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EDITORIAL

The 2024 *Journal of Education, Technology and Computer Science* yearbook consists of three main thematic parts, whose overall theme is the problems of computerisation of education and related psychological issues.

In the first part, entitled *Selected Problems of Technical Education*, we get acquainted with articles presenting, among other things, a proposal for the inclusion of objectives in the 3rd educational cycle of primary school in Slovakia; curricular solutions for primary education also in Slovakia; attention to the qualification of teachers as an important factor in teaching technology. The part concludes with an article on the use of graphic programmes in secondary and higher education.

The second part, entitled *Selected Problems of Computer Science* applications, consists of papers presenting, among others, parallel programming in computer environments; the use of VR technology in teaching electrical engineering on the example of the VES application. This part concludes with a paper presenting modelling approaches and tools for predicting the arrival of the next wave of pandemics.

The third part, entitled *Selected Problems in the Psychology of Education*, describes the current status in terms of schools' readiness to implement teaching aimed at developing commutative thinking; a study of the popularity of the CodeCup team programming competition in Hungary; the principle of polymorphisation in teaching mathematics; and the possibilities of intellectual development of humans after the age of 60. This section concludes with a study on the links between music and technology as a factor in the interdependence of students' mental health.

Readers are encouraged to critically analyse and prepare polemical texts in relation to the diverse topics of educational research covered in the quarterly.

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WOJCIECH WALAT[1], **TOMASZ WARZOCHA**[2]

Oświadczenie autorów artykułu pt. „Podręczniki szkolne w Galicji w II połowie XIX i na początku XX wieku w świetle prac Komisji Podręczników Szkolnych przy Radzie Szkolnej Krajowej" opublikowanym w czasopiśmie „Edukacja – Technika – Informatyka" (2018) dotyczące zapożyczeń z artykułu Profesor Marii Stinii

Statement by the authors of the article „School Books in Galicia in the Second Half of the Nineteenth and Early Twentieth Centuries in the Light of the Work of the Commission for School Handbooks at the National School Board" published in the journal "Education – Technology – Information Science" (2018) regarding borrowings from an article by Professor Maria Stinia

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Abstrakt

Składamy na ręce Pani Dr hab. Marii Stinii, prof. UJ nasze przeprosiny za zaistniałą sytuację związaną z nieuprawnionymi zapożyczeniami z artykułu Pani Profesor pt. *Podręczniki w gimnazjach galicyjskich w latach 1860–1918*, który został opublikowany w Pracach Komisji Historii Nauki Polskiej Akademii Umiejętności 6, 5–39 w 2004 roku. Przeprosiny kierujemy również do Redakcji obu czasopism oraz środowiska naukowego historyków.

Słowa kluczowe: oświadczenie autorów, nieuprawnione zapożyczenia, podręczniki szkolne, Galicja II połowa XIX w.

Abstract

We extend our apologies to Professor Maria Stinia at the Jagiellonian University, for the situation concerning unauthorised borrowings from her article entitled handbooks in Galician grammar schools in the years 1860–1918, which was published in Works of the History Commision of Science of the Polish Skills Academy of 6, 5-39 in 2004. Our apologies are also addressed to the Editors of both journals and to the scientific community of historians.

Keywords: statement of authors, borrowings, handbooks, Galicia second half of the 20th century

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Przeprosiny i działania naprawcze

W związku z zaistniałą sytuacją podjęliśmy się szeregu działań naprawczych, które polegają na tym, że

1) artykuł w numerze specjalnym czasopisma „Edukacja – Technika – Informatyka" z 2018 roku, w którym ukazał się przygotowany przez nas artykuł, został na stałe zablokowany, co oznacza powstrzymanie procesu rozpowszechniania jego treści;

2) zobowiązujemy się również do prowadzenia systematycznych działań monitorujących elektroniczne bazy danych w celu usunięcia wadliwego artykułu z obiegu prac naukowych w możliwym dla nas zakresie;

3) niniejsze przeprosiny zamieścimy w bieżącym numerze czasopisma „Journal of Education, Technology and Computer Science", będącego kontynuacją „Edukacji – Techniki – Informatyki", oraz przekażemy je Redakcji „Studia Historiae Scientiarum", które z kolei jest kontynuacją „Prac Komisji Historii Nauki Polskiej Akademii Umiejętności".

Wyrażamy nasze głębokie ubolewanie w związku z zaistniałą sytuacją, a jednocześnie zobowiązujemy się że w każdej sytuacji po dostrzeżeniu i w następstwie ujawnieniu braków i nieprawidłowości w przedmiotowej sprawie podjęte zostaną działania naprawcze. Składamy podziękowanie za przychylność ze strony Pani Profesor Marii Stinii dla podjętych przez nas działań zmierzających do usunięcia wadliwego artykułu. Zobowiązujemy się także do zwrócenia należytej staranności związanej z etyką nauczyciela akademickiego przy opracowywaniu kolejnych publikacji naukowych.

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PART ONE

SELECTED PROBLEMS OF SCHOOL EDUCATION

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JOZEF PAVELKA

Proposal for the Breakdown of the Objectives of Technical Education in 3. Cycle of Primary School in the Light of the New School Reform

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Abstract

In relation to the aims and objectives of the ongoing curriculum reform in Slovakia, the study presents a possible approach to working with the newly conceived educational objectives of technical education in primary schools in Slovakia, based on an analysis of the educational area of Man and the World of Work.

Keywords: technical education, educational objectives, primary school, curriculum reform

Introduction

As part of the curriculum reform in Slovakia, new objectives and new educational content were set for technical education in primary schools through the State Educational Programme (SEP) and educational standards.

The educational area of Man and the World of Work (M&WW) is characterised in the new curriculum as follows. The basic building blocks of the field of HR and WL are three components: Technology, Entrepreneurship and Initiative and Career Education. All three components are interlinked so that the emphasis is on the development of technical, creative and critical thinking in the educational domain. Emphasis is placed on developing students' technical and career literacy. The term technical literacy refers to pupils' ability to use, manage, evaluate and understand technology.

The content of the learning area of M&WW is linked to the solution of practical tasks, which are procedurally linked to planning, active experimentation and learning from experience. Pupils should be able to navigate the world of technology, to understand trends in technological development and the context of scientific progress, but also the impact of human activity on the world. Emphasis is placed on the creative and innovative use of technological tools to achieve a goal, or to draw conclusions based on evidence (SPP, 2023).

The subject matter of the study. Educational standards of the educational area Man and the world of work for the 3rd cycle

The curriculum sets the Educational Standards of the educational area of HR and WORK separately for the 1st to 3rd cycle of education (grades 1 to 3, 4 and 5, and 6 to 9 of primary school) and separately within each cycle for the individual components of Technology, Entrepreneurship and Initiative and Career Education in 3 parts: performance standard, content standard and activities.

The learning objectives and content in the Technology component largely replicate the objectives and content that have been set by the learning standards from 2015 to date. What is new in the SPP is that, in contrast to the educational standard of the previous teaching subject Technology, which partly included objectives and contents related to entrepreneurship and initiative and to a large extent also to career education, the SPP sets a new separate educational standard for both the Entrepreneurship and Initiative (PaI) component and the Career Education (CE) component.

It is not the purpose of this study to present a complete analysis of the educational domain of M&WW. The aim is to present a proposal or analytical guide on how technology teachers can approach working with the new educational standard of the educational area M&WWset for Cycle 3.

The main aim of the 3rd cycle is to learn about and work with materials and technologies for their processing. Pupils learn not only to use technical devices and objects, but also to design, make and evaluate them. They learn to analyse their creative and technological abilities and thus develop their technical literacy. Pupils are able to apply basic strategies and methods of career planning, thus developing their vocational literacy. (SPP, 2023)

The curriculum introduction sets out the main learning objectives for Cycle 3 of the M&WW learning area for all 3 components (Technology – Career Education – Entrepreneurship and Initiative) and Years 6 to 9 of Primary School in one block. In the same way, the specific (concrete) objectives for each component are given in the blocks for grades 6 to 9 of the third cycle of primary schools. It is not clear from this block-by-block breakdown which of the component objectives belong to each grade in Cycle 3. At first glance, this form of elaboration seems to be in order, since the contents, objectives and activities of the learning domain M&WW are to be implemented and fulfilled during the 4 years of education of the 3rd cycle. The problem, however, is how teachers approach the development of the Thematic Education Plans (TEPs) for each year of Cycle 3 – haphazardly or analytically. The only tool that can guide technology teachers to a serious and justifiable breakdown of the stated objectives of the Technology component (and other components) into grades 6 to 9 of primary school is the existing and still valid Educational Standard of the subject of technology for lower secondary education from 2015.

Development (analysis of research results). Proposal for the breakdown of the objectives, learning content and activities of the Technology component of the educational field of M&WW in the 3rd cycle of primary school

The starting point for the creation of Table 1 was the curriculum for the educational area M&WW (pages 11 to 14) – the Technology component. Table 1 does not incorporate the performance and content standards set out in the SPP for the Career Education and Entrepreneurship and Initiative components. Their specific breakdown into the different grades of Cycle 3 is left to the Technology teachers themselves. In breaking them down into grades, they should apply the requirements of age-appropriateness, challenging objectives and learning content, logical and graded sequencing, appropriate and correct interrelationship of the specific objectives of all three components of the M&WWlearning area, etc.

The breakdown in Table 1 presents an analytical proposal for the possible inclusion of the new performance objectives, learning content and activities set out in the SPP in Years 6 to 9 of primary school (Cycle 3). The proposal takes into account the existing breakdown set out in the 2015 Educational Standard for the subject of technology. The proposed breakdown enables teachers of technology to be significantly better oriented to the requirements set out in the curriculum (M&WW) for Cycle 3 and thus more consistently and qualitatively to develop the SPP curriculum for each year of Cycle 3 of primary school. It should be noted that in a number of cases in Table 1 the subject headings are assigned to more than one year of cycle 3, e.g. year 3 of cycle 3. 6th to 9th Primary School – thematic area Processing of technical materials. Further elaboration of the above-mentioned subject area is left to the teacher, who sets specific objectives, learning content and activities for specific years 6 to 9 of primary school, taking into account, for example, the difficulty and number of work operations, their age appropriateness, time requirements, etc.

Table 1. Breakdown of the requirements of the Technology component for Years 6 to 9 of Primary School (Cycle 3)

Grade	Performance standard The pupil can:	Content standard	Activities
	Thematic area Patents and Inventions		
6.	– independently search for and use knowledge about various inventions, discoveries and patents,	– history of technology – making a project on the topic of Slovak and world inventors and the theme of remarkable technical solutions in the life of urban and rural man in the past,	Discovery Resolution, inventions and patents. Application of examples of the use of Slovak and world inventions in practice.

Thematic area Graphic communication			
6. and 7.	– draw a simple technical drawing, select a suitable view to display the body in 2D view (front, top, side view), create technical documentation for your own simple product in electronic form, – simulate and compare the roles of a designer, engineer, designer and worker, – use artificial intelligence to solve specific tasks, evaluate work with artificial intelligence, validate AI responses with other sources and critically evaluate them,	– creating a technical drawing, – graphic communication – application of line types and orthogonal projection in the creation of a technical drawing drawing, – displaying objects in 2D, – assessing the difference between an engineer, a designer, a designer, a worker – their main tasks, activities and differences between them. – Independent creative activity of pupils (design, creation of products).	Creation of technical drawings.
Thematic area Technical materials, properties, practical applications			
6. and 7.	– compare, distinguish and investigate the properties of different woods, metals, plastics, ceramic and composite materials, glass, rubber, textiles, being able to give examples of their use and to carry out a simple experiment to compare selected properties of different types of materials, – demonstrate the possibilities of recycling, separating and disposing of selected technical materials from a technical point of view,	– technical materials (wood, metals, plastics, ceramics, rubber, glass, etc.), – basic properties of technical materials, recycling of technical materials,	
Thematic area Processing of technical materials			
6. to 9.	– to implement selected work procedures of manual and machine machining of materials on the product according to a technical drawing and justify the choice of machining when creating a simple product, – behave as a conscious consumer and use digital tools in a variety of work to work in a variety of activities and team projects, applying the principles of occupational health and safety at work,	– activities in manual processing of technical materials (measuring, contouring, cutting, shearing, bending, straightening, filing, rasping, rasping, chiselling, drilling, soldering, structural joining of wood, surface treatment of wooden and metal materials, etc.), – machine and progressive methods of processing wood, metals, plastics,	Independent manual processing of technical materials and manufacture of technical products. Work on small lathes, with a hand drill and machine processing of technical materials (wood, non-ferrous metals and plastics). Assessment the importance and use of simple machines and mechanisms in practice.
Thematic area Simple electrical circuits.			
6. and 8.	create your own simple electrical circuit using a virtual electronic kit and visualise it using digital technologies,	simple electrical circuits (connecting an appliance to an electrical circuit, diode and transistor in an electrical circuit),	Wiring simple electrical circuits. Connecting semiconductors (diode, transistor) to an electrical circuit.
Subject heading Simple machines, gears			
6. and 8.	apply the principles of simple machines in practice and define the types of gears in equipment used in the home,	simple machines, mechanisms in the household – the use of simple machines and mechanisms in practice with regard to their consumption and financial costs according to the energy label	

	Thematic area Residential installations		
8. and 9.	using artificial intelligence to create a list of rules and procedures to eliminate simple faults in the residential installation while observing OHS,	– residential installation (plumbing, sewerage, gas installation, wiring, heating, cooling, recuperation),	Work with kits focused on residential and house installation.
	Thematic area Machines and equipment in the household.		
7. and 8.	identify potential hazards when working with machines, equipment, robots and, for example, using artificial intelligence to create a list of rules and procedures to eliminate simple malfunctions in a residential installation while maintaining OSH,	– mechanical, gas, petrol and electrical appliances and equipment in the home – operator and maintenance of household appliances and equipment, their impact on the environment,	Retrieved from minor maintenance of household appliances and equipment.
	Thematic area Saving costs in the home		
8. and 9.	calculate the consumption and financial cost of running the machinery and equipment used in the home on the basis of the energy label, justify the collection, sorting and disposal of hazardous electrical waste, distinguish between machinery and equipment different types of powered equipment and consider their impact on the environment, and find information on renewable energy sources energy and their use, – work collaboratively in a shared working environment.	– mechanical, gas, petrol and electrical appliances and equipment in the home – renewable energy sources and their use.	

In order to contribute to a higher level of development of primary school pupils in the area of career orientation, entrepreneurship and initiative, the creators of the educational standard for the educational area of M&WW put emphasis on these areas by setting new components for them Entrepreneurship and Initiative and Career Education and developed separate performance and content standards.

It can be assumed that teachers' techniques for formulating the performance standard of the PaI component, such as taking appropriate initiative and independently seeking opportunities to develop one's own idea or respecting intellectual property in the development and presentation of one's idea, and also the performance standard of the CT component, such as applying basic techniques, strategies, and methods of action planning with respect to one's own career direction, will pose significant problems in achieving the objectives of the Technique component. The problem will be not only to develop and plan the timing within the technology lessons, when and methodologically how the PaI and KV objectives are to be implemented, but especially with which technology component curricula to link (also multiple) the achievement of the objectives, and where to get the educational content for the PaI and KV components from, if new technology textbooks corresponding to the requirements of the 2023 curriculum do not exist.

The analysis of the documents Renewal Plan – Component 7 (2021) and Feasibility Study on Generalizable Typical Solutions for Primary Schools (2022) shows that the reform activities (e.g. construction of new primary schools and school libraries) do not envisage at all the construction and completion of school vocational classrooms for technical education (school workshops and vocational classrooms), including their material and technical equipment and retrofitting!

As it is generally known, the goals and objectives of technical education in primary schools have not been met to the required extent in the previous period (Hašková, Lukáčová, 2022; 2023). And here the question is raised: What was the cause of the aforementioned state of affairs? The main reason can be clearly identified as a long-term and unsystematic approach of state authorities, school founders and in some cases the management of primary schools to the creation of the necessary spatial, material and technical and personnel provision of technical education in primary schools. Several published works based on the results of surveys and researches repeatedly confirm that in many schools in the Slovak Republic, school workshops are located in inadequate premises in terms of the applicable OSH standards, workshops have mostly outdated material and technical equipment and the non-professionalism of technical education is at the level of approximately 53%.

Reform material Basis for changes in the educational areas… M&WW states:

– to promote pupils' ability to use innovative thinking, knowledge of science and technology and manual skills to implement their own designs,

– the development of pupils' ability to use and handle technical tools and apparatus as well as scientific data to achieve goals or make decisions, express opinions based on evidence, etc. (SEN, 2021).

If the educational field of M&WW is to move towards the above, then to achieve the desired effect of the reform changes, it is necessary to simultaneously provide dedicated financial support to schools to retrofit the material and technical facilities (MTF) for technical education. Innovation and upgrading of the MTF in schools should become a matter of course and should be related to provision:

– basic and diversified technical material (semi-finished products),

– basic and further content and the objectives of technical education adequate interior equipment of school workshop classrooms,

– basic and appropriate additional technical equipment with teaching aids, apparatus, equipment, technical kits, etc,

– basic equipment with digital resources and ICT.

The absence of the above-mentioned MTF in schools does not enable teachers and pupils, among others:

– to ensure knowledge of the types, properties and uses of materials in practice and thus to develop technical creative thinking, critical thinking, to draw conclusions based on evidence and to carry out interesting and motivationally effective experimental and exploratory activities,

– to carry out real practical activities of pupils with the equipment indicated, pupils are unable to learn about different professions and cannot make objective and self-critical decisions about their future career paths,

– to develop pupils' abilities to use and handle technical devices and equipment, to understand their function, significance and environmental context, to analyse the necessary data, to compare them and to draw conclusions or make decisions,

– to develop digital literacy and to know and communicate to pupils in a short time the 'just what is needed' from a vast amount of information in selected areas of technology.

On the basis of the above, we propose that, as part of the reform changes, the Spatial and MTF Standards for Technical Education for School and Pupil should be added to the reform materials for the educational area of M&WW. If the aims, objectives and content of technical education are changed and innovated, the normative that must be fulfilled in schools within a specified timeframe must also be changed (logically on the part of the state authorities) in an adequate and systematic way. However, the fulfilment of this requirement cannot remain with the schools alone. In this respect, the reform changes being prepared should and must be financially supported and secured by the state – even if additionally. Otherwise, the entire reform effort, its results and teaching in the educational field of M&WW will be implemented on a theoretical level and the reform intentions in the field (including in the Profile of the Primary School Graduate) will not produce the desired results.

Conclusion

Work on the implementation of the school reform in the Slovak Republic is intensively underway and the implementation of the reform in practice has been underway since kindergarten. 2023/2024 is becoming a reality. It is not too late to take the additional measures we have outlined in the field of technical education in primary schools. Their early implementation in school practice can make a significant contribution to improving the basis for the forthcoming reform of secondary technical education and to orienting well-prepared pupils towards study in the secondary VET Centres of Excellence.

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Teacher Qualifications – an Important Factor in the Subject of Technology

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Abstract

The subject of technology in primary schools has not been sufficiently provided with space and material since the reform changes in 2008 and subsequently since the curriculum innovation in 2015. Research by several authors points to this fact. In this article, we investigate the relationship between the views of teachers of the subject of technology on the material and technical equipment of schools for teaching this subject and the qualification of teachers.

Keywords: questionnaire, teacher, technique, qualification, spatial and material-technical equipment

Introduction

There is quite a lot of research that examines the relationship between teacher qualifications and student achievement. For example, Darling-Hammond, Berry, and Thoreson (2001) found a strong relationship between teacher certification and student achievement in their study. Similar conclusions are published by Wayne and Young (2003), who state that there is a relationship between teacher certification and student achievement in mathematics instruction. Clotfelter, Ladd, and Vigdor (2007) report that teacher experience, test scores, and licensing have a positive impact on student outcomes. These effects were most evident for teachers teaching mathematics and reading. Similarly, a longitudinal study by Se Woong Lee and Eunjung Alice Lee found a positive relationship between students' highest educational attainment and the cumulative rates of experience, level of education, and expertise of the teachers who taught them.

Fewer studies focus on examining the relationship between teacher qualifications and teachers' views on students' attitudes toward the subject, or the material and technical support of the subject. Among other things, a quality technology teacher is expected to use not only a sufficient amount of traditional tools and technical consumables in teaching but also a wide range of modern 3D teaching aids (Pavelka, 2018; Pavelka, Plachá, 2018). However, if the teacher is not qualified, they may not even have the necessary material resources at their disposal. The qualification of technology teachers in Slovakia was studied by Hašková (2016) and Hašková and Bánesz (2015), who found that in the sample of 509 elementary schools from regions across Slovakia, the teaching of technology was covered by qualified teachers at a level of 39% of the total number of schools.

Aim and methodology of the research

The aim of the research was to determine the opinions of technology teachers on the material, technical, and spatial support for teaching the subject of technology in elementary schools and students' attitudes toward this subject.

In line with our research objective, we formulated the following hypotheses:

H1: Opinions on the material, technical, and spatial equipment for teaching technology differ between teachers who are professionally qualified to teach it and those who are not.

H2: Opinions on students' attitudes toward the subject of technology differ between teachers who are professionally qualified to teach it and those who are not.

The questionnaire for teachers contained 13 items: five identification items aimed at determining gender, age, length of teaching experience, professional qualification, and the number of years respondents have taught the subject of technology. Another six items were closed-ended. In the sixth item, respondents could choose between yes/no answers, and for items seven to eleven, they could select from scaled responses: slightly agree, agree, slightly disagree, disagree. The last, 12th item of the questionnaire, was open-ended and supplemented item 11.

The questionnaires were distributed to all technology teachers in the Nitra region through the Regional School Administration Office and the Diocesan Office in Nitra. The collected data were evaluated using MS Excel. The data were processed using standard mathematical-statistical methods. Descriptive statistics were used for analyzing the questionnaire items, with absolute and relative frequencies of individual responses. The hypotheses were tested using statistical tests. The output data were statistically verified using the Mann-Whitney U test. The Mann-Whitney U test is used when testing the difference between two independent groups of a continuous variable (Borůvková, Horáčková, Hanáček, 2014). In this test, we test the null hypothesis, which states that the two samples from which the selections are made have the same median value. If the value of the test statistic is greater than the critical value, the null hypothesis is rejected. In conducting the test using a statistical program, the rejection of the null hypothesis depends on the p-value. If the p-value is less than the set significance level of 0.05, the null hypothesis is rejected.

