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ALGORITHMS IN THE EDUCATIONAL PROCESS – OPPORTUNITIES AND LIMITATIONS*

Introduction: Algorithm application is now a common topic in scientific and popular science publications. More and more practitioners and theoreticians associated with teaching, upbringing, and therapy are turning to it, hoping to make their activities more effective and improve their organization.
Research Aim: This article presents the possibilities and limitations of introducing algorithms to the educational process.
Evidence-based Facts: Over the past years, the number of publications dedicated to AI and the process of algorithmization, has increased significantly. Defining the concept of an algorithm, and pointing out its connection with machine learning and AI have paved the way for applying algorithms in many areas of our lives from applications used on personal devices, to medicine, banking, educational policy, and scientific research. The increasing popularization of algorithmization and easier access to this technology have sparked a discussion about its limitations and dangers affecting adults and children, either directly or indirectly.
Summary: Practitioners and researchers involved in educational processes still lack knowledge of the topic under discussion. Few scientific or popular science publications prepared by real specialists are aimed at this audience. Without a thorough understanding of algorithmization, machine learning, and artificial intelligence, the introduction of algorithms to the educational processes may not only fail to achieve the intended results but also lead to disorders in the development of children, adolescents, and adults.

Keywords: algorithm, algorithmization, educational processes, teaching, upbringing, therapy

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INTRODUCTION

Algorithms have been part of our lives for centuries. The first publications on the topic appeared in the 1990s (Khalid et al., 2022; Tzanetos and Douglas, 2021). With the development of science, the term began to describe not only complex computer operations but also simple activities such as dressing or brushing teeth. Algorithmization is now seen in almost all aspects of our lives – even when we are unaware of its existence. The education process is no exception. As early as the 1970s, Landa published a book titled, *Algorithmization in Learning and Instruction* (1977). Since then, new technologies, machine learning, and now – intensively developing – artificial intelligence, have become an integral part of activities at schools and other educational institutions. Algorithms are the starting point for creating the above.

RESEARCH AIM AND QUESTION

This article attempts to answer how far educators, psychologists, teachers, and researchers in social disciplines can develop algorithms that meet the rigid requirements defined for these types of processes.

EVIDENCE-BASED REVIEW

The term "algorithm" (Latin: *algorithmus*) is mainly associated with the Greek *arithmos* which means number and the Arabic *algorism* which means the medieval art of calculating numbers written in digits of the Arabic alphabet using the decimal system. The term comes from the name of a Persian mathematician who lived at the turn of the 8th and 9th centuries, Muhammad ibn Musa al-Khwarizmi. The distorted, Latinized version of his name was Algoritmi. In the Middle Ages, the term *algorithmus* referred to all operations performed on natural numbers (Zawojski, 2018, p. 18).

"Algorithm" is a fairly general term used to describe various ideas, often with overlapping definitions. These concepts range from simple flowcharts and step-by-step protocols to complex computer methods, including machine learning techniques and artificial intelligence systems. They can also be described as, "step-by-step procedures for making decisions to diagnose and solve problems" (Margolis, 1983; Khalid et al., 2022).

This type of algorithm was frequently developed using Horabin and Lewis's (1978) method which consists of the following seven steps:

1. Identify performance requirements
2. Define the problem
3. Determine who will solve the problem

4. Determine how to use the algorithm
5. Develop the first draft
6. Test and tweak until graphically acceptable
7. Test and iterate to achieve knowledge or execution

Initially, algorithms were used mainly in mathematical logic, algebra, and geometry. Nowadays, they are used in economics, psychology, and even philosophy. For the social sciences and humanities, what is crucial is not so much the technical dimension of algorithms, but rather their social construction and the impact they have on specific people and entire communities (Bucher, 2018; Kreft, 2019; Szpunar, 2019). From a sociocultural perspective, an algorithm is therefore more than a set of successive operations – it is a socio-technological system of knowledge creation, for which culture, its norms, and values are no less important. An algorithm understood in this way has a potentially huge impact on all dimensions of modern life.

