 273–274

mobile health (mHealth) – providing and facilitating health-related information through mobile telecommunications and multimedia technologies, including cell phones, tablets and wireless infrastructure. It ranges from simple applications for direct communication to complex systems that remotely coordinate and proactively manage patient care.

Source: Krohn, R. & Metcalf, D. (2012). *mHealth: From Smartphones to Smart Systems* (1st ed.). HIMSS Publishing. https://doi.org/10.4324/9780367648008

natural language processing (NLP) – an interdisciplinary field that combines linguistics, computer science, information engineering and artificial intelligence. NLP concerns the interactions between computers and human (natural) languages, and in particular with ways of programming computers to process and analyze large amounts of data in natural language.

Source: Jurafsky, D. & Martin, J. *Natural Language Processing.* https://web.stanford.edu/~jurafsky/slp3/

smart city – the smart city concept is a relatively new view of the functioning of today's modern cities. It is the result of technological advances and, at the same time, an increase in the environmental awareness of society. It combines three key areas that define the direction of change – computerization of the city, digitalization and sustainable development. The smart city is a response to the needs of modern society living in metropolitan areas. Such cities have emerged as a result of the intelligent use of digital information, including in such areas as education and knowledge transfer, mobility, energy, environment, health and public services.

Source: Gieleciak, Z. & Szaflarski, K. *Zarządzanie inteligentnym miastem–smart city (na przykładzie miasta Tychy)* [Managing an intelligent city–smart city (based on the example of Tychy]. Globalna Gospodarka, Zarządzanie, Prawo i Administracja, p. 39.

speech synthesis – a collection of techniques and methods for transforming written text into an acoustic speech-like utterance that mimics human speech (TTS – Text-To-Speech). Typically, a system of this type uses NLP text analysis, phonetic analysis of a string of voiced words with parameters, and a low-level synthesis system that produces an acoustic speech signal. Phonetic analysis involves converting text available in written form into a string of phonemes, taking into account specific phonetic phenomena occurring in the language, such as intonation, accents, and voicing. An acoustic signal can be synthesized by various methods, such as by playing and combining elementary sounds from computer memory or concatenationally, i.e., using recorded samples of the voice of the speaker.

Source: ScienceDirect. Speech Synthesis. https://www.sciencedirect.com/topics/computer-science/speech-synthesis

telemedicine – a form of medical and healthcare delivery that combines elements of telecommunications, information technology and medicine. Telemedicine is distinguished from telehealth and eHealth, which refer to a broader range of remote healthcare services than telemedicine. Telemedicine specifically refers to remote clinical services, while telehealth and eHealth can refer to remote non-clinical services. Telemedicine also takes into account the aspect of professional liability when performing remote medical services. Through the use of new technologies, it helps break down geographic barriers, allowing the exchange of specialized information in the form of static and dynamic images (highest quality ECG, ultrasound, MRI images). It also enables diagnoses to be made at a distance. A major application of telemedicine is in the surgical community, which uses it to conduct operations at a distance. Modern technology, using high-speed processors and algorithms for digital signal processing and compression, makes it possible to transmit high-resolution images, as well as interactive audiovisual transmission with exceptional accuracy and in real time.

Source: https://pl.wikipedia.org/wiki/Telemedycyna

Turing test / reverse Turing test – a test to assess whether a machine is capable of imitating a human to such an extent that it cannot be distinguished from a human. It was developed in the 1950s by the brilliant English mathematician Alan Turing. In 1950, Turing proposed this test as part of his research into creating artificial intelligence – replacing the emotion-laden and, in his mind, meaningless question "Do machines think?" with a better-defined question.

The test is as follows: The judge (a human) conducts a conversation in natural language with two other parties. If the judge is unable to reliably determine whether either party is a machine or a human, then the machine is said to have passed the test. It is assumed that both the human and the machine are trying to pass the test by behaving as close to a human as possible.

In the reverse Turing test, a computer program engages in a textual dialogue with a human and another computer. The program's task is to distinguish the human from the computer. A popular version of this test is CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart), which can be encountered on many websites. Most often, a distorted image of random characters is displayed, and a person is supposed to type in the characters correctly read from the image using a keyboard. In another version, the solution to a simple equation has to be typed in. In doing so, it is expected that the computer is unable to "read" the image or find the solution.

Source: https://www.sztucznainteligencja.org.pl/slownik/

virtual reality – VR, fantomatics – an image of artificial reality created by using information technology. It involves the multimedia creation of a computer vision of objects, spaces and events. It can represent both elements of the real world (computer simulations) and completely fictional ones (science fiction computer games).

Source: https://pl.wikipedia.org/wiki/Rzeczywisto%C5%9B%C4%87_wirtualna

The monograph presented here draws the reader's attention to the opportunities, threats and challenges posed by the application of artificial intelligence (AI) solutions in education. The authors have skillfully presented their considerations, placing them within four broad thematic sections: Society and the State, Education, Industry and Services. Structuring the discussion into sections highlights the multidimensionality and multifacetedness of the AI issue. Simultaneously, it indicates how wide the field of AI applications can be when educational needs are taken into account.

The interdisciplinary approach to this issue used in the study also shows that AI deserves to be called a megatrend affecting society and the economy, including the education sector. The value of the presented publication is not only cognitive, but practical in nature as well. The issues discussed and the formulated recommendations relating to the challenges as well as the opportunities emerging from the implementation of AI solutions in education are to support the efforts of education policy-makers, teachers, teacher-training institutions and representatives of education administrators.

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