Research results

The research involved 63.10% women and 36.90% men. The gender of respondents was not considered during the selection process; however, as we can see, women teach the subject of technology in elementary schools more often than men.

Approximately one-third of technology teachers participating in our research were aged 31–42, while less than one-third (29.2%) were aged 42–55, and 26.20% were aged 56-65. The smallest group of respondents (12.30%) was under 30 years of age or exactly 30.

An interesting finding is that approximately the same number of respondents (almost a quarter) have been teaching for either more than 25 years (26.15%) or less than 5 years (24.62%). Around 16.92% of respondents reported a total teaching experience of 6–10 years, and 15.38% had 21–25 years of experience. The duration of working as a teacher for 16–20 years was reported by 9.23% of technology teachers, while 7.69% had been teaching for 11–15 years. Based on this, we can conclude that although experience in teaching this subject is essential, in our opinion, new employees in schools can bring fresh ideas and suggestions for the subject.

More than half of technology teachers in the Nitra region do not have the professional qualification to teach the subject. Only 49.20% of teachers are qualified to teach technology, which likely affects the quality of the teaching process.

We also examined how many years the surveyed teachers have been teaching technology. More than half of the respondents have been teaching the subject for less than five years. Approximately 20% of respondents have taught technology in elementary schools for 6–10 years. The same proportion of respondents – 9.23% – have been teaching the subject for 11–15 years and more than 25 years. Approximately 5% (4.62%) have been teaching technology for 16–20 years, and the smallest group of respondents (3.08%) has been teaching the subject for 21–25 years. From this, we can infer that while technology teachers in elementary schools in the Nitra region have generally been teaching for a long time, only a small portion of them have extensive experience specifically with the subject of technology, which may be related to a lack of expertise in teaching. More than 70% of respondents have been teaching this subject for less than 11 years.

In the 6th item of the questionnaire, we asked whether "The school has spatial equipment for teaching the subject of technology (workshops, school grounds, practice kitchen)."

The majority of respondents, 78.5%, agreed that their school has the necessary spatial equipment for teaching technology, including workshops, school grounds, and a practice kitchen. A total of 13.80% agreed to a lesser extent, and 6.20% slightly disagreed. Only 1.50% of respondents completely disagreed with the statement. Based on this, it can be concluded that most of the elementary schools surveyed in the Nitra region have good spatial facilities for teaching the subject of technology.

Next, respondents were asked to express their opinion on the statement: "The spatial and material-technical equipment of the school allows me to teach the subject of technology in accordance with the State Educational Program (SEP) and the School Educational Program (SchEP) (hour allocation and educational standards)". According to 61.50% of respondents, the level of spatial and material-technical equipment in their school allows them to meet the educational standards in accordance with the SEP and SchEP. Less agreement with this opinion was expressed by 26.20% of respondents, while 10.80% slightly disagreed, and 1.50% disagreed with this statement. From these results, it follows that approximately 13% of elementary schools, according to the opinion of technology teachers, do not have sufficient material and spatial equipment to meet the educational standards of the technology subject, which negatively impacts students' acquisition of practical skills.

The eighth item of the questionnaire investigated respondents' opinions on whether students have the opportunity to develop their work skills through independent work. Almost three-quarters of respondents (72.30%) answered that, in their opinion, students have the opportunity to develop work skills through independent work. Less agreement with this opinion was expressed by 18% of technology teachers. Slightly disagreeing with the idea that students have the opportunity to develop work skills through independent work were 7.70% of technology teachers in elementary schools in the Nitra region, while 1.50% disagreed entirely, which aligns with the negative responses given by teachers to the previous two items concerning school equipment. According to the majority of technology teachers, students do have the opportunity to develop their work skills through independent work.

The ninth item of the questionnaire sought teachers' opinions on whether students are interested in learning the subject of technology. More than half of the respondents (50.80%) answered that, in their opinion, students show interest in learning technology. Less agreement with this view was expressed by 38.5% of teachers, while 9.20% slightly disagreed with the statement that students are interested in learning technology, and only 1.50% of technology teachers disagreed.

Item 10 of the questionnaire asked whether today's students are skilled in using hand tools, according to the teachers' opinions. Only 13.8% of respondents agreed with this statement, 50.80% agreed to a lesser extent, and 23.10% slightly disagreed with the idea that today's students are skilled in using hand tools, while as many as 12.30% of respondents disagreed that students are skilled in using tools.

In item 11, we wanted to gather teachers' opinions on whether the subject of technology influences students' career choices. Nearly half of the teachers believe that the subject of technology influences students' choice of future profession. Approximately one-third of respondents somewhat agreed that this subject affects students' career choices. 12.30% of respondents slightly disagreed with the influence of the subject of technology on students' career choices, while 7.70% of technology teachers in elementary schools disagreed entirely with this statement. These results suggest that most respondents believe that this subject influences students when choosing their future careers.

We supplemented this item with item 12, in which respondents could explain their previous opinions in their own words. Nine respondents did not use this opportunity, and 18 respondents said they could not express an opinion on the issue. The other responses were categorized based on which statement they were explaining.

Reasons supporting the statement that the subject of technology influences students' career choices:

– it depends on the technical proficiency of the student (7 respondents),

– through this subject, students acquire technical skills, learn to cook, work with finances, etc., and develop an interest in technical skills (7).

– an enthusiastic teacher can influence a student (1).

Reasons supporting the statement that the subject of technology does not influence students' career choices:

– students are not interested in manual work (12),

– teaching the subject of technology requires material-technical and spatial equipment that not all schools have (3),

– other factors have a greater influence on students' decisions – parents, the internet (3),

– limited scope of technology education (2),

– unqualified teacher (1),

– not every topic covered in the subject affects students' future career choices (1) (Štetková, 2023).

Verification of Hypothesis H1

Table 1 presents how teachers' views on the material-technical and spatial equipment for teaching the subject of technology are influenced by their professional qualifications. Nearly 34% of teachers with professional qualifications for teaching technology agreed that elementary schools in the Nitra region are adequately equipped for teaching technology, while for teachers without professional qualifications, this share was 28%. Less agreement with this opinion was expressed by 17% of respondents without professional qualifications and 9% of respondents with professional qualifications.

Table 1. Teachers' Views on the Material-Technical Equipment for the Subject of Technology

	The school has the spatial facilities for teaching the subject of technology (workshops, school grounds, practice kitchen).				
	I somewhat disagree	I somewhat agree	I do not agree with the statement	I agree	Total
qualified	6.15%	9.23%	0%	33.85%	49.23%
unqualified	4.62%	16.92%	1.54%	27.69%	50.77%
Total	10.77%	26.15%	1.54%	61.54%	100%

We tested the null hypothesis: The views on the material-technical and spatial equipment for teaching the subject of technology do not differ between teachers who have the professional qualifications to teach it and those who do not.

Table 2. Mann Whitney U-test for H1 hypothesis

Mann-Whitney U	471.000
Wilcoxon W	1032.000
Z	–.865
p	.387

For the possible rejection of the null hypothesis, the size of the p-value, which is shown in Table 3 under the row "Asymp. Sig. (2-tailed)," is decisive. In our case, the p-value is greater than 0.05 (p=0.387), so we do not reject the null hypothesis: "The views on material-technical and spatial equipment for teaching the subject of technology are the same for teachers who have the professional qualifications to teach it and those who do not." In practice, this means that the difference between the views on material-technical and spatial equipment for teaching the subject of technology between teachers who are qualified to teach it and those who are not is not statistically significant.

Verification of Hypothesis H2

In Table 3, we present how teachers' professional qualifications influence their views on students' attitudes towards the subject of technology.

Table 3. Teachers' opinions on students' attitudes towards the subject of technology

	Students are interested in learning in the subject of technology.				
	I somewhat disagree	I somewhat agree	I do not agree with the statement	I agree	Total
qualified	1.54%	15.38%	0.00%	32.31%	49.23%
unqualified	7.69%	23.08%	1.54%	18.46%	50.77%
Total	9.23%	38.46%	1.54%	50.77 %	100%

We tested the null hypothesis: The opinions on students' attitudes towards the subject of technology do not differ between teachers who have the professional qualification to teach it and those who do not.

Table 4. Mann Whitney U-test for H2 hypothesis

Mann-Whitney U	361.500
Wilcoxon W	922.500
Z	–2.425
p	.015

As we can see, the p-value is less than 0.05, specifically 0.015. This indicates that the difference in opinions regarding students' attitudes towards the subject of technology between teachers who have the professional qualification to teach it and those who do not is statistically significant.

Discussion and conclusion

We found that most technology teachers in the Nitra region do not have professional qualifications to teach the subject; however, the differences were minimal, as nearly 50% of teachers are qualified to teach it. In our opinion, this fact also affects students' interest in the subject of technology. According to the technology teachers, elementary schools in the Nitra region have adequate spatial and material-technical equipment for teaching technology. They also believe that students are interested in the subject, and, according to most respondents, it also influences their choice of future career. However, as reported by the teachers, students are not very skilled in using hand tools.

Although the technology teachers did not indicate that students have significant problems performing practical activities, they did respond that working with hand tools is not entirely easy for them. We found that there is no statistically significant difference between the opinions of teachers who are qualified to teach technology and those who are not regarding material-technical and spatial equipment for teaching the subject. On the other hand, the difference in opinions on students' attitudes towards the subject between qualified and non-qualified teachers is statistically significant. Teachers who are qualified to teach technology are more optimistic in believing that students are interested in the subject. We think these two attributes are interconnected. A qualified teacher is enthusiastic about the subject of technology, which can be reflected in their students' interest in technology. Conversely, if a student is interested in technology, a qualified teacher will further support that interest.

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AR Application Design Requirements for Technical Education

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Abstract

We cannot question the importance of technical education at the present time. Each education has its own specifics, which must be considered during scientific and research activities. The paper deals with the AR application design in education. Within this contribution, we are based on the characteristics of augmented reality and the possibilities of developing applications for education, which relate to the Cognitive Theory of Multimedia Learning and our experience with the possibilities of creating applications in augmented reality. Based on this, in the contribution we defined five key areas (appearance, functionality, content, cognitive effectivity and sharing, compatibility and connectivity) of requirements for the design of AR applications with the specification of cognitive effectivity for technical education.

Keywords: augmented reality, technical education, AR application, design requirements

Introduction. Augmented reality in education

The first appearance of Augmented reality (AR) date back to the 1950s when Morton Heiling, a cinematographer, thought of cinema is an activity by taking in all the senses in an effective manner. In 1962, Heilig built a prototype of his vision which he described in 1955 in „The cinema of the Future" named Sensorama, which predated digital computing (Furth, 2011). Real prototype based on AR principle can be estimated around 1968 when Ivan Sutherland created the first head-mounted 3D display which projected a simple framed graphical view into a room (Pasaréti *et al.*, 2011).

Augmented Reality (AR) combines real-world environments with computer-generated objects, allowing users to naturally interact with overlaying three dimensional (3D) objects in the physical environment (Azuma, 1997). This technology is realized by application and device, which can possibly represent all information, as illustrated on Figure 1 on the left picture. Augmented reality technology integrates digital information with real environments in which people live. Everything is processed and produced in real time. This is one of the main differences with virtual reality, which uses artificial environments. Augmented reality uses the real world and completes it with digital information (Curcio, Dipace, Norlund, 2016). This technology is less developed largely because it needs even more processing power. It must interpret the real world and adhere to it all the digital information available to the system in question. This means processing a reality with infinite variables that change without a closed argument (Fernandez, 2017).

We also considered AR application that require removing real objects from the environment, which are more commonly called mediated or diminished reality (Azuma, 1997), in addition to adding virtual digital objects, Removing objects from the real world corresponds to covering the object with virtual information that matches the background to give the user the impression that the object is not there. Virtual objects added to the real environment show information to the user that the user cannot directly detect with his senses. This application is represented by a tablet device on Figure 1 on the right picture. Mixed reality combines real and virtual settings in various ways, to enable psychological immersion in a setting that blends physical and digital phenomena (Liu, Dede, Huang, Richards, 2017).

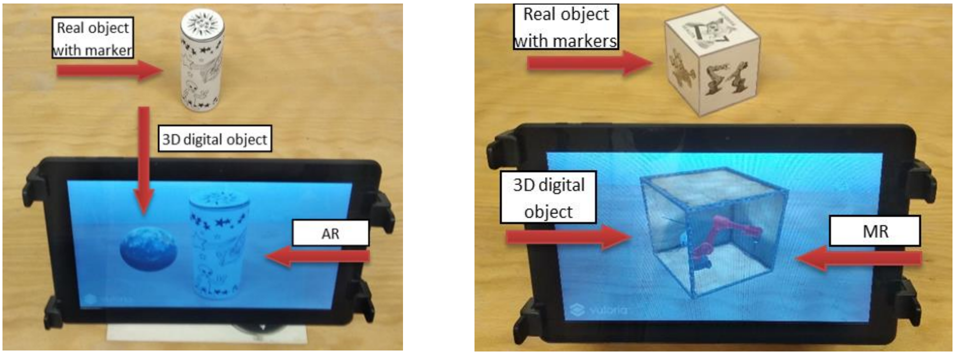

Figure 1. Augmented reality (left picture) and mixed reality (right picture) represented by tablet device

With the principle of Augmented Reality (AR), this space is enlarged even further. A virtual world co-exists with and is embedded in the physical world. Both worlds have their own full 3D existence in geometric and photometric properties and have dynamic evolvement over time. There are intricate relationships and exchanges between the two worlds in which one world adapts to, or influences, the other. The human user closes the interaction loop and generates a demand for understanding these relationships. The continuous flow, in which both worlds are viewed and manipulated, reaches a new quality of human–computer–physical–reality interaction. (Zlatanova, 2002)

Basic characteristic of augmented reality the Madden (2011) defined as:

– combines the real world with computer graphics,
– provides interaction with object in real-time,
– tracks object in real time,
– provides recognition of images or objects,
– provides real-time context or data.

From view of sciences researches of augmented reality for the last quarter of a century the results experienced a relatively large increase, which is also captured by several systematic review studies (Carmigniani, Furht, 2011; Dey, Billinghurst, Lindeman, Swan, 2018; Garzón, 2021) focused on research subject.

Based on the analysis of its evolution, (Garzón, 2021) pose three generations of AR applications in education. The first generation covers the period from 1995 to 2009 and could be described as hardware-based AR, as the delivery technology was the protagonist of the AR experience. The second generation covers the period from 2010 to 2019 and could be described as application-based AR, as the AR experience focused on AR applications rather than AR hardware. Finally, the third generation runs from 2020 onward and seems to be characterized by dedicated AR devices such as smartglasses and Web-based AR.

The popularity of augmented reality grew with the creation of applications for mobile devices (Madden, 2011) which became more accessible to the public, and with the development of the mobile game Pokémon Go™ (Garzón, 2021), which was of great interest to users. Pokémon Go™ is a mobile video game that requires real-world walking to "catch" augmented reality (AR) virtual creatures (Baranowski, Lyons, 2020). It has become increasingly accessible, affordable, and popular as advanced equipment is no longer required, which can be conveniently used on smartphones. Notably, the AR adoption in education has simultaneously increased, exhibiting potential in teaching and learning. The process creates an interactive visual learning form to provide a better learning experience. Thus, this idea allows educators to leverage the concept of interactive experience in an educational setting (Lam, Lim, Tan, 2023).

Teachers, engineers, researchers and practitioners are developing different tools and methodologies that include this technology, to benefit students and teachers by enriching the learning and teaching experiences. However, as reported by (Wu *et al.*, 2013), studies related to AR remain immature compared to studies of other technologies in education.

The analysis of the data in the systematic review (Garzón, 2021) does not show significant differences in effect sizes per level of education. Therefore, the results seem to indicate that the level of education does not moderate the impact of AR on education. However, it is necessary to consider that the number of studies in some levels of education is too low or inexistent. Advantages of using AR in educational settings go from psychological to learning aspects, learning gains continue to be the most reported advantage of AR systems in education followed by motivation. It is important to mention that each new study continues to report multiple benefits that help improve, not only the academic level of students, but also many other personality traits such as autonomy, creativity and collaboration. In addition, the fact that AR systems increase students' motivation and academic achievement could eventually reduce the costs associated with grade repetition and early school/college dropout, and the social problems that these events may cause. Despite the apparent multiple benefits that AR brings to education, this technology still has some difficulties to overcome, such as complexity, technical issues and some resistance from teachers.

In the technical or engineering education area we can find practical applications e. g. (Töröková, Török, Kočiško, Kaščak, 2020) and the possibilities of using extended and augmented reality applications in technical education for the preparation of future teachers (Korenova, Kožuchová, Dostál, Lavicza, 2019). When developing augmented reality applications, it is necessary to consider the specifics of each field of education so that the effectiveness of education reaches the required level. Therefore, it is necessary to pay attention to this issue.

The subject matter of the study. Requirements for AR application design for technical education

Augmented reality is based on a person's sensory perception of the physical world through digital equipment and digital content, which expands the real world with a virtual one. Therefore, how a person perceives such a mediated reality must be considered first when developing applications. From a user's perspective (Krüger, Buchholz, Bodemer, 2019) according to Azuma (1997) the technology that delivers the AR experience is characterized by three characteristics (examples are presented in Figure 2. a), b), c)):

1. Contextuality – this means that the user perceives the displayed virtual elements (e.g., objects, pictures, text) in the context of the real world around them (e.g., physical objects, other learners), with AR it is possible to situate learning in a relevant context, which may increase the authenticity and ground students in reality.

2. Interactivity – this entails that users experience the virtual elements reacting to their and other learners' actions. Because virtual objects in AR are placed inside the real world, they lend themselves to natural and intuitive inter-

action that is not possible with screen-bound virtual objects (e.g., "real" touching, gesture-based interaction). On the other hand, users can manipulate the virtual AR objects in other ways than purely physical objects (e.g., input of new data to change simulations, control through input devices) and can receive realistic and immediate feedback upon their input.

3. Spatiality – this means that the virtual elements should seem to exist in the same space as the real world. This represents a large part especially in the development of spatial imagination, which does not only mean understanding between 2D and 3D content, but also that elements are arranged in space.

For the process of acquiring knowledge to occur, it is not enough that these three characteristics are only perceived by the user, but they must be properly cognitively processed in relation to the set goals of education, that is, it must be clear what the user is to learn with the help of this technology. Therefore, it is important that the design of the application also considers cognitive load theory in relation to taxonomies of learning objectives. Cognitive Load Theory defines how the brain can only process selective incoming sensory data into working memory (Rudolph, 2017).

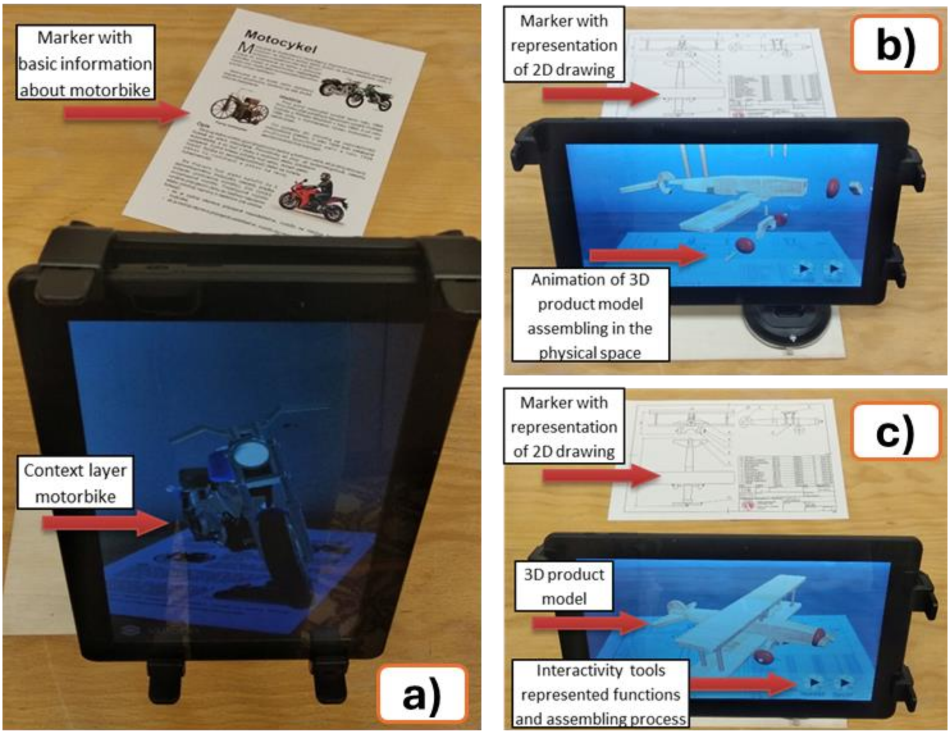

Figure 2. a) Contextuality, b) Interactivity, c) Spatiality of augmented reality

Research methodologies and tools

Based on the essence of the definition of AR, we can say that this technology, from the point of view of its digital content and its form of representation, falls into the category of multimedia applications, and we can classify it from the point of view of didactics as a multimedia didactic tool. In general, didactic principles must therefore be considered when designing an AR application. In the didactics of professional technical subjects, the explanation of these didactic principles has become established:

- principle of activity and awareness,
- the principle of purposefulness and education in teaching,
- the principle of science and adequate proportionality,
- the principle of connecting theory with practice, school with life,
- principle of visuality,
- principle of repeatability and sequence,
- the principle of the durability of knowledge and the all-round development of students' knowledge of abilities,
- the principle of collectivity in teaching and respect for the individual characteristics of students.

In multimedia learning the learner engages in three important cognitive processes. The first cognitive progress, selecting, is applied to incoming verbal information to yield a text base and is applied to incoming visual information to yield an image base. The second cognitive process, organizing, is applied to the word base to create a verbally based model of the to be explained system and is applied to the image base to create a visually based model of the to be explained system. Finally, the third process, integrating, occurs when the learner builds connections between corresponding events (or states or parts) in the verbally based model and the visually based model. (Mayer, Moreno, 1998) In order to effectively engage the learner in the learning process, designers developing an AR application should balance the use of visual and verbal information. In this area Mayer (2002) developed Cognitive Theory of Multimedia Learning and has spent almost three decades researching and updating this theory as instructional multimedia has evolved, which were based on 12 principles of multimedia design (Rudolph, 2017).