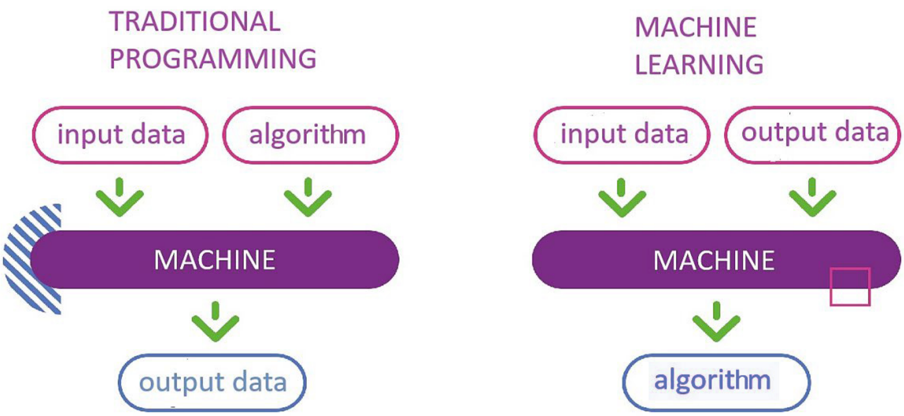
The main features of algorithms include:

- correctness (guarantees that an algorithm generates the predicted result for all possible input data because it has a specific, unambiguous, and well-defined set of instructions as well as an end condition);
- unequivocality (an algorithm should generate the same results with the same set of input data);
- universality (means that a set of rules can be implemented for specific cases of the problem or adapted to different situations; algorithms must therefore have a certain degree of flexibility);
- efficiency (an algorithm is a set of rules used to deal with a problem promptly, preferably with the most effective use of resources) (Scheider and Gersting, 1995).

The most common types of algorithms include linear algorithms, conditional algorithms, and repetition algorithms (Wróblewski, 2019). The first type is also called sequential because it does not specify any conditions, and each step in this algorithm occurs in a specific order, so only after completing one can we move on to the next one. An example of a linear algorithm is furniture assembly instructions. The conditional algorithm is more complex. It defines a situation with several choices and, depending on the choice, we can take subsequent steps as a consequence of this choice. An example would be scheduling a meeting. If we schedule a meeting, we can make certain arrangements. If not, we will face other consequences. There is also a repetition algorithm when we have to repeat a sequence of steps to perform an action, e.g. when we connect to a bank for a specific purpose by selecting subsequent PIN digits.

The above-mentioned operations can be performed by a human or – with a large amount of input and output data – an algorithm created by a machine. We then call it machine learning. But the algorithm is then the target effect and not the output effect (i.e. necessary to take any action). The differences are illustrated in Figure 1.

Figure 1.
Machine learning vs traditional programming



Source: (Gralak, 2020).

This is an important distinction because it points to two important roles of algorithms. On the one hand, they can be used to achieve a goal through a planned and repeatable sequence of operations based on input data. On the other hand, they may result from these operations, enabling more complex tasks to be undertaken with large amounts of data.

Machine learning can utilize various types of algorithms. Currently, there are three main categories of algorithms used in machine learning: supervised learning, unsupervised learning, and reinforcement learning. The first and most commonly used category of algorithms is supervised learning. This category uses labeled data (having a single solution, with attached labels that make the data recognizable) to predict the results for other data. Unsupervised learning algorithms receive data that is unlabeled (it can have many or infinitely many solutions). Using this data, they create models and assess the relationships between different data points to provide greater insight into the data. The last major type is reinforcement learning algorithms, which learn from the feedback they receive for the outcome of their operations. This usually comes in the form of a positive or negative reward. A reinforcement learning algorithm usually consists of two main parts: an agent performing an operation and an environment in which the operation is performed. The cycle begins when the environment sends a "status" signal to the agent. This queues the agent to perform a specific operation in the environment. When the operation is performed, the environment sends a "reward" signal to the agent, informing it of what happened, so that the agent can update and evaluate its last operation. Then, with this new information, it can repeat the operation. This cycle repeats until the environment sends a termination signal (Pazdanowski, 2012).

The above algorithms are often an element of statistical analyses in scientific research. They are also an important element of artificial intelligence. A detailed description of selected examples of the use of the above-mentioned algorithms is presented in Table 1.

Table 1.
Descriptions of machine learning categories

Category	Example	Description
Supervised learning	Classification	The algorithm classifies something as one or the other, but never both
	Regression	The algorithm uses the dependent and independent variables to estimate a possible different outcome (prediction or generalized estimate)
	Decision tree	It classifies data based on selection criteria in the so-called decision nodes. With data divided into classes, we can use this data to build rules that classify old or new observations with maximum accuracy
	Random forest	The random forest algorithm is a wide collection of different decision trees, hence its name. It builds different decision trees and combines them to obtain more accurate results. It can be used for both classification and regression
	Linear regression	Linear regression is a supervised learning algorithm used for regression modeling. It is mainly used to discover the relationships between data points and make predictions and forecasts
Unsupervised learning	Clustering	The goal is for each data point to belong to only one cluster, with no overlap. There can be more than one data point in a given cluster, but a data point cannot belong to more than one cluster
	Gaussian mixture model and K-means clustering	They deal with sorting data into predetermined clusters based on proximity. However, Gaussian models are a bit more versatile in terms of the cluster shapes they allow. K-means clustering allows data to be clustered only in circles where the centroid is at the center of each cluster. Gaussian blending can handle data that lands on the graph in more linear patterns creating longitudinal clusters. This allows for greater clarity in clustering if one data point falls within the circle of another cluster

Supervised and unsupervised algorithms	Neural networks	A neural network algorithm is a set of artificial intelligence algorithms that imitate human brain functions. They are usually more complex than many of the algorithms discussed above and have applications beyond some of the ones discussed here. In unsupervised and supervised learning, they can be used for classification and pattern recognition
Reinforcement learning algorithms	Value-based	In a value-based reinforcement algorithm, the agent pursues the expected long-term return rather than just the short-term reward
	Rule-based	A rule-based reinforcement learning algorithm typically takes one of two approaches to determining the next course of action. Either the standard approach, in which any state produces the same action, or the dynamic approach when it calculates and determines certain probabilities. Each probabilisty has a discrete reaction
	Model-based	In this algorithm, the programmer creates different dynamics for each environment. This way, when the agent is placed in each model, it learns to act consistently under all conditions

Source: Author's own study based on (Witten and Frank, 2005; Sarker, 2021; Ersozlu et al., 2024).

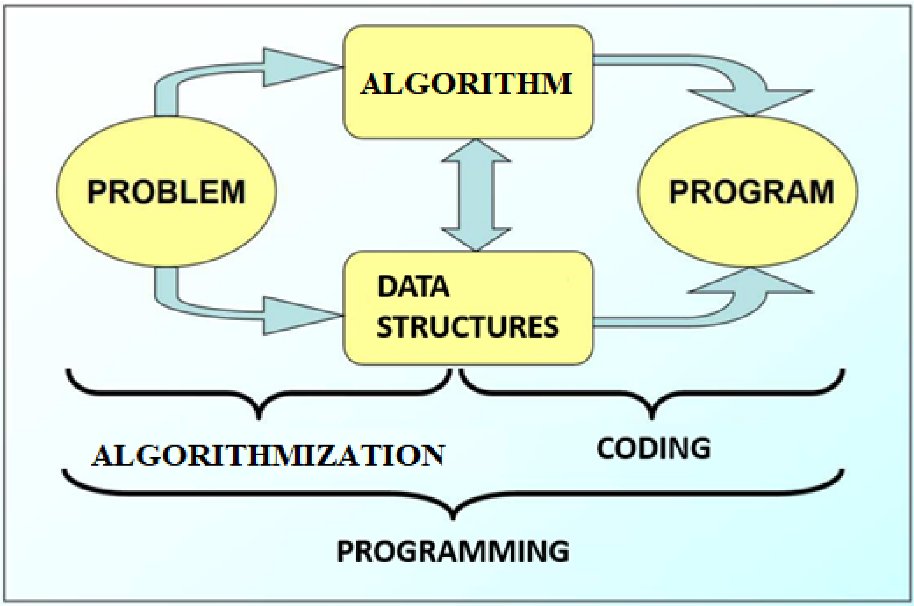
Each algorithm therefore consists of a specific goal, data, and result. Given the same input data, under the same conditions, the algorithm will repeatedly (and therefore predictably) generate the same results. This way achieving the assumed goal can take place in the shortest possible time while minimizing costs. The modularity of algorithms also makes them usable in many areas where the whole algorithm or its parts can be implemented. One such area is the education process, where machines can be used in simultaneous analysis of a large amount of input and output data to create a more advanced algorithm.