Development (analysis of research results)

Augmented reality is a very young industry, and there are still no generally accepted standards for developing AR applications (Ablyaev, Abliakimova, Seidametova, 2020). Based on our experience with the use of existing applications, our own development of AR applications for mobile devices, research of creating possibility such applications by the game engine Unity and Vuforia, and a theoretical study based on the sources used in this document, we have established the following 5 areas of requirements for the design of AR applications considering technical education needs.

1. Appearance

The application should have a visually attractive, clear and intuitive graphic interface, in which the control elements are clearly identifiable, grouped into logical groups and subgroups, so that the spatial contiguity principle is preserved (Mayer, 2002). The interface should be created in a responsive design so that the graphic resolution of the controls and content is maintained on different screen sizes and is sufficiently readable. The interface should not interfere or overlap the content itself. 3D content should have a realistic appearance, not only in shape similarity, but appropriate materials, textures, shaders, effects, particle systems should be used, which approximate the image of the virtual world as closely as possible to the physical one.

2. Functionality

Depending on the complexity of the application, it is necessary to consider what will be the concept, and the model of the application used (Amory, Seagram, 2003). It is important that the sequence of steps leads to the acquisition of a certain cognitive level of knowledge, e.g. memorization, understanding, application, analysis, evaluation or creativity. The application should have an action guide created, for example in the form of pop-up windows, navigation or an avatar, so that the user can consistently navigate through the content and select controls. The main functionality should be active interactivity, which means that the user should receive feedback through his actions, for example in the form of a simulation, a pop-up window with an evaluation of the correctness of the solution, the possibility of sharing the result and receiving feedback from the wider public, the possibility of verifying whether his solution in the real world is in harmony with the virtual and so on.

3. Content

Only the display of 3D content without additional contextual information such as text, animation or the possibility of manipulation cannot be considered to be in accordance with the principle of multimedia (Mayer, 2002). For example, only a static display of a machine, where it is not clear what kind of machine it is or what its activity is, does not lead to the acquisition of knowledge, as the user cannot cognitively evaluate what is the subject of the displayed information. In the case of AR applications, the carrier of contextuality can be either a marker or virtual content. For an easier understanding of the phenomena, it is not necessary, in accordance with the principle of coherence (Mayer, 2002), that a lot of details be present, for example, to illustrate the principle of the operation of the machine, it is not necessary to display all parts of the machine, but only those that basically present the principle of its functionality, or it is possible to separate these parts from the whole.

4. *Cognitive effectivity*

The application should be created in such a way that the cognitive level of the set goals can be clearly demonstrated, measured and controlled. Applications that do not have a clear educational goal cannot be considered educational applications. Applications should be researchable before their introduction and demonstrable cognitive effectiveness in relation to conventional didactic means. In relation to technical subjects, the cognitive effectiveness of AR applications should be aimed at:

– the acquisition of terminological concepts of parts of technical machines, devices and tools,

– the reading and creating technical visualization and drawing documentation,

– the choice of technological procedures, tools, tools for manufacturing products,

– the understanding how simple and complex technical principles work,

– the manipulation and operation with machines, devices and tools,

– the own design of technical solutions and innovations.

5. *Sharing, compatibility and connectivity*

The availability of AR applications is a key aspect for their introduction into education. A user who does not know how to access AR applications, whose device is not compatible with the platform for which the application was created or does not have access to its content cannot learn. Therefore, a necessary requirement for the creation of such applications is that they are available for the widest possible spectrum of devices and their platforms. At the same time, these applications should have a more complex character, so that a lot of micro-applications are not produced. The size of the data and the performance requirements of data processing equipment are also related to the complexity of the solutions. Therefore, it appears to be the most appropriate form of creating Web-based AR applications (Qiao *et al.*, 2019).

Conclusions

To organize and organize the conditions of the educational process in the fulfilment of the educational curriculum, the teacher should have the opportunity to choose suitable didactic resources to ensure the effectiveness of the educational process. Through our testing of the possibility of creating applications in augmented reality and the study of available scientific and research resources, we found that these possibilities to creation of AR applications are almost unlimited, respectively the limitations are connected with the price and availability of technical equipment and software solutions for the creation of AR applications, the time required to create such an application and skills (3D modelling, programming, graphic processing, creation of animations and effects…) to create these applications. Without a didactic approach and respect for scientific research results in the field of cognitive acquisition of knowledge, the application cannot effectively fulfil the function of a didactic tool. Our intention was therefore through this contribution to determine 5 areas of key requirements for the creation of educational AR applications with the definition of the area of cognitive efficiency within technical education.

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The Use of Graphic Programs in the Educational Process of Technical Subjects at Secondary Schools and Universities

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Abstract

In the era of digital transformation in education, graphic programs are becoming an indispensable tool in the educational process of technical subjects at secondary schools and universities. Their use extends beyond innovative methods of knowledge transfer and positively influences the development of students' cognitive abilities, such as spatial imagination, analytical thinking, and problem-solving. Moreover, mastering graphic programs prepares students for the demands of the current labour market in fields such as engineering, architecture, and design. This study analyses the use of graphic programs in the education process of technical subjects at secondary and higher education institutions, focusing on their specifics in the context of each educational level.

Keywords: graphic programs, technical subjects, cognitive skills, digital transformation of education

Introduction – pedagogical benefits of graphic programmes

Graphic programs offer numerous benefits in teaching technical subjects. They increase student engagement, enable visualization of abstract concepts, and develop spatial reasoning. They improve work efficiency and accuracy, foster creativity and innovation, and prepare students for professional practice. However, implementation also presents challenges, such as financial and time constraints, the need for technical support, and the risk of over-reliance on technology.

The future of graphic programs in education lies in integration with cloud services, utilization of virtual and augmented reality, development of collaborative tools, and implementation of artificial intelligence.

Aim and methodology of the research

The aim of the study is to present selected graphical computer programmes which are useful in technical education as well as the presented method to analyse their functionality.

Research results - taxonomy of graphic programmes in technical education

Several dominant categories can be identified in the broad spectrum of graphics programs applied in engineering disciplines:

1. **CAD software (Computer-Aided Design):** this software is a fundamental pillar in the study of disciplines such as engineering, construction, architecture and design. It allows students to create accurate 2D and 3D models, technical drawings, simulations and analyses. The most widely used CAD programs include:

- **AutoCAD:** A highly sophisticated program with extensive functionality, used primarily in universities and professional practice. AutoCAD it's a very simple software for creating 2D and 3D drafting, yet it is very powerful. With the new released instalments, the only limitation it's user's creativity. In the figure below its presented AutoCAD's user interface (*Autodesk Auto CAD 2025*).

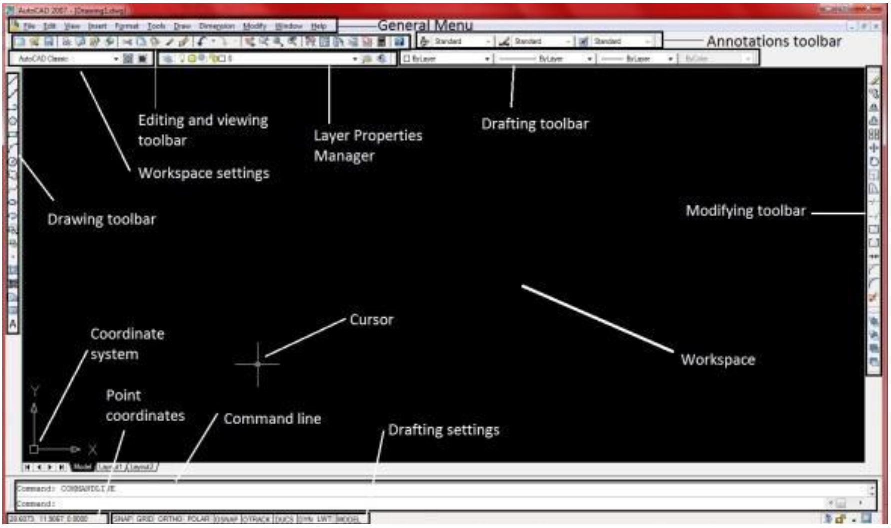

Figure 1. AutoCAD user interface

- **SolidWorks:** an intuitive and user-friendly program with advanced 3D modelling tools, often implemented in teaching in high schools and colleges. Getting started with SOLIDWORKS can be a challenge, especially for new users coming from 2D CAD programs.

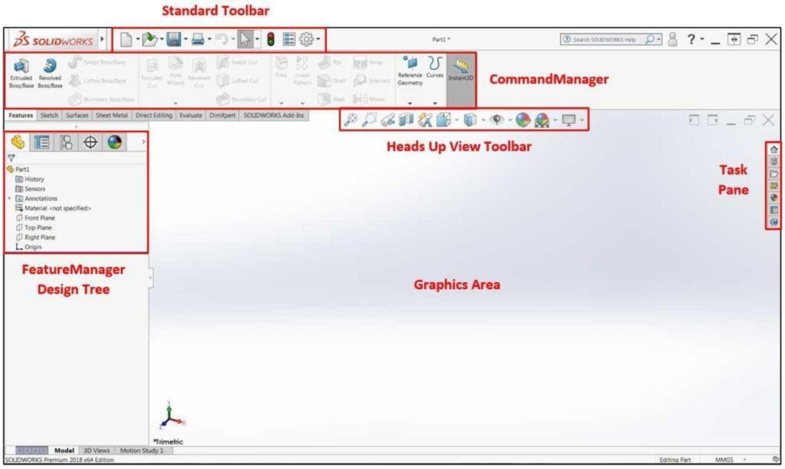

Figure 2. SolidWorks user interface

- **CATIA:** (Computer Aided Three-dimensional Interactive Application) is a comprehensive software system developed by Dassault Systèmes. It is a leading CAD/CAM/CAE software used for 3D modelling, simulation, and analysis. Its wide range of applications makes it an indispensable tool in various industrial sectors, particularly in the automotive, aerospace, and manufacturing industries.

It enables designers and engineers to design complex products, simulate their behaviour in a real-world environment, and optimize their performance. Due to its complexity and advanced features, CATIA is a typical tool for higher education studies in technical fields and scientific research. Students and researchers use it to solve complex engineering problems, simulate various processes, and develop innovative products (*CATIA*, 2023).

- **Inventor:** Autodesk Inventor is a popular CAD software developed by Autodesk. It focuses on 3D mechanical modelling, product design, and simulation. Due to its intuitive interface and wide range of features, it is suitable for secondary and higher education in fields such as engineering, industrial design, and manufacturing.

Inventor allows students and engineers to create accurate 3D models of parts and assemblies, generate technical documentation, and simulate the functionality and performance of designs. The software offers tools for parametric modelling, finite element analysis, motion simulation, and visualization. Its flexibility and compatibility with other software make it a sought-after tool in industrial practice.

2. **Mathematical software:** Mathematical software is an integral part of the study of engineering subjects, enabling students to solve complex mathematical problems, create graphs, analyse data and visualise mathematical models. The most prominent programs in this category include:

• **MATLAB:** (short for "MATrixLABoratory") is an interactive environment and programming language developed by MathWorks. It is a powerful tool for numerical computation, simulation, data visualization, and programming, used in a wide range of scientific and technical fields.

MATLAB offers a comprehensive system of functions and tools for mathematical operations, signal processing, image analysis, system control, and much more. It allows users to create models, prototypes, and simulations of complex systems, analyse and visualize data, and develop algorithms. Due to its flexibility and extensive function library, MATLAB is a popular tool in higher education in fields such as mathematics, physics, engineering, and economics (*MATLAB*).

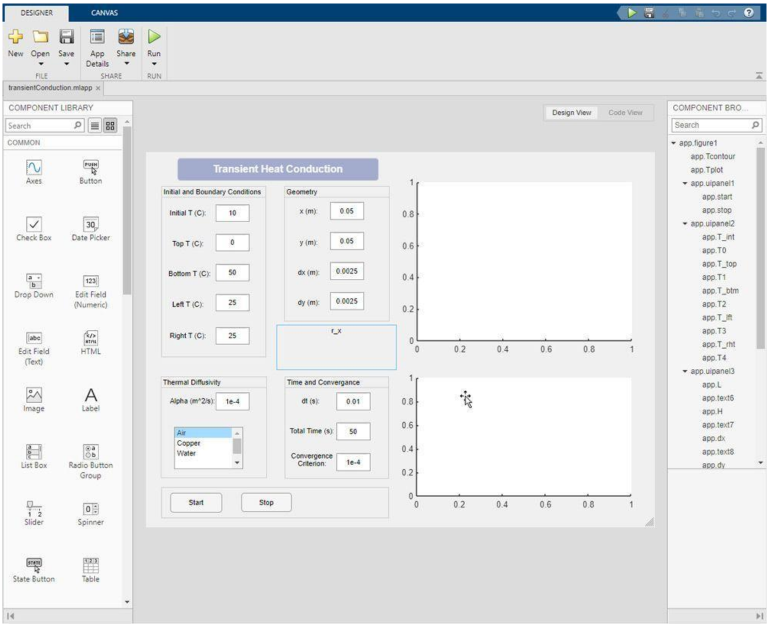

Figure 3. MATLAB user interface

• **Wolfram Mathematica:** is a modern computational system developed by Wolfram Research. It is a powerful software with extensive capabilities for symbolic and numeric computation, graphical data processing, and programming. Mathematica is used in scientific research, education, and various industrial sectors.

Mathematica offers a unique environment for solving mathematical problems, simulating physical phenomena, analysing data, visualizing, and creating interactive models. Its strength lies in its ability to work with symbolic expressions, which allows for precise mathematical calculations and manipulations. It also offers extensive function libraries for various fields of mathematics, physics, computer science, and engineering. Due to its complexity and wide range of possibilities, Mathematica is a suitable tool for higher education studies and scientific research (*Wolfram Mathematica*).

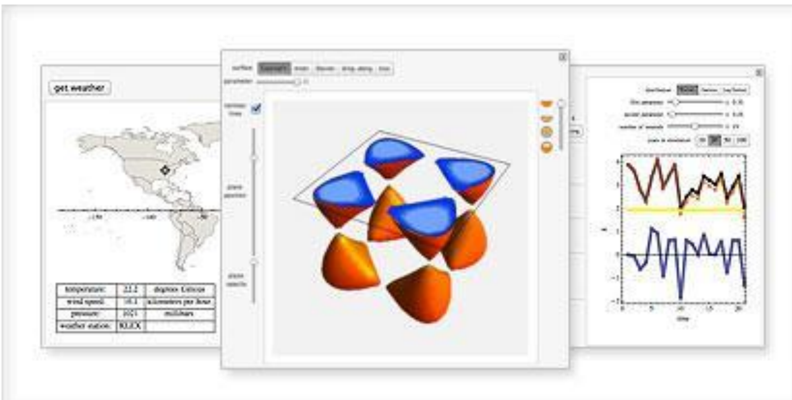

Figure 4. Mathematica user interface

- **Maple:** is a powerful mathematical software developed by Maplesoft. It focuses on symbolic computation, mathematical analysis, data visualization, and programming. With its intuitive interface and wide range of features, it is suitable for secondary and higher education in subjects such as mathematics, physics, and engineering.

Maple enables students and teachers to solve complex mathematical problems, perform symbolic manipulations, numerical approximations, graphical representations, and create interactive applications. The software offers tools for algebra, calculus, differential equations, linear algebra, statistics, and many other areas of mathematics. Its ability to work with symbolic expressions allows for precise solutions and a deeper understanding of mathematical concepts.

In addition to education, Maple is also used in scientific research and various industrial sectors where complex mathematical problems need to be solved.

3. **Simulation software:** represents a broad category of programs that allow for virtual modelling and analysis of various systems and processes. It is used in various fields, from technical sciences and engineering to economics and social sciences. In the context of technical education, simulation software allows students to experiment with different parameters, test proposed solutions, and optimize technical systems without the need for physical prototypes.

Simulation programs offer the possibility to visualize complex physical phenomena and processes, analyse their behaviour over time, and predict their evolution. Students can thus gain a deeper understanding of theoretical concepts and apply them in practice. Among the most used simulation programs in technical education are:

- **Ansys:** Ansys is a comprehensive Multiphysics simulation software developed by Ansys, Inc. It is one of the leading tools for engineering simulations, allowing for modelling and analysis of complex physical phenomena and processes. Its wide range of applications includes areas such as solid mechanics and structural analysis, thermal analysis, electromagnetism, fluid dynamics, and many others.

This program uses the finite element method (FEM) to solve complex engineering problems. It allows for simulating the behaviour of materials and structures under the influence of various loads, temperature changes, electromagnetic fields, and fluid and gas flows. Ansys offers a wide range of modules and tools for different types of simulations, including structural analysis, thermal analysis, fluid flow analysis, electromagnetic analysis, and acoustic analysis.

Due to its complexity and advanced features, Ansys is mainly used in higher education institutions within engineering disciplines and in scientific research. Students and researchers use it to solve complex engineering problems, optimize designs, and develop innovative products. Ansys is also widely used in industrial practice in various sectors, such as the automotive industry, aerospace industry, energy sector, and manufacturing (*Ansys – Engineering Simulation Software*).

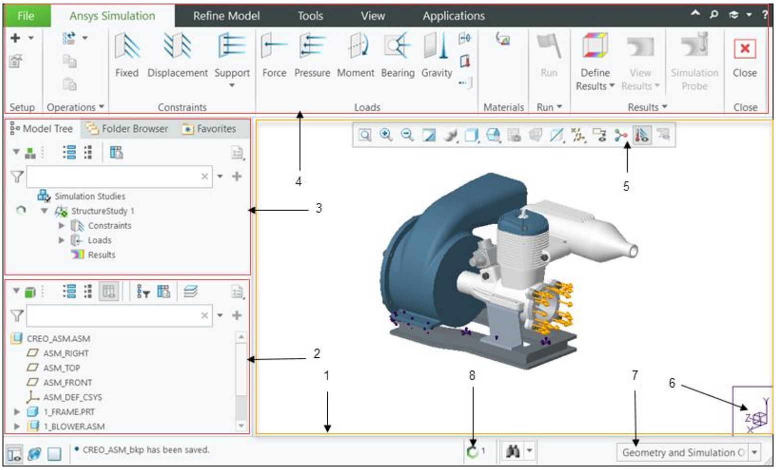

Figure 5. Ansys user interface

- **COMSOL Multiphysics**: is a powerful software for Multiphysics simulations developed by COMSOL, Inc. It allows for modelling and analysing a wide range of physical phenomena and processes, including mechanics, acoustics, electromagnetism, thermal processes, chemistry, and fluid flow. Its strength lies in the ability to combine different physical models and simulate their interaction, which is crucial for understanding complex systems.

It features a user-friendly interface and a flexible modelling environment. It offers extensive libraries of physical models and material properties, as well as tools for geometric modelling, meshing, and visualization of results. Thanks to its modularity, it is possible to adapt the software to the specific needs of the user and extend its functionality with additional modules for specialized simulations.

It is suitable for higher education studies and research in various technical fields, such as mechanical engineering, electrical engineering, physics, and chemistry. It allows students and scientists to gain a deeper understanding of physical principles and apply them in solving real-world problems. In addition, COMSOL is also used in industrial practice in the development and optimization of products and processes (*COMSOL*).

- **Simulink:** Graphical environment for modelling and simulation of dynamic systems, integrated with MATLAB. Used in high school and university courses such as automation, robotics and cybernetics.

4. **Graphic editors:** are software applications designed to create and edit digital graphics. They are divided into two basic types:

- **Raster graphic editor** – works with images composed of pixels, i.e. coloured dots arranged in a grid. Suitable for photo editing and creating realistic images. Examples: Adobe Photoshop, GIMP.
- **Vector graphic editor** – works with images defined by mathematical curves and shapes. Suitable for creating logos, illustrations, technical drawings, and diagrams. Examples: CorelDRAW.

Among the most famous graphic editors are:

- **Adobe Photoshop:** is a leading raster graphics editor developed by Adobe Inc. It is a professional tool for editing and creating digital images, used in a wide range of areas, from graphic design and photography to web design and multimedia creation.

Photoshop offers a comprehensive system of tools and functions for photo retouching, colour manipulation, creating effects, drawing and painting, working with layers, and much more. It allows users to create complex graphic compositions, edit images in detail, and add various effects. Due to its flexibility and extensive function library, Photoshop is a standard tool in the graphic design industry.

In the context of education, Photoshop is suitable for secondary and higher education in fields such as graphic design, multimedia creation, photography, and data visualization. It allows students to gain practical experience in editing and creating digital images and develop their creativity and technical skills (*Adobe Photoshop*).

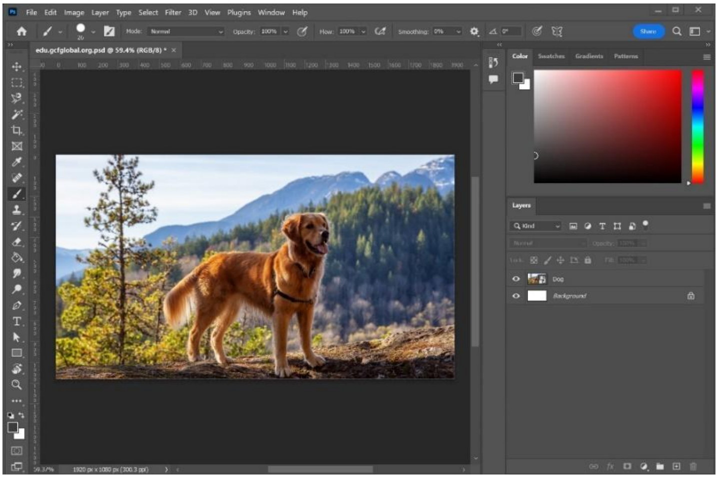

Figure 6. Adobe Photoshop user interface

- **GIMP:** (GNU Image Manipulation Program) is a free and open-source raster graphics editor that represents a powerful alternative to Adobe Photoshop. It offers a wide range of features for editing and creating digital images, including tools for photo retouching, colour manipulation, drawing, painting, and creating graphic effects.

Due to its free availability and extensive functionality, GIMP is an ideal choice for secondary and higher education in fields such as graphic design, photography, and multimedia creation. It allows students to learn the basic principles of working with raster graphics and develop their creative and technical skills without having to invest in expensive software.