The concept of education is still not clearly defined. In Poland, however, there is a common approach that education is the subject of research in the discipline of pedagogy and includes: teaching, education, and upbringing (Niemierko, 2009). Teaching is understood as a conscious, purposeful, and planned process of acquiring skills and knowledge and shaping attitudes and personality within formal and informal activities. This concept is also associated with therapy (which determines the effectiveness of educational activities in children with developmental disorders or difficulties), psychological-pedagogical help, and rehabilitation.

Linking algorithms and algorithmization to broadly understood education is difficult due to their common association with computer and mathematical processes. The *lingo* used in many professional publications makes it difficult for educators or psychologists to navigate the topic and take full advantage of its possibilities minimizing its imperfections and analyzing it critically (Nijenhuis-Voogt et al., 2021).

Children are introduced to programming and coding already at the level of preschool education. For several years now, these classes have been common and eagerly conducted by teachers. Presumably, then, the basic conceptual scope of programming and coding is known to educators, teachers, practitioners, and scientists from disciplines such as psychology or pedagogy. In publications on the subject, the relationships between them are presented transparently, including algorithms (Figure 2).

Figure 2.
Relationships between computer programming, algorithmization, and coding



Source: (Wroński, 2020).

Algorithmization is therefore an important element of the programming process. If we understand it as the ability to plan actions, then algorithmization in its simplest/colloquial understanding is a series of defined, logically ordered actions or commands (with the possibility of repeating and/or modifying the steps) that should allow the user to achieve their goal as quickly as possible.

Virtually any type of algorithm can be used in education, teaching new skills, and transferring/acquiring knowledge. An example of a linear algorithm is the methodology of teaching mathematics or computer science. Conditional algorithms are common in social and emotional education, and the repetition algorithm is one of the basic elements used in curricula.

At higher levels of education, sorting algorithms (used to arrange data in a specific order) or searching algorithms (used to find a specific element in a data set) are also common. Graph algorithms used for route planning or social analysis (e.g. sociometric studies) are less frequent. The use of algorithms in education can be divided into two categories – the use related to new technologies and the use not related to new technologies. Learning using algorithms consists of dividing the given material into sequences of questions and answers, ordered so that correct answers to the preceding questions are necessary for formulating answers to the subsequent questions. This teaching method is primarily used to shape specific skills and habits (until they are automatized) and acquiring knowledge is a secondary goal (Grover and Pea, 2018; Nijenhuis-Voogt et al., 2021).

Teaching independence is also based on algorithms (learning to dress, speak, walk, and eat). The methodology of education is also a set of algorithms (learning to write and read, learning math and grammar) that can be found in the prepared lesson plans, conducted lessons, but also in worksheets or tests.

The scope of using algorithms increases significantly when discussing new technologies in education. The relationship between technology and education has evolved over the years. Films, radio, television, computers, smart boards, and more recently, mobile phones and wearable gadgets are present in the educational landscape. Intensified digitalization has led to the creation and introduction of various guidelines, policies, and recommendations at the national and international levels regarding the implementation of technology in schools and other educational institutions. The growing amount of data has forced the use of further IT achievements such as algorithms and machine learning. They are widely used to analyze and interpret information (e.g. profile students, launch early warning systems, and identify trends in educational choices). Unsupervised analysis and the use of data are considered a key element of the so-called "algorithmic education" (Grover, 2017; Basso et al., 2018). This vision is realized when advanced systems, enriched with big data and unsupervised learning algorithms, are used more and more often in educational ecosystems in contexts where teachers may no longer be needed (Castillo et al., 2022).