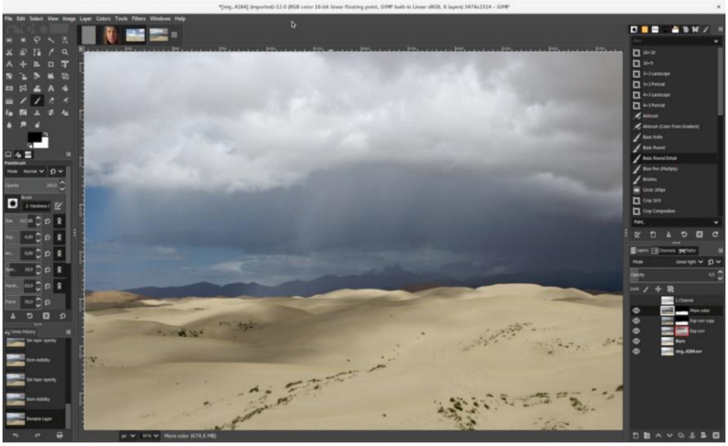

Figure 7. GIMP user interface

In addition to education, GIMP is also used in professional practice by graphic designers, artists, and photographers who are looking for a free and powerful alternative to commercial graphic editors (*GIMP*).

- **CorelDRAW Graphics Suite**: is a comprehensive software package developed by Corel Corporation, with CorelDRAW as its core vector graphics editor. It is a professional tool for graphic design, illustration, publishing, and web design. CorelDRAW offers a wide range of features for creating and editing vector graphics, including tools for drawing, shaping, typography, colour management, and effects.

It is characterized by an intuitive interface and advanced tools that allow for creating accurate and detailed illustrations, logos, technical drawings, brochures, flyers, and many other graphic materials. The software offers extensive libraries of shapes, fonts, and clipart, as well as the ability to import and export various file formats.

In the context of education, CorelDRAW is suitable for secondary and higher education in fields such as graphic design, illustration, technical drawing, and multimedia creation. It allows students to gain practical experience with vector graphics and develop their creativity and technical skills.

Conclusion

In the current context of digital transformation in education, graphic programs play a crucial role in preparing students in technical fields for the demands of today's job market. Their implementation in the educational process allows students to gain practical experience with tools and technologies that are standard in industrial practice. Furthermore, graphic programs foster the development of students' cognitive skills, such as spatial reasoning, analytical thinking, and problem-solving. However, the effective use of graphic programs in education requires not only adequate technical provision but also thoughtful integration into curricula and professional development for educators. It is important to find the right balance between acquiring digital skills and developing fundamental technical knowledge and manual skills. The future of graphic program utilization in technical education is promising. Further software advancements, integration with cloud services, utilization of virtual and augmented reality, and implementation of artificial intelligence are expected. These trends will further expand the possibilities of graphic programs and contribute to more effective and engaging instruction in technical subjects.

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PART TWO

SELECTED PROBLEMS OF USING INFORMATION TECHNOLOGY IN EDUCATION

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Parallel Programming in PC and Computer Cluster Environment – Selected Computational Problems

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Abstract

Parallel programming is a skill that requires the use of technologies and techniques that allow applications to use multiple threads/processes simultaneously. In some cases, this is a condition for their launch or correct operation. This article presents selected aspects of such a programming using the example of two proposed applications: for PC computers with the .NET platform and application designed for a computer cluster operating in the GNU/Linux system. These are two applications with different purposes – the first uses image processing mechanisms, while the second – is the implementation of precise numerical calculations. The proposed applications were designed in the context of using multithreading and multiprocessing technologies. The obtained results indicate that implementing appropriate programming techniques is an important aspect of programming various types of applications, ensuring their correct operation and acceleration of long-term calculations.

Keywords: thread, process, synchronization, OpenMPI, Amdahl's law

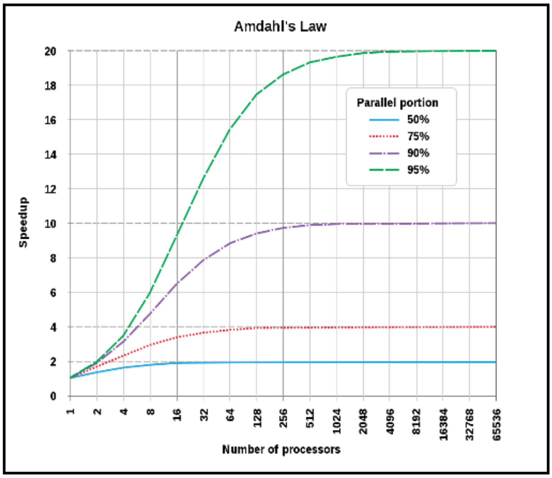
Introduction

Sequential calculations, by default are performed serially, this means that one thread performs calculations one by one as they are placed in the application code. This method works well for small workloads or when tasks have strong data dependencies.

It should be noted that there are computational problems that require the use of large computing power and a large amount of memory. Without these conditions solving such tasks is problematic and sometimes even impossible. The answer to this is parallel programming whose idea is to break the computation into subtasks and assign each of them to a different thread or process that can run independently of each other (Robey, Zamora, 2021; https://www.open-mpi.org 2024). Moreover, each thread can run on a different processor core within the same physical system or on the computer cluster which usually – especially in the second case – significantly translates into increased speed of operation (Rainders, 2007; Robey, Zamora, 2021).

Parallel programming is a relatively narrow specialization in the broadly understood field of programming. There are several internationally published scientific journals dedicated only to this programming technique. Solutions presented there are concerned to many fields of science and technology (e.q.: Collange, Defour, Graillat, Iakymchuk, 2015; Herrmann, Kuchen, 2023; Birath, Ernstsson, Tinnerholm, Kessler, 2024). However, this topic is also presented in other journals, (e.q.: Szyszko, Smołka, 2018; Hielscher, Bartel, 2024), if only the problem under consideration requires parallelization of computations.

What kind of increase in computational speedup we can expect depends on how much we can split a program code which can be assigned to separate threads or processes. The theoretical relationship between their number and application performance is described by Amdahl's law (Rainders, 2007). It indicates that the maximum acceleration of the execution time is limited by the largest indivisible part of the program. The specific courses and well known analytical formula, which should be treated rather as a classical approach, are shown below:



$$S = \frac{1}{(1-P)+\frac{P}{N}} \tag{1}$$

where: S – maximum speed up of the program,
N – amount of threads/processes,
P – is percentage of program code, that can be parallelized (parallel portion).

Figure 1. Amdahl's law of speeding up program execution depending on the number of processors (https://www.researchgate.net 2016)

Figure 1 shows the saturation of the curve representing the acceleration of the program. This means that with the number of processing units, theoretically approaching infinity, the time to solve a given task is established because the acceleration cannot exceed the value determined by the sequential part of the program code – which of course is a feature of even the most modern computing systems, including computer clusters.

One of the important aspects in parallel programming is the problem of synchronizing threads/processes so that each works efficiently on their task and maintains data integrity. Two or more threads can use and change the same variable. If the processes are not synchronized, the variable will not reach the proper value after the calculation is completed. This applies to both solutions implemented using cluster technologies, as well as applications created for PC computers. In our article, using the example of created applications, we show how implementing parallelized code has a positive impact not only on the speed of operation, but also on their responsiveness. We also pay attention to selected aspects of synchronization, which in turn ensures the correctness of the calculation of shared variables. Presented applications were implemented in the .NET programming environment and the C# language, as well as in the C++ language environment and the OpenMPI library of the didactic computing cluster, which is equipped with the Department of Computer Science at the State University of Applied Sciences in Jarosław (PANS Jarosław).

Technology of multithreading

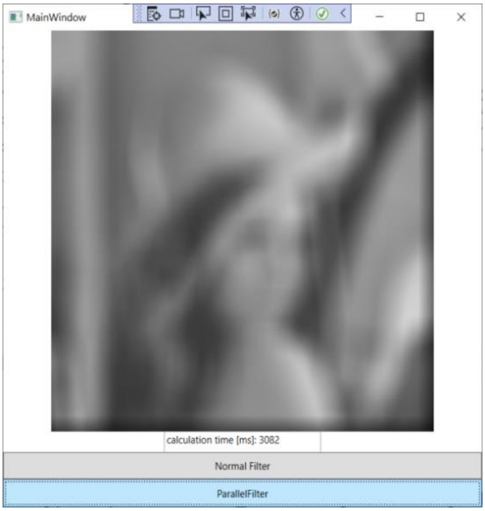
As the name suggests, a program that implements a multithreading feature can have the code run on multiple threads at the same time. We can treat threads as workers and the program as the supervisor of the workers. Multithreading is the ability of the "supervisor" to split the work among his "workers" instead of having just one worker do all the work on their own. Each thread is given a unique ID. This way the flow remains controllable and the threads can be managed through dedicated libraries to avoid leaks and errors. In our case we consider *Task Parallel Library* (TPL) for .NET Framework (https://learn.microsoft.com/pl-pl/dotnet/standard/parallel-programming 2022)

The main reason to use, and the biggest advantage of multithreading is the application execution speed. If implemented correctly, multithreading can cause the code to finish much faster than it would in a single thread. Moreover, running complex code on only one thread can sometimes create application security issues or other deficiencies in its functioning. On the other hand though, keeping multiple threads in check, starting them, making sure they don't interrupt each other pose a serious challenge, therefore writing programs that make use of multithreading is much more difficult and takes much more time. What is more, errors that originate from using multithreading are much more difficult to spot.

It should be noted that not all cases of implementing multithreaded technology collide with the problem of synchronization related to the sharing of variables. There exist applications in which threads can be executed asynchronously, concurrently, and even in parallel, while the synchronization mechanism comes down only to the "supervisor" collecting the results from the "workers". As an illustration of this problem, an application from the field of image processing was implemented. The figures below show the performance results of an averaging filter for a bitmap image (https://eeweb.engineering.nyu.edu) with a resolution of 512x512 pixels. The filter calculates new values of each pixel as an average of the other pixel values from the area of the sliding 40-pixel wide window, which provides an intense blurring of the image. The filter works in two versions: a serial version and a parallel version. The output under the image shows the running time of both versions of the filter.

a)

b)



c)

Figure 2. Original image (a) as the input to the averaging filter and calculation times in milliseconds: for serial calculations (b) and for parallel calculations (c)

The application was implemented in the C# language environment and the .NET platform. For the version of the parallel filter, the total image area was divided into 4 blocks of pixels, which is determined by the variable declared in the first line of the application code (Figure 3). Each block of parallel filter is processed by a separate thread, while the serial calculations run in the context of the main thread only. Additional threads of the parallel filter were run in the context of the task factory (*Task.Run*() method) using the default queuing mechanism. The *Filter*() method – used as a parameter – calculates the average value for each pixel in a 40-pixel window. Synchronization between additional threads and the main thread is provided by the *WaitAll*() method (the last red code line). It causes the main thread to wait until the additional threads complete their calculations. Running the application on a PC with Intel Core i7 2.2 GHz processor indicates that filtering the image in 4 additional threads speeds up the calculations several times.

```
const int number_of_blocks=4;
var tasks = new Task[number_of_blocks];
for (int i = 0; i < square_block; i++)
{
  if  (i == square_block - 1)  wEnd = (int)bitmap_k.Width;
  var hStart = 0; var hEnd = th;
  for (int j = 0; j < square_block; j++)
   {
     if (j == square_block - 1) hEnd = (int)bitmap_k.Height;
     var fWstart = wStart; var fWEnd = wEnd; var fHstart = hStart; var fHend = hEnd;
     tasks[block++] = Task.Run(() => Filter(img, imgCpy, w, h, WindowSz, fWstart, fWEnd, fHstart,
fHend));
     hStart = hEnd; hEnd += th;
   }
     wStart = wEnd; wEnd += tw;
 }
Task.WaitAll(tasks);
```

Figure 3. Application code snippet responsible for running the filter algorithm in 4 tasks-threads

Taking into account the formula (1) for the proposed application, in which P = 0.82 and N = 4, it can be stated that the estimated value of the maximum speed up obtained from Amdahl's law and the value obtained in real conditions are similar.

The second important aspect is that implementing filter calculations in additional threads makes the main application window responsive — unlike the serial filter version, where the graphical interface and the filter run in the same, main application thread.

Multiprocessing programming with using MPI – solution of a selected numerical problem

The application presented in the previous chapter concerns solutions that can be used on PC computers. However, demanding computational processes, e.g. complex engineering calculations, may require the construction of applications implemented on high-performance computing systems – usually computer clusters that implement computational algorithms in a distributed multiprocessor environment.

Applications built for computing clusters can use MPI *(Message Passing Interface)* technology. It is a set of libraries used to enable communication in parallel computing architectures. It provides useful functions in C, C++ and Fortran that allow control over multiple processes even if they are run on different machines (https://www.open-mpi.org 2024). The interface also supports synchronization and communication functionality between a set of processes. This communication involves sending messages between processes, hence the name – message passing interface. These messages may be, for example, variables of different types, representing data for various computational problems. In our research we used a cluster located in PANS Jarosław running under the GNU/Linux operating system with the *OpenMPI* library in the form of a loadable module. Simplified diagrams and general parameters of the cluster are shown on Figure 4.

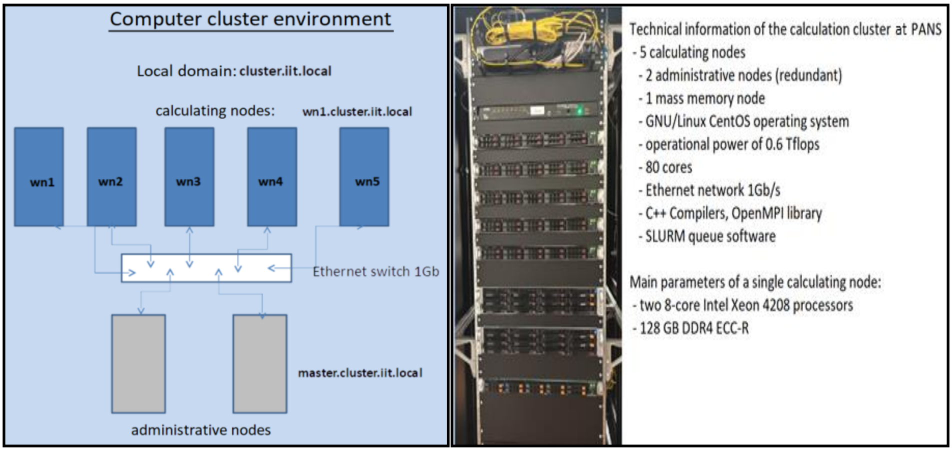


Figure 4. Computer cluster's connections and general specification of the nodes

Calculating nodes *wn1÷wn5* as well as the administrative node *master* (in redundant solution) are connected via an Ethernet switch. The built applications must be placed on the one of the master nodes that has the tools to compile and run them on calculating nodes.

Some problems from various fields of technology require calculation of definite integrals of a function of one variable. Calculated values of the integrals may represent different physical quantities describing a given phenomenon or object. Appropriate calculations can be performed for data in the form of analytically given integrands or when discrete values of an unknown function are given only.

In numerical computations, one of the key problems is to ensure the best possible accuracy. It is usually associated with the need to adopt discretization steps in time or space that can require resources significantly exceeding the capabilities of PC computers. Implementing calculations on a computer cluster with the OpenMPI library requires programmers to develop a different concept of calculations than in the case of the serial approach - which is not always easy. This of course also leads to the need to rebuild the serial application code into a new form. To demonstrate this problem in integral calculations, Simpson's quadrature was used in the form given by formula 2 (Flowers, 2000):

$$F = \frac{1}{3}\Delta x[f(a) + 4f(a+\Delta x) + 2f(a+2\Delta x) + 4f(a+3\Delta x) + 2f(a+4\Delta x) + + \cdots + 4f(b-\Delta x) + f(b)] \qquad (2)$$

where: F denotes value of integral, a, b – b oundaries of calculations, Δx – discretization step of the independent variable x.

In C++ the code of in sequential version might look like on the Figure 5:

```
long double f (long double x)
{
   return sin(sqrt(x));
}
long double F (long double a, long double b, long int n)
{
   long double dx = (b - a) / (double)(n - 1);
   long double output = f(a) + f(b); int multiplier;
   for (long int i = 1; i <= n; i++)
   {
```

Figure 5. Program code that allows to calculate sequentially the integral of the function $f(x) = sin\, sin\, (\sqrt{x})$ in the interval [*a*, *b*] and with a number of steps *n*

Used declaration of the variable *n* allows the number of steps to be entered into the calculation area depending on the upper range of the *unisgned int* type, which should be sufficient in most practical applications. It should be noted, however, that PC calculations in the upper range of this type are time-consuming and may lead to errors.

As mentioned earlier, the implementation of the above algorithm in a computing cluster environment with the OpenMPI library requires the development of a different concept than the serial one for calculating the integral according to the formula (2). MPI is a standard for sending so-called messages between processes. This means that it is possible to run applications within multiple processes distributed across computing nodes, with the ability to transfer data between these processes. In our research, this idea was used so that individual processes performed calculations for a finite number of Simpson's formula components. Figure 6 shows the essence of the adopted solution.

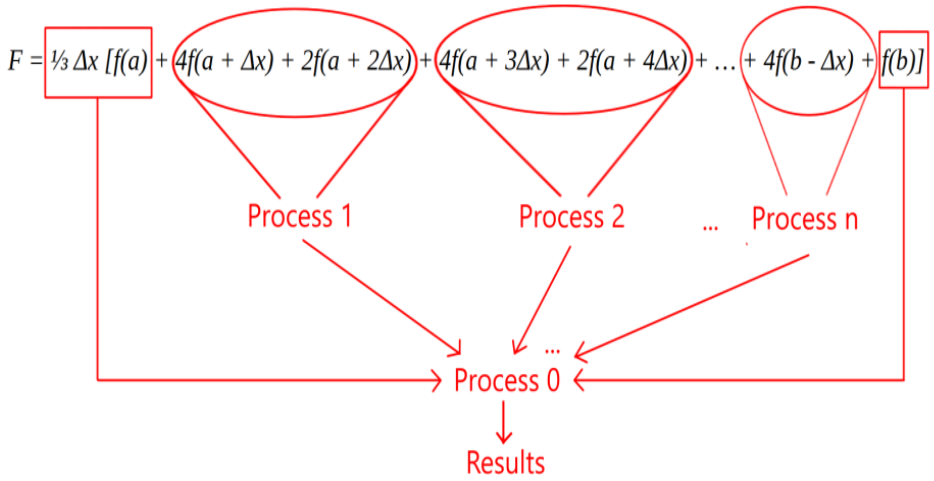


Figure 6. Visual explanation of idea the Simpson formula calculations by processes of OpenMPI library

Each library process has its own unique identifier expressed as a natural number. In our case, process no. 0 (called as root) was elected for storing the first and last elements of the Simpson formula (which do not repeat). Moreover, the middle parts of the formula are divided into other available processes. Once the calculations are done, the outcome of each of them is collected in root process, which sums partial totals and yields the final result of calculations. The most important part of the code of application is shown in the figure below.

```
// Calculate the function results at the first and the last index
if (processRank == 0) outcome = f(a) + f(b);
// Getting the equal range to perform calculations in
    unsigned int start = processRank * npart + 1; unsigned int end = (processRank + 1) * npart;
// Calculate the rest of the formula
    int multiplier; double addition = 0.0;
    for (unsigned int i = start; i <= end; i++) {
        // determining the multiplier
        if (i % 2 == 0) { multiplier = 2; } else { multiplier = 4; }
        addition += multiplier * f(a + (double)i * dx);
    }
    // Gathering the results
    if (processRank == 0) {
        outcome += addition;
        for (int j = 1; j < processNumber; j++) {
            MPI_Recv(&addition, 1, MPI_DOUBLE, j, MPI_ANY_TAG, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
            outcome += addition;
        }
    } else { MPI_Send(&addition, 1, MPI_DOUBLE, 0, processRank, MPI_COMM_WORLD); }
```

Figure 7. Main part of OpenMPI application code

Sending partial sums to the root process is implemented using two OpenMPI library routines: MPI_SEND and MPI_RECEIVE ensure correct calculations – and very importantly – synchronization between processes. This means that the shared variable *outcome*, representing each partial sum, is correctly incremented in the root process. The figure below presents the final results of the integral calculations of the function $f(x) = sin\, sin\, (\sqrt{x})$. For comparison, the results for sequential calculations according to the code from Figure 5 are also included.

The calculations were performed for the same conditions, i.e. the integration interval [*a*, *b*] and the discretization step Δx. The SLURM computational task queuing system was used to run the application on the cluster. It is a convenient tool that allows running the application with a specified number of processes declared by the parameter *n* on *N* computational nodes. According to the technical data (Figure 4), the application can be run on a maximum of 5 computing nodes (*N*=5). Each of them has 16 processor cores, so the maximum number of available cores is 80. Of course, the declared number of processes, using the *n* parameter can be greater than the number of cores, but our results include a number of processes equal to the maximum number of physical cores of the cluster. The computation times for different variants are given on Figure 8.

Obtained results show that even sequential calculations on a PC and on a selected cluster node differ significantly due to the more efficient processor and larger RAM resources of the node. Using the full computing power of the cluster means that the computation time is almost 100 times shorter than on a PC. Therefore, the adopted parallel computation algorithm can be considered highly effective.

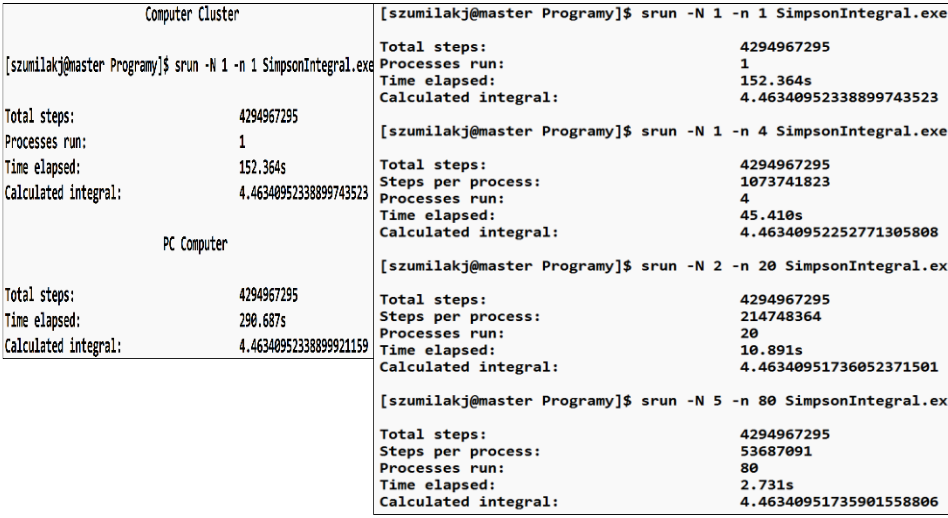


Figure 8. Comparison of calculation results obtained on the computer cluster and PC

Conclusions

This article discusses some aspects of the parallel programming used in applications for PCs and computer clusters. The general idea of programming for both technologies is similar – it is about fully utilizing the capabilities of modern computer systems, and in particular their multi-core/multi-threaded processors. Both technologies offer dedicated libraries with appropriate classes and their methods. One common feature is also the need to ensure synchronization between threads/processes – this is one of the key aspects defining the correctness of the solutions – as indicated in the part describing the presented applications. Of course, there are many more of these aspects and problems and it is impossible to mention all of them in such a short study.

The examples presented clearly indicate that implementing parallelism features requires programmers to have a specific approach already at the application design stage, in order to create the possibility of using the aforementioned parallel programming libraries. In the first application, an approach was used in which the image was divided into sections of pixels, and each of them was processed independently by dedicated threads. It should be noted that the data from individual sections of the image are independent of each other, so the processing can actually be carried out in a parallel manner. This not only increases the speed of calculations, but it also ensures the responsiveness of the main application thread, implementing the GUI interface. A similar parallelization scheme applies to the OpenMPI application, in which dedicated processes calculate independent sets of components of a numerical formula. The presented simulation results for different conditions of code distribution between cluster nodes show the high effectiveness of the approach used in accelerating calculations. Of course, there are other additional aspects of numerical calculations – which could not be discussed due to the volume of the article – such as the problem of integration accuracy, development of the problem for integrals of functions of two variables or the problem of applications of the presented solution in specific engineering tasks. It is also worth pointing out the enormous scientific and educational benefits resulting from the access to a computer cluster. This allows planning dedicated classes for students, giving the opportunity to familiarize themselves with the physical structure of the cluster, management of its operating system, the system for managing computational tasks and finally, the implementation and launch of OpenMPI applications. It seems that this allows students to be equipped with specific knowledge and skills that can additionally enrich their possibilities of adapting to the requirements of the IT industry.

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TADEUSZ DASZCZYŃSKI

The Use of VR Technology in Teaching Electrical Power Engineering on the Example of the VES Application

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Abstract

The article presents the use of virtual reality (VR) technology in the process of teaching electrical power engineering, based on the Virtual Electrical Switchgear (VES) application. The author discusses the advantages of using VR in education, pointing to interactivity, the possibility of carrying out practical tasks and improving student engagement. The functions of the VES application were also presented, which allow the simulation of realistic scenarios related to learning how to build and operate MV switchboards. The article also includes research results confirming the effectiveness of using this application in the teaching process, including increasing the effectiveness of learning and improving students' understanding of issues. An important perspective for the development and further use of VR technology in the field of teaching electrical power engineering was noted, contributing to improving the quality of education in this field.

Keywords: Virtual Reality, VR in education, teaching process, higher education didactics

Introduction

After the crisis related to the Covid-19 pandemic and the outbreak of the war in Ukraine, the accompanying reorganization of the global supply chain and rising inflation, energy instability and lack of trained staff have been added to the challenges of the industrial sector. Compared to the 2015/16 academic year, where the total number of students in Poland was 1,405.1 thousand, in the 2022/23 academic year, 1,223.6 thousand people studied (Statistics Office in Gdansk, 2023). According to the assumptions of the European Commission "Education and Training 2020" and the report on the Agenda for the Modernization of Higher Education (European Commission, 2011), higher education faces many important problems. One of the main challenges is, among others, improving the quality and relevance of teaching and learning. Market expectations towards universities seem to be unchanged and are expressed in qualified, competent, innovative and talented graduates. Students are future knowledge workers and, after completing their studies, they should have thorough education, knowledge, practice and experience in a specific field. Graduates broadly educated and prepared to take up work will have an impact on the economic development and prosperity of the European market. However, the potential of European higher education institutions in terms of their role in society and their ability to contribute to Europe's prosperity is not fully exploited. Research under the Human Capital Operational Program in 2014 showed that nearly 80% of employers reported problems with finding qualified employees. Internal research among students indicates a high demand for practical exercises, which the university is unable to provide due to limited staff and equipment resources. It seems that the implementation of digital teaching techniques, including virtual reality, can help universities increase the attractiveness of classes and improve the quality of teaching.

Virtual reality (VR) is a technology that provides an interactive computer-generated environment, usually with a dynamically changing scenario, in which you can see and move. VR simulates the user's physical presence in an artificially created world and allows him to interact with this virtual environment (Bowman, McMahan, 2007).

This article explores the utilization of VR technology in teaching electrical power engineering, focusing on the innovative VES application as a case study. By leveraging VR, educators can provide students with dynamic, interactive, and realistic simulations that closely mimic real-world scenarios encountered in the field of electrical power engineering. Through VES, students can engage in hands-on experiences, such as troubleshooting network failures, conducting equipment maintenance, and navigating complex electrical systems, all within a safe and controlled virtual environment.

VR technology in education

Virtual Reality (VR) technology has emerged as a powerful tool in various fields, revolutionizing the way we perceive and interact with digital environments. In the realm of education, VR holds immense potential to transform traditional teaching methodologies, offering immersive and experiential learning experiences. One area where the application of VR technology showcases significant promise is in the domain of electrical power engineering education.

VR is used in those industries where making a mistake may result in damage to health or exposure to costs related to the destruction of equipment, like electrical power engineering. Due to the affordability and wide range of possibilities of this technology, it is gaining more and more popularity all over the world.

Among others, Schneider Electrics used virtual reality as a training medium in the field of electrical power devices offered by the company (Schneider Electrics, 2022). Another example of the use of virtual reality in practice is a project implemented by Enea Operator, consisting in mapping a training means for learning work under voltage. This project involves the development of training scenarios for selected Main Power Supply Points and MV stations (Enea Operator, 2019).

The integration of VR technology into the teaching of electrical power engineering offers numerous benefits, including enhanced student engagement, improved comprehension of complex concepts, and the opportunity for practical skill development. Additionally, VR facilitates personalized learning experiences, allowing students to progress at their own pace while receiving immediate feedback and guidance.

This article not only discusses the functionalities and capabilities of the VES application but also presents empirical evidence supporting its effectiveness in enhancing the learning outcomes of students in electrical power engineering education. Furthermore, it explores the potential implications and future directions of VR technology in advancing pedagogical practices within this field.

VES application

The main goal of the VES project was to develop and implement an innovative platform for cognitive training using VR and AR technologies for a virtual laboratory of power equipment. As a result of the project, an innovative application using VR technology was created, intended for learning the construction and operation of, among others, MV switchboards and an application for mobile devices using AR technology.

The main aspect of the VES application that was used for the work is the virtual model of the medium voltage (MV) switchgear. A switchgear is a set of electrical power equipment operating at the same rated voltage, used to distribute electricity. It consists of a structure equipped with busbars and insulating elements, as well as electric power equipment serving as distribution, protection or measurement (Elektrometal Energetyka S.A., 2021). The MV switchgear implemented in the application is based on the real model of the switchgear produced by Elektrometal Energetyka S.A. presented in Figure 1.

MV switchgears with power equipment are characterized by characteristic electrical quantities, the values of which depend on the method of execution, electrical solutions and materials used. These values are crucial when selecting the equipment, and the designers make every effort to achieve the highest possible values of current, voltage or temperature to which the switchgear will be adapted, while keeping its dimensions and production costs as small as possible.

Figure 1. MV switchgear from Elektrometal Energetyka S.A.: on the left pic taken in the Laboratory of Power Apparatus and Switching Processes, on the right from (Elektrometal Energetyka S.A., 2021): A – control circuit compartment, B – busbar compartment, C – mobile module compartment, D – connection compartment.

For the proper functioning of the VR application, a set of necessary devices was used, which included:

– VR glasses, two touch controllers included in the Oculus Quest 2 set,

– A computer equipped with a modern processor and graphics card, with sufficient computing power,

– Monitor displaying a view from the perspective of using VR glasses, used to analyse the respondent’s movements in real time,

– Router for exchanging information via WiFi between the computer and the VR set.

The created laboratory stand is shown in Figure 2. In the further description of the application, for easier identification, the user is the person who is currently using VR glasses, and the avatar is the character that the user moves in the virtual world.

Figure 2. Laboratory setup in the Laboratory of Power Apparatus and Switching Process

The start screen, shown in Figure 3, consists of a tutorial button and 3 functional levels of the application. It is additionally possible to select the application language, i.e. Polish or English (upper right corner of the board). The table is additionally used as a source of information regarding switchboards, i.e. general information regarding MV switchboards, individual requirements and rated parameters, as well as standardization and certification.

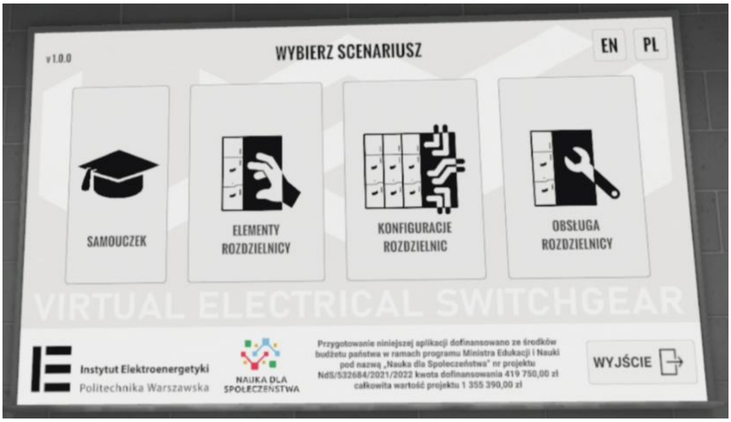

Figure 3. The start screen of VES application

By embedding 3D models of devices in virtual switchgear rooms (e.g. in those modelled on real industrial facilities), separate functional parts of the switchboards and components (e.g. switching devices, bus systems, measuring transformers) were visualized. The individual functional elements of the switchboards and the power supply system itself are presented in the form of an interactive single-line diagram. The diagram will enable you to link the symbol used in it with the corresponding switchgear element.

The VES application consists of the following levels of training and functional VR simulations:

1) Level I – Construction of elements of the energy distribution system and switching activities during normal operation of the system (Figure 4),

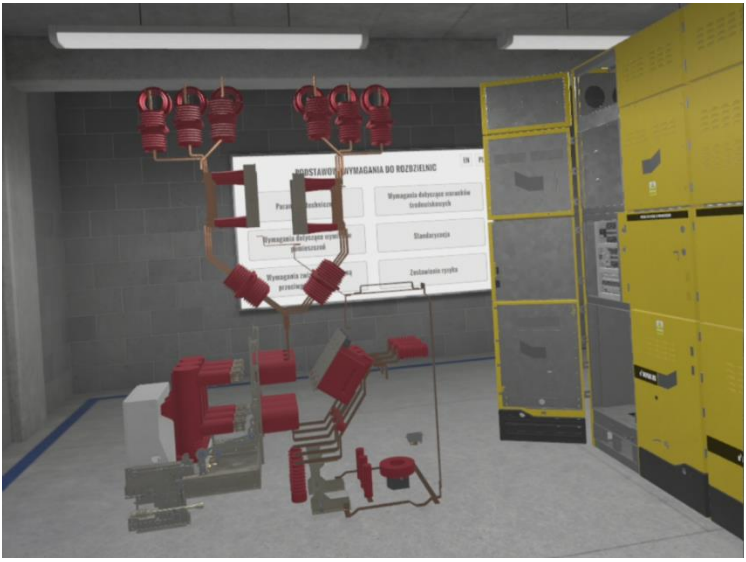

Figure 4. A screenshot from the Level I part of the VES application

2) Level II – configurator of MV switchgear systems (Figure 5),

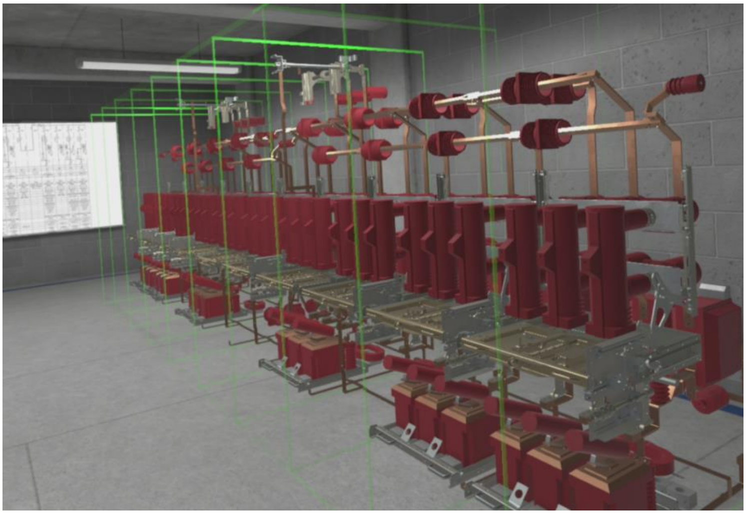

Figure 5. A screenshot from the Level II part of the VES application

3) Level III – building the right platform for cognitive training (Figure 6).

Figure 6. A screenshot from the Level III part of the VES application

VES application tests at WUT

In the 2023/24 academic year, initial tests of the VES application were carried out in academic and industry environments. 16 questions were developed and the test participants (51 people in total) answered them after working with the VES application for 20 minutes. Below are the results of the most important survey questions.

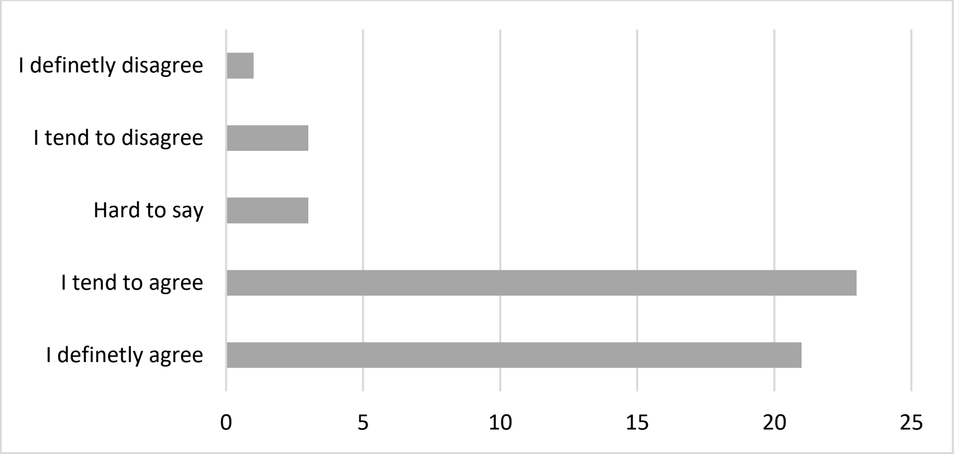

Figure 7. Results of answers to issue 1 – I feel that I have gained new knowledge

Most test participants appreciated the possibilities of using VR technology in science and felt that they had gained new knowledge related to the construction of MV switchboards (Figure 7). Immersive VR experiences can be extremely motivating for students because they provide exciting and interesting ways to learn (Figure 8). This can help increase student engagement and encourage them to explore the topic further. Most research on VR technology confirms that it can use different senses to provide a more integrated learning experience and that it requires greater concentration, which translates into higher educational value. Most also confirmed that the application itself does not cause excessive discomfort related to the use of VR technology (Figure 9).

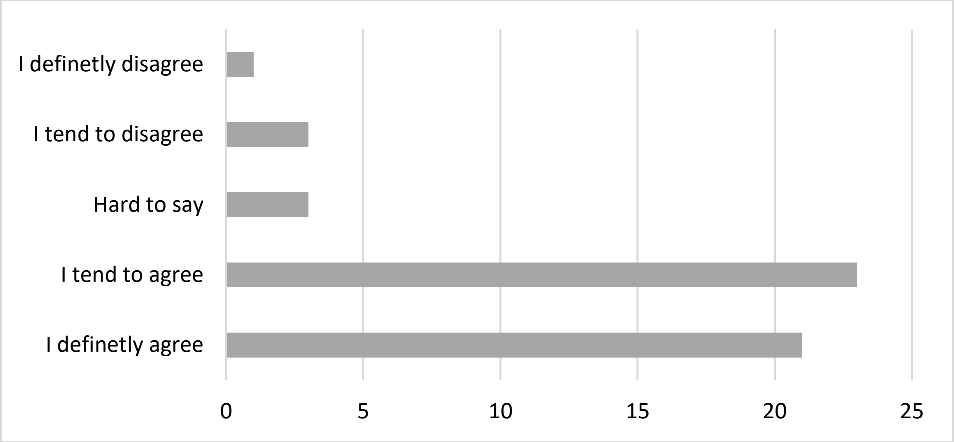

Figure 8. Results of answers to issue 6 – VR exercises required more concentration from me than if they took place in reality

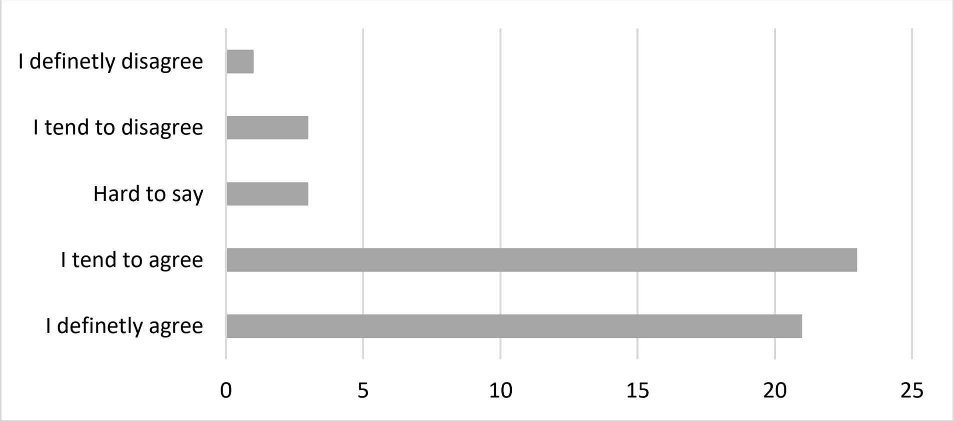

Figure 9. Results of answers to issue 7 – My level of concentration during the exercise was high

Conclusions

This publication explores the development and utilization of a VR application designed to enhance the learning experience of construction and operation procedures for MV switchgears, which are critical components in the electrical power distribution systems, and ensuring safe and efficient operation is of paramount importance. Research related to the VES application has led, as confirmed by experience (ENERGETAB fair 2022, 2023), to the introduction to the educational and research market of a unique and innovative product and service that will be used in training knowledge and skills in the construction and operation of power equipment. Available literature and market research show that this will be the first product of this type available in Poland. This will also allow for the creation of a new quality of academic teaching and research and development work. A qualitative change in conducting laboratory classes will allow for better results in the education of future engineering staff.

Overall, the integration of VR technology, exemplified by the VES application, represents a paradigm shift in the way electrical power engineering is taught and learned. By harnessing the immersive capabilities of VR, educators can cultivate a dynamic and engaging learning environment that fosters critical thinking, problem-solving skills, and real-world applicability, ultimately shaping the next generation of electrical power engineers.

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PAWEŁ DYMORA [1], **MIROSŁAW MAZUREK** [2],
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A Comparative Analysis of Selected Data Mining Algorithms and Programming Languages

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Abstract

This paper evaluates the performance of ten selected data mining algorithms in the context of classification and regression and the effectiveness between two popular programming languages used in data science: Python and R. The algorithms included in the study were Naive Bayes Classifier, K-Nearest Neighbors (k-NN), Support Vector Machine (SVM), Decision Tree, Random Forest, Gradient Boosting Machine (GBM), Logistic Regression, Linear Regression, Ridge Regression, and LASSO Regression. The study aimed to evaluate how the various algorithms perform in classification and regression tasks in the context of a specific problem, in this case fraud detection. The performance of the algorithms was evaluated based on key metrics such as accuracy, execution time, the difference between the best and worst results, and in terms of mean square error (MSE). Moreover, learning tools such as R and Python enable students not only to perform multidimensional data analysis, but also to predict future trends and changes. The ability to work with data, modelling and visualisation are key competences in the context of many areas of modern life and to support the making of accurate business decisions.

Keywords: data mining algorithms, Python, R, accuracy, mean square error

Introduction

Nowadays, our lives are inextricably linked to the vast amount of data generated by various systems and applications. This increase in information creates not only challenges but also incredible opportunities to extract valuable insights that are of great importance both in business and in literally every aspect of our lives. In today's world, the ability to effectively analyze data has become a key skill for making more accurate business decisions and optimizing the operation of various systems. One of the key tools in this area is data mining, a process that enables the detection of hidden patterns and relationships in data sets. It is worth noting that we also encounter data mining algorithms on various platforms daily. An example is Netflix, which analyzes our preferences and offers personalized recommendations for movies and series based on them. The same is true for online ads, which target our interests based on previous product browsing. These algorithms are also present in social media, providing us with personalized content, suggested contacts, or customized ads. While the concept of data mining may seem abstract and complicated, the reality is that everyone has already encountered its impact on everyday life. Although the term may not be commonly used in the media, the impact that data mining algorithms have is undeniable. Analyzing big data brings many challenges, such as capturing, storing, analyzing, searching, sharing, transmitting, visualizing, querying, and updating, as well as protecting privacy and the source of the data. Analyzing datasets makes it possible to discover new relationships, identify business trends, prevent disease, fight crime, and many other applications.

The article presents the functioning of selected algorithms, showing their importance and inevitable presence in our lives. Considering the potential for future applications, it is safe to say that data mining is a key element of the future, opening up new prospects for both business and society as a whole. Both R and Python are free open-source tools, making them readily available to students worldwide. Their popularity in scientific research, medicine, epidemiology and business data analysis means that knowing how to use them is becoming a valuable competency for students in terms of their competitiveness in the job market.