The educational process, however, includes not only teaching and learning but also diagnostics and therapy. Diagnostics is understood here as determining the strengths and challenges of a given person in all areas of their development in specific conditions. For many years, standardized psychological tests were used for this purpose. Over time, their computer versions were introduced.

In recent years, more and more applications have appeared that are supposed to enable health monitoring and even remote diagnosis. These include, for example, the Daylio mental health diagnostics application, the HealthNote preventive examination application, the Sleep Cycle sleep monitoring application, the Brain Test for mental effort, or Comarch HealthNote.[1] In the area of children's health

[1] www.pulsmedycyny.pl/comarch-healthnote-poznaj-darmowa-aplikacje-do-monitorowania--zdrowia-osob-chorych-przewlekle-1104189

protection, there are applications used for parental protection (Outsido, Bark, Mobicip, or Norton Family). At first, they were intended only for young people and adults and mainly used in medicine. A recent innovation is the KAPPa application, which successfully diagnoses children and adolescents with special educational needs, including mild intellectual disabilities, visual or hearing impairments, autism spectrum disorders, language communication disorders, developmental dyslexia, and ADHD (Bedyńska et al., 2021; Papuda-Dolińska et al., 2023). This application is intended for psychologists, educators, and other trained individuals. Soon, the number of products based on algorithms, machine learning, or artificial intelligence may increase, which, by utilizing parts of, e.g. medical applications, will be directed toward educational activities. This is possible since both disciplines are similar in terms of the subject of impact (people), the method of impact (preventive or therapeutic intervention), and being based on the so-called evidence, i.e. scientifically verified procedures and products. In education, this is a trend that has been developing very intensively in recent years (Chojak, 2021).

The research activities mentioned above successfully use machine learning. Machine learning is currently developing most intensively in scientific research and educational policy planning, which require the use of advanced statistics. Many decisions that once required professional evaluation are now pre-programmed (Bovens and Zouridis, 2002).

The benefits of using algorithms and machine learning also include:

- improved predictive modeling (the ability to analyze large amounts of data makes it possible to identify patterns or trends; this way more accurate predictive models can be developed and precise forecasts can be prepared, which in turn results in more objective and accurate decision-making) (Guo et al., 2023);
- increased efficiency and automation of basic data, which allows specialists to focus on more complex and creative aspects of their research; this, in turn, may result in an acceleration of the pace of scientific discoveries;
- improved analysis and interpretation of data and patterns, especially the ones hidden in other data, often difficult to notice by humans; moreover, algorithms support quick data interpretation and visualization, helping humans understand complex phenomena (Iwasiński, 2016).

Even though algorithmization is developing intensively in education, among others thanks to intelligent tutorial systems and recommendation algorithms for personalized learning (Chen et al., 2022), recent analyses have shown that (despite the popularity of the algorithms) over 75% of respondents declare a lack of trust towards this technology, its functioning, and the data it generates (Kaufman et al., 2023). Teachers were also included in these analyses. We can talk about the limitations of using algorithms in educational processes from a global and a local perspective.

According to the UN, algorithms (ICT) used in social policy affect the lives of a huge number of people around the world (Alston et al., 2019). However, the method and rules of their creation are not subject to scientific verification, public consultations, or public discussion (Zouridis et al., 2020). It is also highly probable that their designers (anonymous statisticians, IT specialists, programmers, and their employers and clients) may be biased, influenced, or even manipulated by their clients. There is a lack of control mechanisms (Wedel, 2014) that significantly complicates the implementation of the requirements related to transparency and accountability of the undertaken activities. Despite this, these technologies are promoted as a cost-effective, efficient, fair, and bias-free way of administering data. Meanwhile, the knowledge generated by algorithms is probabilistic, and conclusions concern the co-occurrence of phenomena (correlations), not cause-and-effect relationships (Kotnarowski et al., 2021). From a narrower perspective, risks lie also in individual building blocks of algorithms. We already indicated that each algorithm should consist of at least three elements: 1) defining the goal, 2) closed data sets, 3) certainty that a repeated process will produce the same result.