Data Mining

Data mining is a research process that aims to uncover hidden patterns and information in vast data sets. This interdisciplinary field uses techniques from machine learning, statistics, and database systems to extract valuable insights from data. It is a key step in data analysis, intending to transform raw data into an understandable structure, ready for further analysis and use. The main purpose of data mining is to perform semi-automatic or automatic analysis of large amounts of data to identify previously unknown significant patterns. These patterns can include clustering of data records (cluster analysis), detection of unusual records (anomaly detection), and identification of relationships between data (association rule mining, sequence patterns) (Han, Kamber, Pei, 2011; Fayyad, Piatetsky-Shapiro, Smythm 1996).

To achieve this, database techniques such as spatial indexes are often used. It is worth noting that data collection, data preparation, and interpretation of results and reporting are not directly related to the data mining process itself, but can be additional steps in the overall process of extracting knowledge from data (KDD). There is a difference between data analysis and data mining. Data analysis typically focuses on testing models and hypotheses on an available dataset, for example, in the context of evaluating the effectiveness of a marketing campaign, regardless of the amount of data. Data mining, on the other hand, uses machine learning techniques and statistical models to uncover hidden patterns in large amounts of data, which exceeds the capabilities of traditional data analysis (Olson, 2007; Deepali, 2013).

In research practice, different methods of model evaluation are often used to select the best model. One popular technique is comparative model evaluation, which involves using different methods for the same data and selecting the best performing model, or building a complex model using several techniques. A key component of this step is model evaluation and combination techniques, which have a significant impact on the effectiveness of the predictive model being developed. Some examples of such techniques are (Hastie, Tibshirani, Friedman, 2009):

1. **Model aggregation (bagging):** This technique involves combining multiple models that are trained on different subsets of the data to produce more stable and accurate predictions. In bagging, the results from different models are often averaged or upvoted to help reduce variance and improve prediction quality.
2. **Reinforcement/Boosting:** Reinforcement is a technique that involves sequentially building weak models, each focusing on improving the errors of the previous model. By focusing on the harder-to-predict cases, amplification leads to an improvement in overall prediction quality. Popular amplification methods include AdaBoost and Gradient Boosting, for example.
3. **Model contamination (stacking, stacked generalizations):** In this technique, the predictions of different models are combined using an additional model called a meta-model. The meta-model is trained on the prediction results of other models, which can lead to even better prediction results by taking advantage of the diversity of predictions.
4. **Meta-learning):** This approach is based on adapting the model to different data sets by analyzing past results and adjusting learning strategies. Meta-learning can help automatically adapt the model to new data, which can lead to better generalization and higher prediction performance.

Selected data mining algorithms

There are many algorithms used in data mining. The article discusses in detail such algorithms as the Naive Bayes Classifier, K-Nearest Neighbors, SVM, Decision Tree, Random Forest, GBM, Logistic Regression, Linear Regression, Ridge Regression, and LASSO Regression (Feng, Pan, Jiafu Daqiang, Athanasios, Xiaohui, 2015; Dymora, Mazurek, Jucha, 2023).

Classification algorithms

In statistics and machine learning, classification is the process of assigning observations to specific categories or classes based on their characteristics or features. This can be something as simple as marking an email as spam or non-spam, to more complex tasks such as diagnosing a disease based on a patient's medical data. In practice, each observation is analyzed for a variety of characteristics, which can be categorical (like blood type), ordinal (like size), numerical (like the number of occurrences of a word in an e-mail), or real (like blood pressure measurement). Classification can be based on a single feature or a combination of multiple features. Classification algorithms vary in their approach but generally work by comparing observations with others that have already been classified, using similarity or distance functions. These algorithms can be based on statistics, such as Logistic Regression, or on machine learning techniques, such as Decision Trees or Neural Networks (Hastie, Tibshirani, Friedman, 2009; Feng, Pan, Jiafu Daqiang, Athanasios, Xiaohui, 2015).

1. Naive Bayes Classifier

The history of machine learning runs deep in time and surprisingly in simplicity. By going back to the roots, we discover fundamental assumptions that are still a key part of today's methods. One of these milestones is Bayes' theorem – named after the 18th-century English mathematician Thomas Bayes. This theorem, seemingly modest in its form, opens the door to deep considerations of probabilistic inference and classification. It is a technique used to solve the problem of sorting decision classes, where the task of the Bayes classifier is to assign a new case to one of the classes, while their set must be finite and defined a priori (Feng-Jen, 2018; Berrar, 2019).

2. K-Nearest Neighbors

As with the history of machine learning, the concepts of K-Nearest Neighbors go deep back in time, with an equally surprising simplicity. So let's go back to the roots to uncover the underlying assumptions that are still the foundation for today's methods. One of those cornerstones is K-Nearest Neighbors, a technique that has revolutionized the way machines learn and process data. The history of K-Nearest Neighbors dates back to the 1950s when it was first introduced by Evelyn Fix and Joseph Hodges in 1951. The algorithm was later extended by Thomas Cover. The basic premise of the K-Nearest Neighbors algorithm is that similar cases should be associated with each other. The method is an example of lazy learning, meaning that there is no training phase for the model – it is constantly busy storing training data. When a new data point arrives, the K-Nearest Neighbors algorithm analyzes the training set to find the k closest points (neighbors) and makes a prediction based on that. The basis of the K-Nearest Neighbors algorithm is the calculation of distances between data points in the feature space (Zhang, 2016; Mucherino, Papajorgji, Pardalos, 2009).

3. Support Vector Machine (SVM)

The history of the SVM algorithm dates back to the early 1960s when Vladimir Vapnik and Alexey Chervonenkis introduced the concept of VC-dimension and the concept of statistical learning theory. However, it was not until the 1990s that the SVM algorithm gained popularity, largely due to the work of Vapnik and his colleagues at AT&T Bell Labs. Their research led to the development of SVM as an effective tool for high-performance classification, especially in cases where the number of features exceeded the number of samples. The introduction of the kernel trick concept allowed SVM to be applied to nonlinear data, greatly expanding its applications (Srivastava, Bhambhu, 2010; Zhang, 2012).

4. Decision Tree

The history of Decision trees dates back to the 1960s when the method was first described by prominent researchers in the field of machine learning. The method has evolved over the years, with advances in computer technology and increasing applications in various fields. The origins of the Decision Tree can be traced to the 1960s when Ross Quinlan developed the ID3 (Iterative Dichotomiser 3) algorithm, which was one of the first Decision Tree algorithms. Quinlan later developed this algorithm into a series of more advanced methods, such as C4.5 and CART (Classification and Regression Trees) (Feng *et al.*, 2015; Lee, Cheang, Moslehpour, 2022).

5. Random Forest

Over the years, the Random Forest algorithm has covered many key stages of development, from its initial concepts in the 1990s to its recognition as one of the most important algorithms in the field of machine learning. Initially, the random decision forest method was proposed by Tin Kam Ho in 1995. He introduced the random subspace method, which in his view was a way of implementing the "stochastic discrimination" approach proposed by Eugene Kleinberg. The method involved using random subspaces of features to build Decision Trees, intending to reduce correlations between trees and improve the overall accuracy of the model. The development of this method was continued by Leo Breiman and Adele Cutler, who registered the trademark "Random Forests" in 2006. Breiman, using Ho's earlier work and his concept of bagging (bootstrap aggregating), introduced a technique that combined random feature selection and bagging to create sets of Decision Trees with controlled variance. Breiman and Cutler's contribution to the development of the Random Forest algorithm was crucial, as they combined various earlier ideas into a coherent methodology that has gained immense popularity in the world of machine learning (Schonlau, Zou, 2020; Angshuman, Mukherjee, Das, Gangopadhyay, Chintha, Kundu, 2018).

6. Gradient Boosting Machine (GBM)

The Gradient Boosting Machine's origins date back to the 1990s, when Jerome H. Friedman published his paper on the gradient boosting technique. Initially used for regression, the algorithm was later developed and adapted to classification problems by Leora Breiman and Adele Cutler in 1997. Their work, which described the Gradient Boosting Machines algorithm as a technique for combining multiple Decision Trees to improve prediction quality, helped popularize the approach in the world of machine learning. Gradient Boosting Machine (GBM) is a powerful machine learning algorithm applied to both classification and regression problems. Its strength lies in its ability to create complex predictive models by combining multiple weaker models to improve prediction quality. Compared to other algorithms such as Random Forests or Decision Trees, GBM is known for its unique ability to adapt to training data through iterative error correction, making it one of the most widely used tools in the field of machine learning. GBM was quickly recognized as one of the most successful machine learning methods due to its ability to deal with different types of data and its flexibility to adapt to different problems. Through continuous improvement and adaptation, the Gradient Boosting Machine has become an indispensable item in every data scientist's toolbox (Lu, Mazumder, 2020; Natekin, Knoll, 2013).

Regression algorithms

Regression analysis is a comprehensive set of statistical methods that help understand and describe the relationships between different variables. The main purpose of regression analysis is to study how one variable, called the dependent variable, affects other variables, called independent variables or predictors. Regression analysis has two main applications. First, it is used to predict future values of the dependent variable based on known values of the independent variables. This is very similar to what is done in machine learning, where models are built to make predictions based on training data. Second, in some cases, regression analysis can be used to infer possible causal relationships between variables, although this aspect requires caution and additional analysis. It is important to note that regression analysis in itself does not confirm causality between variables but only describes the relationships between them in a given data set (Montgomery, Peck, Vining, 2021).

1. Linear Regression

Linear Regression is one of the simplest and most widely used algorithms in statistics and machine learning. Its primary purpose is to model the relationship between a dependent variable (y) and one or more independent variables (x). It is widely used for forecasting and in many places gives sufficient results. The task of linear regression is simply to fit a straight line to the data. It is worth noting that linear regression assumes that the relationship between the characteristics and the explanatory variable is more or less linear (Seber, Lee, 2012).

2. Logistic regression

Logistic Regression was introduced as a response to the need to model binary variables. Its origins can be traced back to the 1930s when British statistician Ronald A. Fisher introduced the concept of discriminant analysis as a way to distinguish between two groups. However, the proper formalization of Logistic Regression as a statistical tool is attributed to Joseph Berkson, who in the 1940s introduced the concept of discriminant analysis. Generally, Linear regression is used to estimate the dependent variable in case of a change in independent variables. Whereas logistic regression is used to calculate the probability of an event (Hilbe, 2009; LaValley, 2008).

3. Ridge regression

Another type of regression is ridge regression. The history of Ridge Regression is related to Tikhonov's concept of regularisation, which was invented independently in different contexts. It became widely known through its application to integral equations in the work of Andrei Tikhonov and David L. Phillips. In the statistical literature, thanks to Hoerl, it is known as Ridge Regression. The name is derived from ridge analysis, where 'ridge' refers to the path from the maximum constraint. Ridge Regression is a technique used in statistical analysis and machine learning to model data, especially when the independent variables are highly correlated. It is an extension of Linear Regression that introduces an additional regularisation parameter to reduce the impact of colinear variables on the model. Unlike Linear Regression, which minimizes the sum of squares of the residuals (RSS), Ridge Regression adds a penalty to the size of the regression coefficients, leading to more stable and interpretable models. Compared to Logistic Regression, which is used to predict binary outcomes, Ridge Regression is typically applied to regression problems where the resulting dependent variable is continuous (Saleh, Arashi, Golam Kibria, 2019; Hoerl, 2020).

4. Lasso regression

On the other hand, the lasso regression model was originally developed in 1989. It is an alternative to classical least squares estimation that avoids many of the problems of overfitting when we have a large number of independent variables. Lasso regression (Least Absolute Shrinkage and Selection Operator) is a linear regression technique used to estimate model coefficients that introduce regularisation. Lasso regression is useful in cases where there are multiple features, some of which may not be significant. It can help to identify significant features, reduce data redundancy, and increase the interpretability of the model (Ranstam, Cook, 2018; Zhang, Wei, Lu, Pan, 2020).

Languages and libraries used for data analysis

Programming languages play a key role in data mining, enabling the creation of algorithms, the automation of data analysis processes, and the visualization of results. They enable analysts to effectively manage, process, and draw valuable insights from data. The choice of the right programming language depends on the specifics of the project, the tools available, and personal preferences. Programming languages such as Python, R, SQL, Java, and SAS are most commonly used in data mining. This article will use two of the most popular ones, Python and R (https://www.taazaa.com/python-tools-for-data-mining/; https://www.rdatamining.com/).

Python

Python is extremely popular due to its simplicity and rich ecosystem of libraries that support various aspects of data analysis. The main libraries used in the survey are (https://www.taazaa.com/python-tools-for-data-mining/):

1. `CSV` is a library that allows data from `csv` files to be easily loaded into Python, which is useful for data analysis, importing and exporting data from different systems, and automating data processing. It also allows data generated in Python to be saved to `csv` files for easy later use or sharing with other users and systems. The `csv` library supports various delimiters and `csv` formats, making it a versatile tool for working with tabular data in Python.

2. `Sckit-learn` is a library in Python that provides tools for machine learning. It is commonly used to build and evaluate predictive models. The library includes a wide range of algorithms, including regression, classification, clustering, and dimensionality reduction. `Scikit-learn`'s main applications include data preprocessing, feature engineering, model selection, and performance evaluation. The library also includes a set of tools for cross-validation and hyper-parameter optimization to create accurate and efficient models. `Scikit-learn` integrates with other tools in the Python ecosystem, such as `NumPy`, `SciPy`, and `matplotlib`, making it a versatile and powerful tool for data analysts and machine learning researchers.

3. `Matplotlib` is a library in Python for creating a variety of graphs and data visualizations. It is useful for data analysis, scientific research, engineering, and machine learning. Matplotlib allows easy customization of the appearance of graphs, supports numerical data from `NumPy`, and supports a variety of user interfaces, making it a versatile tool for data visualization in Python.

4. `Seaborn` is a high-level visualization library for the Python language that is based on `Matplotlib`. It is used to create attractive and informative statistical graphs. `Seaborn` facilitates the generation of graphs such as dot plots, histograms, box plots, and heat maps. With its ease of use and aesthetically pleasing default styles, `Seaborn` is a popular tool in data analysis and data science.

R language

R is a programming language specifically designed for statistical analysis and data visualization. The research used (https://www.rdatamining.com/):

1. **`Readr`** is a library in R, part of the `tidyverse` package, used to quickly and accurately import data from `CSV`, `TSV`, and other text formats. It allows easy control of data types, headers, and separators, which is crucial for data analysis and statistical modeling.

2. **`Caret`** is a tool for building, validating, and comparing machine learning models. It is particularly appreciated for its support in data management, such as partitioning into training and test sets and data standardization. `Caret` also offers tools for feature selection and dimensionality reduction, which supports model optimization and reduces the risk of overfitting. In addition, caret provides various cross-validation techniques, enabling fair comparison of the performance of different models. Its unified interface makes it easy to experiment with the various machine learning algorithms available in R and to quickly evaluate and select the optimal model. These features make `caret` an extremely useful tool for data scientists and machine learning professionals.

3. **`E1071`** is a data analysis and machine learning tool specializing in classification and regression. It provides implementations of algorithms such as support vector machine (SVM), k-nearest neighbors (kNN), Bayesian classifiers, and decision trees. `e1071` also provides tools for model cross-validation and data processing, including normalization and standardization. It is a valued tool in the R community for its versatility and usefulness in developing advanced data analysis and predictive models.

4. **`Ggplot2`** is a visualization library based on graph grammars. It is widely used to create elegant and highly customizable charts. The main tenets of `ggplot2` include the use of layers, which are added to the graph, allowing complex data visualizations to be created with ease. The library offers a wide range of geometries such as points, lines, bars, and areas, and also supports different data types such as time series and categorical data. Thanks to its flexibility and aesthetics, `ggplot2` is the preferred tool for data analysts and researchers to present data clearly and professionally.

5. **`KableExtra`** is an extension for the `knitr` package that allows you to create beautiful and interactive HTML and PDF tables in your reports. The main

features of `kableExtra` include adding formatting to tables, such as coloring rows and columns, adding headers, and footers, and the ability to add labels to tables. This package is particularly useful for generating data reports, presenting analysis results, and visualizing data clearly and professionally. Thanks to its ease of use and flexibility, `kableExtra` is a popular tool in the R environment for those involved in data analysis and results reporting.

Comparative analysis of data mining algorithms

In this work, the *Credit Card Fraud Detection Dataset 2023* dataset was used, which contains information on credit card transactions. This data has been collected for analysis and mining in the field of machine learning, as well as for performing various analyses on financial transactions (https://www.kaggle.com/datasets/nelgiriyewithana/credit-card-fraud-detectiondataset; Aggarwal, Yu, 2008). The dataset used to perform the study was divided into 31 parts. Each of them is responsible for a different task performed during the data analysis done in the work. The first is the unique ID for each record, so you can find out how many rows are in the database. The first column will not affect the performance of the algorithm. The range of these records is from 0 to 568,629 which means that there are 568,630 records in the database there. The next part belongs to the input data, based on which the algorithms will be able to assign to a class. There are 28 features defined in the database used, and named from V1 to V28.

The purpose of the analysis is to compare the effectiveness and time efficiency of selected data mining algorithms in the Python and R programming languages. An assessment was made of how the different algorithms handle the tested data, how fast they can process the data, and how they perform in different language environments, which is important, especially for large data sets. In this article, we will make a detailed comparison of the results of applying seven different data mining algorithms on a single database, using two popular programming languages: Python and R. The algorithms Naive Bayes Classifier, K-Nearest Neighbors, SVM, Decision Tree, Random Forest, GBM, and Logistic Regression, are widely used in data analysis and pattern detection. The second stage of the comparison will be to examine the MSEs for the Linear Regression, Combs, and LASSO algorithms. In the analysis presented here, each of these algorithms has been tested a hundred times for both the Python language and the R language, on the same database. This duplication of the experiment will allow us to obtain stable and comparable results, and to understand whether the choice of the right algorithm has a significant impact on performance on a given database. The purpose of the analysis is to investigate which algorithm performed best against bank fraud and to understand whether the choice of a particular algorithm can affect the effectiveness of data analysis.

To carry out an evaluation of the effectiveness of the algorithms for Python and R language and to determine whether the choice of one of them can affect the results achieved, at the beginning of the study we compared the effectiveness of the seven selected algorithms in terms of percentage of matching, then we will focus on the best and worst sample of these algorithms, and finally we will compare the execution time. Next, the mean squared error was examined. Table 1 compares the algorithms in terms of corresponding class assignments. When we look at the first three algorithms, one might think that the programming language does not have much impact on the efficiency of algorithm execution. However, when we come to further analysis we see a difference of almost 8 percentage points in the effectiveness of the Decision Tree algorithm and more than 10 percentage points for the GBM algorithm. Such differences between these two algorithms may tempt us to think about the choice of the programming environment.

Table 1. Efficiency of algorithms by programming language

Algorithm name	Effectiveness Python [%]	Effectiveness R [%]
Naive Bayes Classifier	91.893	91.912
K-Nearest Neighbors	99.918	99.589
Support Vector Machine	99.684	98.677
Decision Tree	99.498	91.979
Random Forest	99.969	99.539
Gradient Boosting Machine	97.875	87.332
Logistic Regression	96.428	96.515

Table 2 shows a comparison of the best and worst results obtained by a given algorithm. During this comparison, it is safe to say that the differences between the best and worst results for both languages were not large. The biggest difference was recorded for the Random Forest algorithm in R language where the difference was almost 2 percentage points. If we look at the previous disparity, it can be considered small. In addition, from this table, one can read that it was the Python language that achieved 100% efficiency in one of the trials. We could not draw such a conclusion from the comparisons of the earlier subsection. Another point one did not see earlier is by far the weakest results for the R language for the GBM algorithm, where the difference could be almost 10 percentage points.

Table 2. Maximum and minimum efficiency of algorithms by programming language

Algorithm name	Max Python [%]	Min Python [%]	Max R [%]	Min R [%]
Naive Bayes Classifier	92.092	91.684	92.112	91.688
K-Nearest Neighbors	99.989	99.846	99.795	99.370
Support Vector Machine	99.848	99.290	98.954	98.336
Decision Tree	99.811	99.231	92.503	91.406
Random Forest	100.000	99.942	99.881	99.144
Gradient Boosting Machine	98.349	97.442	88.200	86.496
Logistic Regression	96.802	95.998	96.740	96.301

Figure 1 shows the speed of the algorithms. The results show the time disparity between the algorithms. It can be seen that 5 out of 7 algorithms were executed faster in Python. The only algorithms executed faster in R were Linear Regression and Decision Tree. However, when we compare the difference in execution speed between them and the GBM algorithm, one can conclude that the values are not large in favor of the R language.

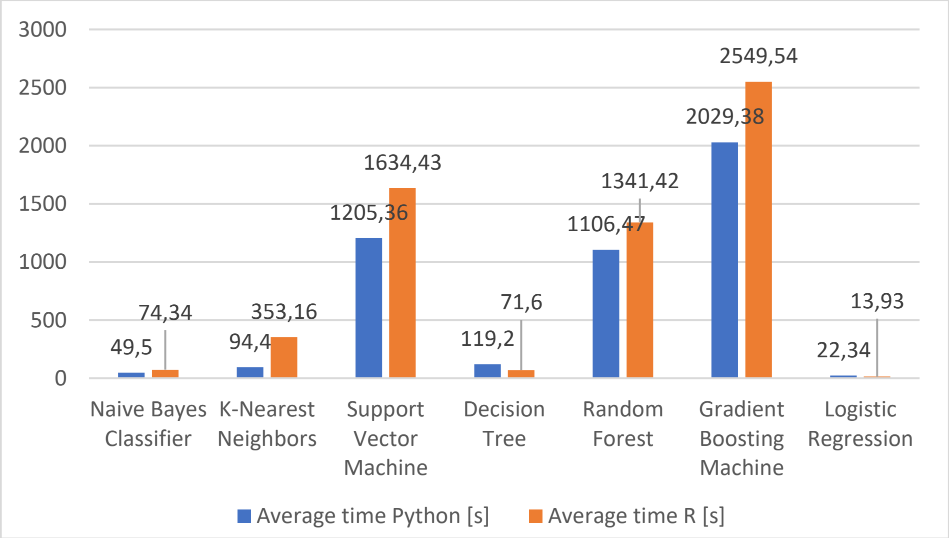

Figure 1. Average execution time of selected algorithms by programming language

The last study was an analysis of the mean squared error of the regression algorithms. Table 3 shows us what the earlier ones did not show us. The poor performance of LASSO Regression is mainly due to the Python language, which completely failed in-class assignments. The error is decisive, and because of this, LASSO Regression performed the weakest, despite the fact that in the R language, this algorithm was not the weakest. It is also worth mentioning that the average MSE turned out to be the best for Linear Regression for both languages.

Table 3. MSE comparison by programming language

Algorithm name	MSE Python	MSE R
Logistic Regression	0.059040064	0.059117396
Ridge Regression	0.059047293	0.059774547
LASSO Regression	0.250000999	0.059125534

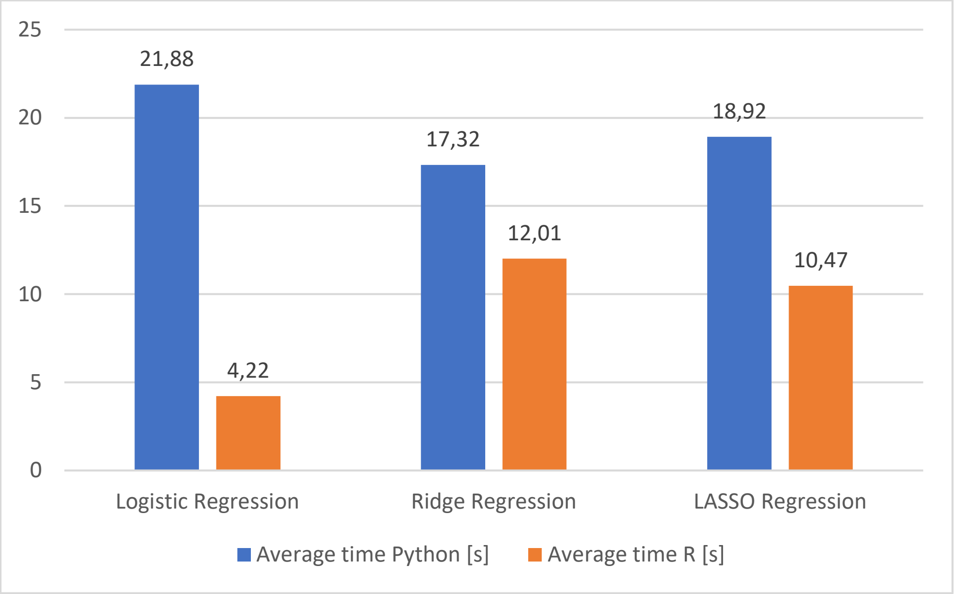

Figure 2. Average execution time of selected algorithms by programming language

Figure 2 shows the execution time. Rather, the results of the algorithms were very close, but when it breaks them down into separate programming languages one can see a much greater disparity, for example, in Linear Regression, where the difference is more than 17 seconds. Having information about the average execution time, which was less than 17 seconds. Algorithm in Python language took more time to get better results.

Conclusion

The article describes and examines 10 different algorithms used in data mining. Each of them is characterized by a different way of execution or different mathematical foundations. It is worth adding that the world of data mining does not end with these algorithms, in fact, it can be said that this is just the beginning. Each of them has its own strengths and weaknesses, so during the process, it's worth checking which algorithm is best suited to the issue at hand.

The research showed that the algorithms used would be able to detect fraud at about 70%. The best algorithms turned out to be the Random Forest and K-Nearest Neighbors algorithms. As for the mean squared error, on the other hand, Linear Regression turned out to be the best. The worst results, on the other hand, were obtained by the Naive Bayes classifier and LASSO Regression algorithms. The GBM and LASSO Regression algorithms achieved the largest differences between their weakest and best results. Another aspect examined was the algorithm's execution time. Here Logistic and Linear Regression performed the fastest, while GBM and LASSO Regression performed the slowest.

It was possible to correctly classify the entire test set obtained by using Random Forest. In the criterion of time, score difference, and efficiency, the best algorithm turned out to be K-Nearest Neighbors, because it performed much faster than Random Forest. As for linear solutions here there is no problem because in all 3 criteria Linear Regression turned out to be the best. The choice between Python and R is relatively easy, as the efficiency results indicated that 5 out of 7 algorithms obtained better results in Python. Similar results were obtained for the mean squared error, where 2 out of 3 algorithms had a lower error than the R language. The difference between the maximum and minimum results also shows that Python outperformed R by the same ratio. Only the R language proved to be better in terms of execution time for linear algorithms, i.e. those in which the mean squared error was tested, where all 3 algorithms were executed faster. In terms of efficiency, execution speed is again in favor of Python, where 5 algorithms were executed faster than in R.

In addition, learning to program in Python or R and work with ML strengthens students' problem-solving skills, formulating hypotheses, testing models and iteratively improving solutions. This practice-based approach to learning develops the ability to understand complex systems. Also nowadays, many employers expect new employees to be able to work with analytical tools and ML. Sectors such as fintech, biotech, e-commerce, logistics and Industry 4.0 are intensively looking for professionals who can build predictive models, analyse data and automate processes using R, Python and ML tools. Therefore, the ability to use data minig tools and apply appropriate algorithms is important for the educational process of students, and this paper can be a valuable contribution to their education.

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Forecasting the Arrival of the Next Pandemic Wave – Modeling and Tools

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Abstract

The scope of the paper is to review the literature on data analysis and visualization in the context of the COVID-19 pandemic and to describe the different tools and methods used in this type of analysis. Examples of the use of these tools in practice and their limitations will also be presented. The paper concludes with conclusions and recommendations for the use of data analysis and visualization to better understand the COVID-19 pandemic and to predict the arrival of future pandemic waves.An important feature of the article is the possibility of a broad overview of modelling possibilities and the selection of appropriate frameworks and tools which can be used in the educational process of data analysis for students for in-depth study and prediction of trends and data, in particular of such important issues as the evolution of pandemic.

Keywords: Forecasting, Covid-19, R language, time series analysis

Introduction

The COVID-19 pandemic, which started in 2019, has changed the lives of people around the world forcing authorities and society to take many preventive measures. One of the most important challenges facing authorities and society is to anticipate the arrival of the next waves of the pandemic so that appropriate preventive measures can be taken. COVID-19 data analysis and visualization have become important tools in the fight against a pandemic, as they allow a better understanding of the spread of the virus and the effectiveness of various prevention measures (Stubinger, 2020; Petropoulos, 2020).

Forecasting is the process of using existing knowledge and data to make a statement about an event that has not yet occurred. This can be based on past patterns and trends and the use of scientific and statistical models. Predictions tend to be more specific in their formulation because they are based on a solid foundation of evidence. An example of prediction would be predicting economic growth based on output, employment, and other macroeconomic indicators (Nielsen, 2020; Hyndman, 2008).

Forecasting, on the other hand, is the process of assessing the probability of future events based on incomplete or uncertain information. Forecasts tend to be less certain and more probabilistic, as they are based on assumptions and scenarios rather than specific data. Forecasting is often used to inform decision-making and planning because it allows a wide range of possible outcomes and their associated uncertainties to be considered. An example of forecasting would be assessing the probability of rainfall over the next few days based on a weather forecast. In this case, the forecast is based on available meteorological data such as temperature, atmospheric pressure, and humidity, but also takes into account the uncertainty associated with the unpredictability of the weather. This forecast can be useful for those planning a trip or organizing an outdoor event, as it allows them to take into account the possibility of rain and take appropriate precautions.

One of the main challenges in predicting and forecasting the next wave of COVID-19 is the dynamic nature of the virus itself. COVID-19 has proven to be highly infectious and capable of rapid mutation, making it difficult to accurately predict its future spread. Other important factors to consider include vaccination rates, potential re-infection in those already infected, and the impact of various intervention strategies such as social distancing or economic closures. Furthermore, the COVID-19 pandemic generated huge amounts of data, including case counts, hospitalizations, deaths, tests, virus mutations and health system response data. Tools such as R and Python are widely used to analyze large data sets (so-called big data), allowing this information to be processed, analyzed and visualized. This provides a more accurate understanding of epidemic trends and is crucial in the training process of students who will work as data analysts and researchers in the future and such qualifications for their professions are crucial.

Time series and data

Time series is a type of data that is related to time and that is collected at regular intervals. Examples of time series include share price data, meteorological data, demographic data, and traffic data. Time series analysis involves predicting future values based on the history of the data. To do this, various statistical and mathematical models are used, such as linear models, ARIMA models, and neural models. These models allow the analysis of trends, seasonality, and other time series characteristics (Nielsen, 2020; Hyndman, 2008; Zagdański, Suchwałko, 2016).

One important step in time series analysis is stationarity. A time series is stationary if its statistics, such as mean and variance, are constant over time. If a time series is not stationary, it is necessary to transform it so that it is stationary before the analysis can be carried out. Another important element of time series analysis is model identification. The identification process involves finding the optimal model that best fits the data. Various methods can be used for this purpose, such as trial and error, Akaike approximation, or Bayesian approximation.

Different methods can be used to forecast the value of a time series, depending on the characteristics of the data. These methods include simple forecasting based on the mean, forecasting based on linear regression, or forecasting based on neural networks (Zagdański, Suchwałko, 2016; Dymora, Mazurek, Jucha, 2023).

The data analyzed represent cases of infection and death from COVID-19, a disease caused by the SARS-CoV-2 coronavirus. The data are for cases worldwide and cover the period from 1.01.2020 to 31.12.2022.

The publicly available dataset was downloaded from the official WHO (World Health Organization) website. Table 1 below describes the data contained in the file.

Table 1. Description of the data used in the analysis

Column name	Data tape	Description
Date_reported	Date	Date of notification to WHO
Country_code	String	ISO country code Alpha-2
Country	String	Country, territory, area
WHO_region	String	WHO regional offices
New_cases	Integer	New confirmed cases
Cumulative_cases	Integer	Total number of confirmed cases
New_deaths	Integer	New confirmed deaths
Cumaltive_deaths	Integer	Total number of confirmed deaths

	A	B	C	D	E	F	G	H
1	Date_reported	Country_code	Country	WHO_region	New_cases	Cumulative_cases	New_deaths	Cumulative_deaths
2	03.01.2020	AF	Afghanistan	EMRO	0	0	0	0
3	04.01.2020	AF	Afghanistan	EMRO	0	0	0	0
4	05.01.2020	AF	Afghanistan	EMRO	0	0	0	0
5	06.01.2020	AF	Afghanistan	EMRO	0	0	0	0
6	07.01.2020	AF	Afghanistan	EMRO	0	0	0	0
7	08.01.2020	AF	Afghanistan	EMRO	0	0	0	0
8	09.01.2020	AF	Afghanistan	EMRO	0	0	0	0
9	10.01.2020	AF	Afghanistan	EMRO	0	0	0	0
10	11.01.2020	AF	Afghanistan	EMRO	0	0	0	0
11	12.01.2020	AF	Afghanistan	EMRO	0	0	0	0
12	13.01.2020	AF	Afghanistan	EMRO	0	0	0	0
13	14.01.2020	AF	Afghanistan	EMRO	0	0	0	0

Figure 1. Preview of the first records of a data frame

Data analysis and visualization in R

To initially illustrate the behavior of the data, clear plots were made using R language packages and libraries. Libraries used in this analysis include: `library('ggplot2'); library('dplyr'); library('ggrepel'); library('tidyr'); library('shadowtext'); library('nCov2019')` (Dymora, Mazurek, Jucha, 2023; https://www.rdocumentation.org/packages/).

The world map shown in Figure 2 was generated in R shows the numbers of SARS-CoV-2 infections worldwide. The total number of cases from the first occurrence, i.e. 17.11.2019 to 31.12.2022, is more than 660 million, and the countries most affected include the United States, where the number of total cases has already exceeded 100 million, India, Brazil, France, Germany, Italy or Russia, among others. The fewest cases have been reported in African countries such as, among others: Congo, Libya, and the Democratic Republic of the Congo. However, it is worth looking at the reason for this, which is why a world map has also been drawn up with the number of tests taken, as shown in the figure below.

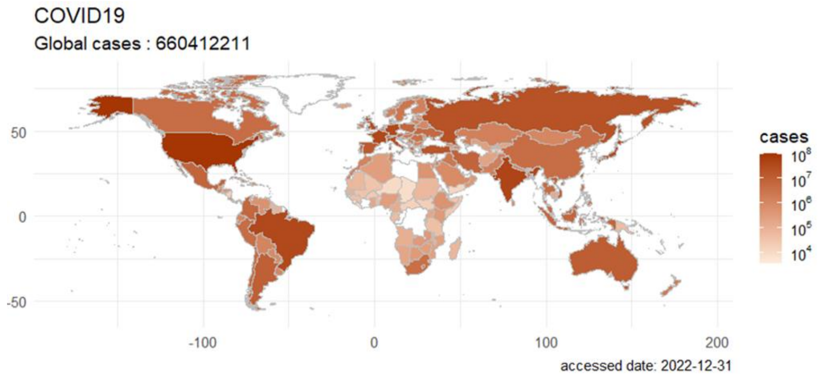

Figure 2. World map showing the number of infection cases

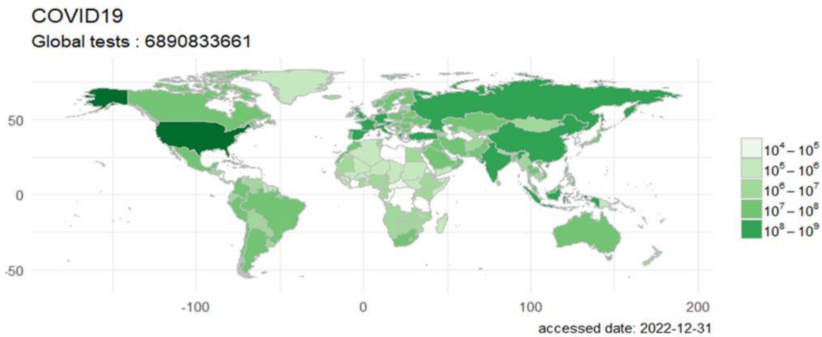

Figure 3. World map showing the number of tests performed

Figure 3 shows a world map with the number of tests performed (17.11.2019–31.12.2022). The total number of tests recorded is more than 6.8 billion, which implies that 1 in 10 people who had a COVID-19 test was positive. Similarly, however, the number of tests coincides with the number of cases detected. Therefore, here one can see the highest number of tests taken in the United States and the lowest in African countries. It can therefore be concluded that many cases have not been reported in Africa due to the negligible number of tests taken.

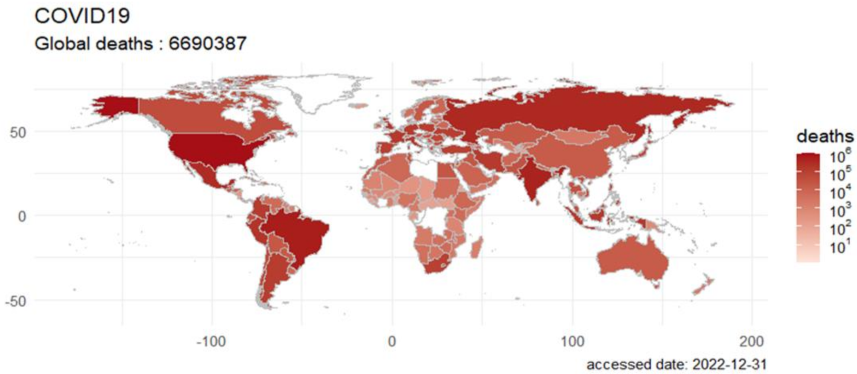

Figure 4. World map showing the number of deaths

In Figure 4, a world map shows a total number of deaths of almost 6.7 million, which, when compared to the number of cases, leads to the conclusion that 1 in about 100 people infected with SARS-CoV-2 dies from COVID-19 disease. The highest number of deaths was reported in the United States, Russia, India, and Brazil.

Time series analysis in R

Various tools and libraries for time series analysis exist in the R language, such as `'forecast'`, `'ts'`, `'timeSeries'` and `'fable'`. These tools allow for the two-rowing, visualization, and forecasting of time series data. They also allow the conversion of time series to stationary series, the identification and fitting of ARIMA models, and the determination of forecast values and their interpretation.

It was decided to present SARS-CoV-2 cases as time series. As a first step, a time series was created from the available data using the `ts()` function, which is available in the `stats` package. The series was also created in the frequency of 365 days, in order to more accurately depict the series on the graph, this setting occurs in the `frequency` parameter and `start=c()`. A time series graph was then created using the `lattice` and `ggplot` packages. Already, the seasonality of the series can be seen with an upward trend in 2020/2021 and

2021/2022. The function `xyplot()` was used to create the graphs. In Figure 5 first analysis showing the time series showing the daily number of COVID-19 infections in Poland was presented.

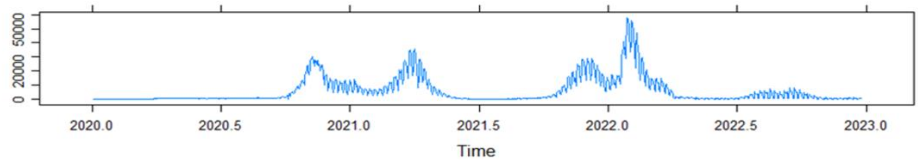

Figure 5. Time series showing the daily number of COVID-19 infections in Poland

In addition, the behavior of the data on the monthly time series is presented using the `monthplot()` (see Figure 6) and `boxplot()` functions (see Figure 7).

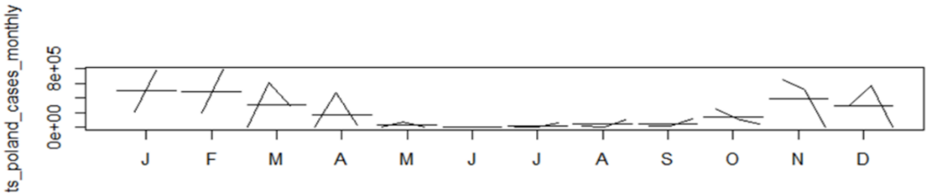

Figure 6. Monthplot chart – COVID-19 infection cases per month in Poland

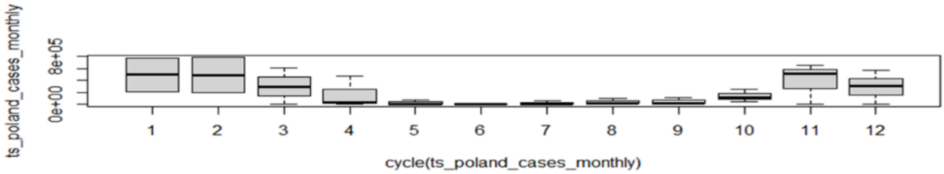

Figure 7. Boxplot chart – COVID-19 infection cases per month in Poland

Using the forecast package and the `seasonplot()` function, seasonal graphs were created by pandemic year (see. Figure 8). It can be seen that there is an increase in cases of both illness and deaths at the end of each year and a decrease at the beginning of the year (winter period).

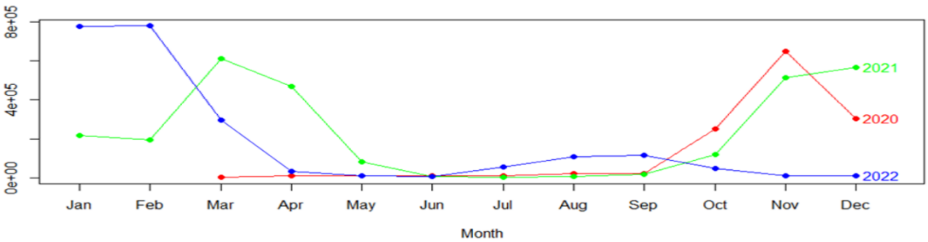

Figure 8. Seasonplot chart – infections over the years

Using the forecast package and the `tslm()` function, series plots are created, showing the trend line (blue color) and seasonality (red color), Figures 9–10. The `forecast` package implements Arima models using available functions, i.e. `Arima()` and `auto.arima()` (automatic selection of coefficients). `Tslm()` is a function in R that is used to model a time variable using linear regression. This function allows the relationship between the explanatory variable and the explanatory variables to be determined in the linear form (Dymora, Mazurek, Jucha, 2023). Analyzing the graphs in Figures 9-10, the seasonality of the data can be clearly seen; the trend overall is neither downward nor upward. Concerning deaths, the seasonality of the series is also present. On the monthly data, however, it can be seen that the trend is minimally downward.

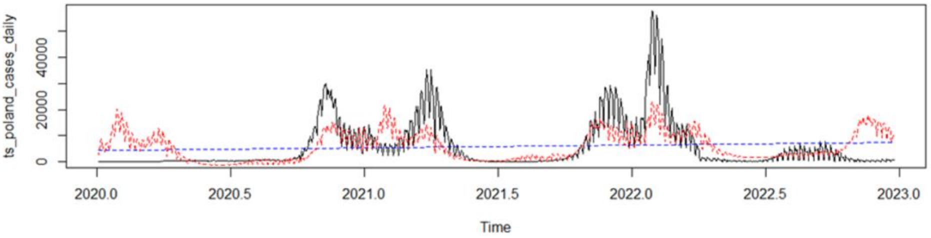

Figure 9. Graph showing seasonality and trend (daily infections) – version 1

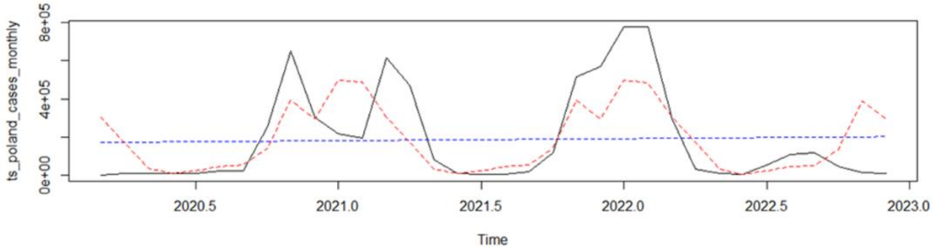

Figure 10. Graph showing seasonality and trend (daily infections) – version 2

Forecasting future values based on historical data in R

There are many different ways to forecast, depending on what the forecast is about and what data is available. Some of the popular forecasting methods are (Nielsen, 2020; Hyndman, 2008; Zagdański, Suchwałko, 2016):

1. Linear regression: this method is used when there is a linear relationship between the explanatory variable (which we want to predict) and the explanatory variables (which are used to make the prediction).