The first challenges appear already at the stage of goal processing. While psycho-pedagogical diagnosis is based on specific international guidelines based on the European ICD 11 classification (International Classification of Diseases 11th Revision) or the American DSM V (Diagnostic and Statistical Manual of Mental Disorders), therapeutic and teaching processes (Babicka-Wirkus and Parezja, 2018; European Agency for Special Needs and Inclusive Education, 2018) or upbringing processes (Radomski and Kalinowska, 2004) are strongly related to socio-demographic and political conditions. Therefore, in this respect, goals are unstable, variable, and often imprecise.

Another challenge concerns the data collection process. Many scientific publications and research (Jarosz and Wysocka, 2006; Zarzecki, 2012; Wysocka, 2013, Chojak, 2021) point to several risk categories:

- related to the researcher (lack of appropriate preparation, prejudices and schematic thinking, difficulty concentrating, fatigue);
- related to the methodology of organizing the study (low-quality tools, tools inappropriate to respondents' age or health condition);
- related to the interdisciplinarity of the research (insufficiently clear and transparent flow of information, increased optimism with decreased criticism and objectivity – the delight effect);
- related to the method of data collection (the researcher is a human or a machine) (Schlund and Zitek, 2024).

A question arises here, whether, in pedagogy or psychology, we can collect data sets that can be described as closed and sufficient, i.e. such that when repeating the algorithm we will obtain the same result, diagnosis, or effect of the teaching or upbringing?

With regard to the teaching and upbringing process, this seems impossible for two reasons. Firstly, the conditions for replicating an algorithm will never be faithfully recreated, because they concern situations with a high degree of individualized development and needs of people participating in a given activity. The interpreted and read data may not be the same. Secondly, it is currently not possible to collect a complete amount of data covering all human characteristics, needs, capabilities, and difficulties, which are constantly evolving and are environmentally determined.

As far as the issue of psycho-pedagogical diagnosis is concerned, the answer could be affirmative. But what if a person has several comorbid diseases? For example, children are very often diagnosed with autism spectrum disorder and ADHD or intellectual disability at the same time. If the goal of the algorithm is to provide accurate and unambiguous diagnostics, it seems impossible in such situations. If the goal was to create the so-called disturbance profile, it is a repeatable process with a repeatable result. The most effective use of algorithms seems to be the so-called screening tests in which, after meeting certain criteria, we only obtain information regarding the need for further diagnostics or the lack thereof. Doing so meets the requirements of algorithms. A similar situation applies to tests for examining the level of development in particular areas without diagnosing any disorders or diseases that could be associated with these results. The acquired data can be used to plan targeted therapy, but the planning itself is a process that is difficult to algorithmize not only because of the infinite amount of data but also because of the so-called cognitive errors (researcher's attitude, stereotypes, practical experience, current attitude, etc.) which may lead to incorrect conclusions, generalizations or biased actions that may be harmful to both participants in a relationship.

Therefore, it is possible to plan certain educational or therapeutic processes (at the policy level, indications and guidelines can be created; the course of diseases or their scope can be predicted), but it would be a mistake to assume that the same plan can be implemented with every child, adolescent or adult in the same way and to the same extent and obtain the same results. This is impossible to implement at the level of specific actions, but it will be effective at the level of macro-measures.

SUMMARY

Algorithmization is becoming more and more common not only at the level of educational policies and scientific research but also in educational processes carried out in specific educational institutions, i.e. in direct contact with people and their everyday lives. We cannot avoid it. However, areas of life/professions where work and cooperation with people are essential should respond to this trend with great caution. In the exact sciences (computer science or mathematics), which algorithms originate

from, and which they are based on, some problems cannot be algorithmized; there are also unsolvable algorithms (Garcia et al., 2004; Guzicki and Zakrzewski, 2005). All the more, social sciences should accept the limitations related to collecting a finite set of data, 100% predictability of the effect, and even the repeatability of a given procedure in light of the unpredictability of human behavior. After all, research into human relationships has shown that algorithms have difficulty predicting romantic attraction and long-term relationship outcomes (Joel et al., 2017).

CONCLUSIONS

The literature on the subject and practical activities indicate that algorithms can be effectively used to collect knowledge and data in many areas. However, they cannot replace the critical assessment of materials or the prioritization of their importance and verification of their truthfulness. Algorithms are useful for statistical data analyses, but the resulting decisions (regarding policy or trends) should be verified and assessed by a human with appropriate knowledge and experience. Moreover, algorithm creators should be verified according to specific criteria, also regarding their personality (e.g. mental disorders).

Algorithmization can be useful in diagnostics when there is a need to analyze large amounts of data (based on strictly defined criteria), which are to constitute a reference point (the so-called evidence) in the process of reliable and rational individualization of therapy (Chojak, 2019).

There are also proposals online to introduce algorithms in the teaching/learning methodology of formulating, for example, simple and complex sentences, dividing a sentence into parts of a sentence and parts of speech. However, what purpose would it serve? Would it support personal development or reduce it to an automaticity of reaching for new technologies even when dealing with simple problems or tasks? Obtaining a quick and correct solution, with a minimum energy cost is one of the ways of activating the punishment and reward system in the brain. This can lead to an addiction: a compulsive and uncritical use of the available technologies that make life easier. As a result, people will create newer and newer inventions as it becomes the main/only/most important goal in life (Chojak, 2019). This seems to be a worst-case scenario but with the lack of control and an uncritical approach to machine learning or artificial intelligence – it may come true.

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ALGORYTMY W PROCESIE EDUKACJI – MOŻLIWOŚCI I OGRANICZENIA

Wprowadzenie: Tematyka zastosowań algorytmów jest obecnie bardzo powszechna w publikacjach naukowych i popularnonaukowych. Coraz częściej sięgają po nią teoretycy i praktycy i związani z nauczaniem, wychowaniem czy terapią, mając nadzieję na zwiększenie efektywności podejmowanych działań oraz ich usprawnienie organizacyjne,
Cel badań: Celem artykułu jest przedstawienie możliwości i ograniczeń implikacji algorytmów do procesu edukacji.
Stan wiedzy: W ciągu ostatnich lat znacznie wzrosła liczba publikacji, poświęconych problematyce związanej z AI oraz procesem algorytmizacji. Zdefiniowanie pojęcia algorytmu, wskazanie jego związku z uczeniem maszynowym oraz sztuczną inteligencją dookreśliło możliwości zastosowania algorytmów w wielu obszarach naszego życia – od aplikacji wykorzystywanych na osobistych urządzeniach, poprzez medycynę, bankowość, politykę oświatową do badań naukowych. Coraz większa popularyzacja algorytmizacji oraz łatwiejszy dostęp do tej technologii, spowodowała podjęcie dyskusji nad jej ograniczeniami i niebezpieczeństwami w sposób pośredni i bezpośredni, dotyczącymi również dzieci.
Podsumowanie: Praktycy i naukowcy zajmujący się procesami edukacji posiadają wciąż niewystarczającą wiedzę dotyczą poruszanego tematu. Niewiele publikacji naukowych czy popularnonaukowych autorstwa realnych specjalistów jest skierowanych do tej grupy odbiorców. Bez dokładnego rozeznania w tematyce algorytmizacji, uczenia maszynowego czy sztucznej inteligencji implikacja algorytmów może nie tylko nie przynieść zamierzonych rezultatów, ale skutkować zaburzeniami rozwoju dzieci, młodzieży i osób dorosłych.

Słowa kluczowe: algorytm, algorytmizacja, procesy edukacyjne, nauczanie, wychowanie, terapia