2. Multiple regression: this method is used when multiple explanatory variables are used to predict the explanatory variable.

3. Decision trees: these models are particularly useful for solving classification problems and are often used in business applications.

4. Random models: these models are used when some independent variables can affect the explanatory variable.

5. Neural networks: these models are often used to solve problems where the data are very complex and difficult to interpret using other methods.

AutoRegressive Integrated Moving Average (ARIMA) is one of the most popular time series forecasting models. It is frequently used in many fields such as business, finance and social sciences to predict future values based on past data. The ARIMA model combines three elements: autoregression (AR), differentiation (I), and moving average (MA) to provide a composite description of a time series. Autoregression is the use of previous data values to predict subsequent values. Diferentialisation is used to 'fix' the series, i.e. to remove trend and seasonality. Moving average uses the average value of the data to describe fluctuations (Nielsen, 2020; Hyndman, 2008; Zagdański, Suchwałko, 2016; Dymora *et al.*, 2023).

ARIMA coefficients are used to describe the impact of each of these three elements on the forecast. There are three ARIMA coefficients: p, d, and q. The p coefficient determines the number of previous values used for forecasting in autoregression. The coefficient d determines the number of times the series is differentiated to 'fix' it. The q coefficient determines the number of recent expected values that are used for forecasting a moving average.

The process of identifying a suitable ARIMA model involves selecting the appropriate p, d, and q coefficients that best describe the time series. This can be done using various tools and methods, such as statistical tests and visual analyses. Once a suitable model has been selected, it can be used to forecast the future values of the series

The choice of method for forecasting future values from historical data depends on a number of factors: whether trends are visible in the data, the nature of the trends, whether accuracy information is needed, and whether the computational complexity of the algorithm is important.

Arima models were used to predict future values based on historical data using the functions available in the `forecast` package, using `Arima()` and `auto.arima()` (automatic selection of coefficients). The invocation of the respective commands together with the parameters is shown in Listing 1.

Listing 1. Using `Arima()` and `auto.arima()` in R

```
# Calculation of MA coefficients
Arima(trenddiff_covid_deaths_monthly, order=c(0,0,1))
# Automatic selection of coefficients
auto.model<- auto.arima(trenddiff_covid_deaths_monthly)
summary(auto.model)
```

The most efficient model of those proposed is the one with automatically calculated parameters (`auto.arima()`). It is characterized by the lowest value of the error metric `'AIC' = 310.8`. The results obtained for the trained model are shown in Listing 2. Listing 3 presents the obtained results for both models – a comparison of the models.

Listing 2. Using `auto.arima()` results in R

```
Series: trenddiff_covid_deaths_monthly
ARIMA(0,0,1) with zero mean

Coefficients:
         ma1
      0.7970
s.e.  0.1171

sigma^2 = 638.7:  log likelihood = -153.4
AIC=310.8   AICc=311.2   BIC=313.8

Training set error measures:
                    ME    RMSE      MAE     MPE     MAPE      MASE       ACF1
Training set 0.3745432 24.8868 20.14803 120.288 201.0402 0.6003476 -0.0384035
```

Listing 3.Comparison of the Arima models

```
> model.1.0.0 <- arima(trenddiff_covid_deaths_monthly, order=c(1, 0, 0))
> model.1.0.0

Call:
arima(x = trenddiff_covid_deaths_monthly, order = c(1, 0, 0))

Coefficients:
         ar1  intercept
      0.4635     0.9997
s.e.  0.1522     8.7498

sigma^2 estimated as 763.7:  log likelihood = -156.48,  aic = 318.95
> model.0.0.1 <- arima(trenddiff_covid_deaths_monthly, order=c(0, 0, 1))
> model.0.0.1

Call:
arima(x = trenddiff_covid_deaths_monthly, order = c(0, 0, 1))

Coefficients:
         ma1  intercept
      0.7977     1.5200
s.e.  0.1168     7.6867

sigma^2 estimated as 618.6:  log likelihood = -153.38,  aic = 312.77
```

The choice of method for predicting future values from historical data depends on several factors: whether trends are visible in the data, the nature of the trends, whether accuracy information is needed, and whether the computational complexity of the algorithm is important. Other important forecasting methods have been developed are:

– Mean-based forecasting – `meanf()` function (see Figure 11),

- Naïve method – `naive()` function (see Figure 12),
- Seasonal naive method – `snaive()` function (see Figure 13),
- Drift-based forecasting – `rwf()` function (see Figure 14).

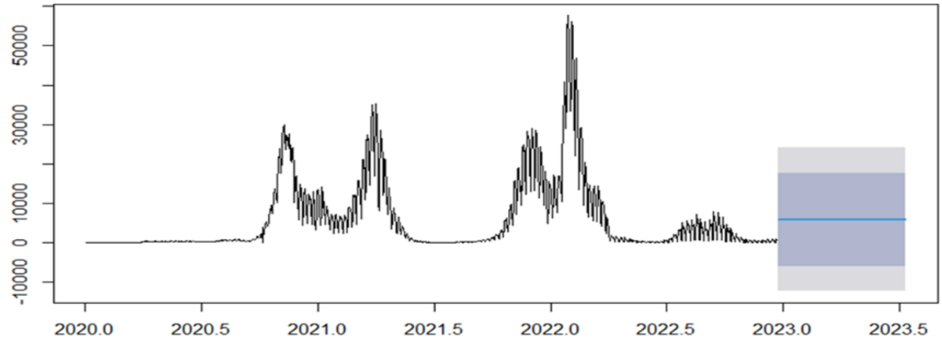

Figure 11. Mean-based forecasting

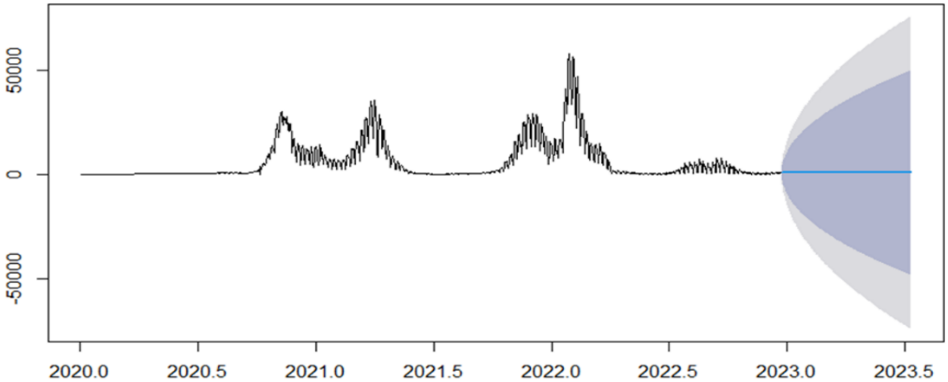

Figure 12. Naive forecasting

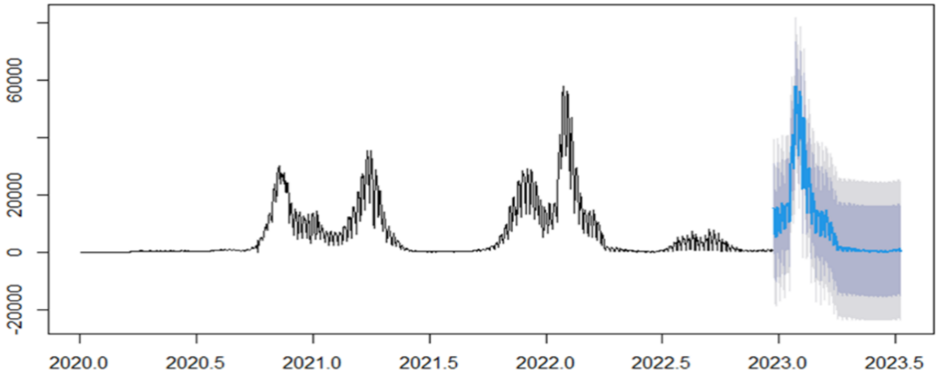

Figure 13. Seasonal naive method forecasting

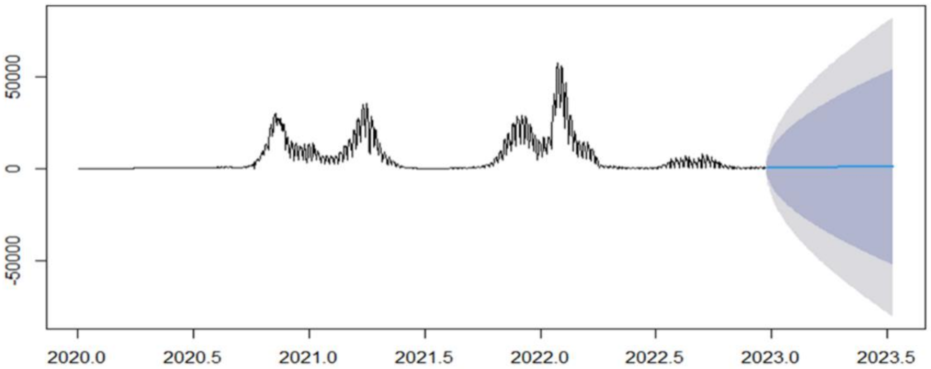

Figure 14. Drift-based forecasting

`rwf()` returns forecasts and prediction intervals for a random walk with a drift model applied to y. This is equivalent to an `ARIMA(0,1,0)` model with an optional drift coefficient. `naive()` is simply a wrapper to `rwf()` for simplicity. `snaive()` returns forecasts and prediction intervals from an `ARIMA(0,0,0)(0,1,0)m` model where m is the seasonal period. If there is no drift (as in naive), the drift parameter `c=0`. Forecast standard errors allow for uncertainty in estimating the drift parameter (unlike the corresponding forecasts obtained by fitting an ARIMA model directly).

Conclusion

The results presented in this paper can be used by governments and health services to plan and make decisions on health policy, manage resources, and prepare for future waves of pandemics. The predictions can also help with planning and coordination between different sectors such as education, transport, and industry.

An important aspect of the work carried out on COVID-19 prediction is also understanding the limitations and errors of the models and how these limitations affect the accuracy of the forecasts. The work has also required continuous adjustment and updating of the models based on new data and changing conditions.

Overall, the results of the project are important for understanding and predicting the evolution of the pandemic and helping to plan and coordinate actions to contain the spread of the virus and protect public health.However, it is important to remember that these predictions are not precise and have their limitations and that actions based on them should be considered as guidelines and not as solutions. Also, it is important to remember that the situation is dynamic and these forecasts should be constantly updated based on new data and changing conditions.

The methodologies and tools presented tools allow the building of predictive models that can predict the development of epidemics, such as waves of infections, their peaks, the simulation of the spread of a virus in a population and the effects of health policies, such as the introduction of lockdown or vaccination. This allows e.g. students to experiment with different scenarios (e.g. changes in social mobility, different vaccination strategies), providing a valuable tool for understanding pandemic dynamics. In addition, these tools enable the creation of interesting visualizations that help to communicate the results of the analyses, whether for scientific, didactic purposes, e.g. in student education, or for a wider audience.

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PART THREE

SELECTED PROBLEMS IN THE PSYCHOLOGY OF EDUCATION

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Current Status and Readiness of Schools to Implement Teaching Aimed at Developing Computational Thinking

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Abstract

Computational thinking and its implementation in the Czech national curriculum is currently one of the major challenges that the pedagogical experts are dealing with, not only in the context of the major revision of the Framework Educational Programmes for Primary Education.

The aim of the presented research work was to find out the current state of implementation of the revised Framework Curriculum Framework aimed at the development of computational thinking in Czech schools. Therefore, the conducted investigation mapped in more detail the attitude of teachers to the changes in the educational area of Informatics and whether they already teach according to the revised Framework of the Framework of the Curriculum, the extent of their knowledge and experience with the new content of this area and finally reveal the state of their working background. The preparation, course and results of this investigation are presented in the paper.

Keywords: Computational thinking, implementation, research investigation

Introduction

The teaching of computer science and related computer science subjects is becoming one of the core components of the modern educational system in modern society. The importance of this education is on a global scale comparable to subjects developing basic key competences (National Institute of Education, 2020; Ministry of Education, 2023), which are important for the personal development of an individual, his active participation in society and future employment in life (Lessner, 2014). The rapid development of digital and computer technologies, the global expansion of telecommunications infrastructure and its availability, the modernisation and automation of industry and other aspects of the so-called “computerisation of society,” are currently affecting all aspects of social life (Gates, 1997; Tapscott, 1998).

In response to this development trend, the topic of targeted development of competences related to the use and mastery of modern information and communication technologies has been opened in the field of pedagogy by educational experts (Perlis, 1962; Wing, 2006; CSTA&ISTE, 2011; European Commission, 2020). Currently, the priority in computer science education is precisely the introduction of teaching that aims at developing competences for the active and creative use of modern information and communication technologies (MoEYS, 2021). These skills are intended to enable students to use the full potential of modern technologies to solve problems and automate specific processes, and to develop their ability to adapt to technologies that are yet to be implemented in society in the future (Wing, 2006; MoEYS, 2014).

The need to integrate the development of IT and digital competences into basic education has long been considered as one of the main educational priorities in Europe and beyond (European Commission, 2020; Ala-Mutka, Punie, Redecker, 2008). Thus, shifting the focus of national curricula towards integrating the principles of teaching that will lead students to actively use digital and information technologies, rather than simply consuming digital content, is currently a major strategy of education policies around the world, along with the development of key competences such as critical and creative thinking and other effective problem-solving skills. In this context, the term “computational thinking” from the English “computational thinking” is increasingly emerging. This concept, which has gained global prominence in the past decade (Lessner, 2014), reflects the need for human populations to adapt to a new technological era based on the integration of information technology into all areas of life.

The issue of introducing the targeted development of computational thinking into national curricula has been an accentuated topic for the last decade among experts who have been exploring the possibilities of changing the overall concept of teaching in basic education to meet the demands placed on individuals by the modern digital society. Since 2006, when Jeannette Marie Wing first presented her definition of computational thinking, the issue has been discussed at a number of summits and has become a key educational goal of many organizations and federations (WSIS, ACM, IFIP, EC). Especially abroad, it has become a major trend in key curriculum revisions dating back to 2012 (The Royal Society, 2012).

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The state of implementation of informatics thinking in the Czech Republic

In the Czech environment, the implementation of computational thinking is still a relatively new issue, although its basic principles have already appeared earlier. The integration of the targeted development of pupils' skills, which should lead to the safe and creative use of digital and computing technologies, is unquestionably a long-term goal of the domestic curriculum strategy. References to a set of skills that can be understood as components of computational thinking, as well as the development of programming skills, have been mentioned in previous education policies (Klement, 2018; MoE, 2014).

The development of computational thinking became a standard part of the primary curriculum only in 2023, after the revision of the Framework Educational Programme for Primary Education (RVP ZV), by the Minister's measure No. MSMT-12464/2023 on the revision of the RVP ZV with effect from 1 September 2023. In accordance with this revision, primary schools in the Czech Republic are obliged to start teaching that will be in line with the revised RVP ZV and will be aimed at the development of pupils' computational thinking. However, this change comes practically a full decade after the first recommendation of the European Commission, which called on member states to integrate the development of computational thinking in schools (CSTA & ISTE, 2011) and with a significant delay compared to neighbouring European countries (Bocconi *et al.*, 2018).

The revision of computer science and related subjects in the domestic environment has long faced technical challenges as well as social and political difficulties. In recent decades, there have been rapid developments in computing technologies and related definitions and understandings of concepts closely related to the teaching of computer science. The very notion of computer science and other related subjects has also evolved in response to domestic social and market demands. These changes, which in some cases have affected the overall domestic understanding of the concept of informatics in education, have contributed to slowing down the process of development of a school system in which the inclusion of teaching aimed at developing programming skills and computational thinking is considered a sign of modernity (European Commission, 2022).

On a global scale, it is evident that the revisions flowing towards the integration of computer science in the basic education curriculum are characterized by a diversity of conceptions of their implementation. Especially when it comes to the integration of targeted development of programming-related skills, a wide range of different educational policies can be encountered. These differences stem from differences in the economic and technological background of schools in a given country, in the different didactic approaches to teaching, in the individual organization, form and content of educational activities, and in the qualifications and training of teachers (Román-González *et al.*), In this respect, the

Czech environment, which did not have a widely established curricular tradition of programming in primary education before the revision, falls into the category of countries where the transition to teaching towards the development of computational thinking is difficult (Klement, Dragon, Bryndová, 2020).

Focus of the research investigation and its objectives

The aim of the research investigation was to determine the current state of implementation of innovative informatics, which is part of the updated RVP ZV aimed at the development of computational thinking, into teaching in primary schools. In addition to the main objective, sub-objectives were set to ascertain the opinions and knowledge of teachers in the different areas of innovative informatics. In relation to the above objective, the main research questions were set.

1. Are teachers familiar with the Primary Education Framework for the Development of Computational Thinking and does teaching take place according to it?
2. Do teachers have knowledge in the three main areas of innovative informatics and do they agree to teach them?
3. Do teachers have sufficient facilities at their school for teaching innovative informatics?

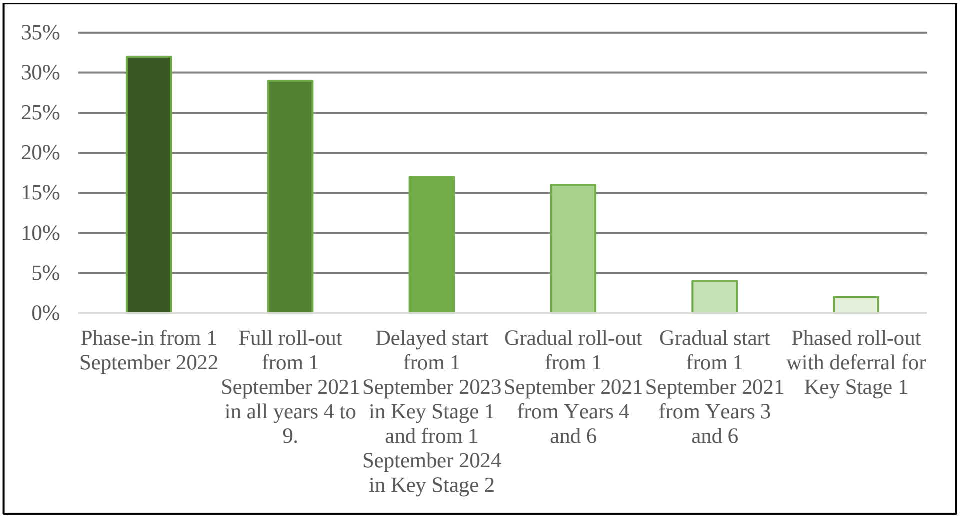
Characteristics of the survey

The research investigation was conducted using quantitative research, specifically an anonymous online questionnaire was used (Chráska, 2016). The research was focused on primary school computer science teachers, therefore the link to the questionnaire form was distributed via email only to specific computer science teachers, which were searched on the websites of individual primary schools across the country.

The questionnaire consisted of 17 closed and 3 semi-closed questions, all questions were mandatory, it was not possible to skip any of them. For clarity, the questions were further divided into 5 sections – Basic Information, Programming and Algorithmization, Basics of Educational Robotics, Computer Science (working with data, coding, basics of computer science) and Status of Hardware and Software in the School. The first section included basic questions on gender, length of experience, school size, endorsement, familiarity with the upgraded RAP, and the respondents' school's start-up to teaching upgraded computer science. The subsequent 3 sections contained the same concept of four questions adapted to each of the three areas of upgraded informatics – programming and algorithmization, educational robotics and computer science. The final fifth section asked about the state of the hardware and software in the respondents' workplaces.

Selected results of the survey

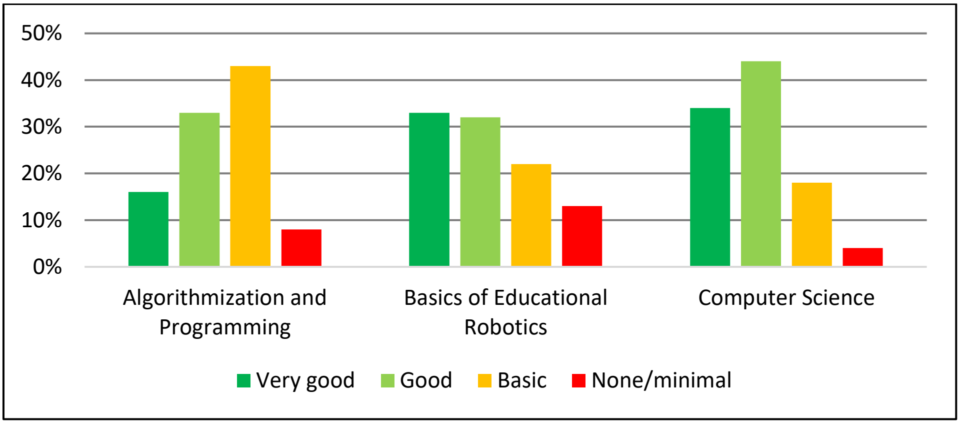
The first question that was included in the basic data section was the question *What is your school's take-up of teaching informatics according to the updated RVP ZV?* Here it was investigated in what way individual schools are taking up the teaching of the upgraded informatics. Teachers chose the option that most closely matched the situation in their workplace from six options. They were also provided with pictures describing the different approaches in more detail. The majority of respondents chose the option of a gradual start of the teaching of innovative informatics at the beginning of the current school year, i.e. in September 2022, namely 65 (32.2%). For 58 (28.7%) respondents, the full start of teaching in all grades already took place in September 2021. The postponement to 2023 for grade 1 and 2024 for grade 2 was chosen by 35 (17.3%) of the schools where the respondents work. The last most frequent response was a phased start from 2021 in Years 4 and 6, with 33 (16.3%) of respondents choosing this option. The remaining 11 respondents were split between the options of a phased rollout from 2021 in Years 3 and 6 and a phased rollout with a delay for Year 1, with 8 (4%) respondents selecting the first option and 3 (1.5%) selecting the second option as shown in the graph below.



Graph 1. On-boarding for the teaching of innovative informatics

From the chart it can be seen that more than half of the schools surveyed were involved in teaching innovative informatics right from the start. The remaining part is waiting for the onset of the new teaching content for understandable reasons such as caution, lack of experience or untrained teachers. This may also be due to the lack of the necessary material and non-material didactic aids.

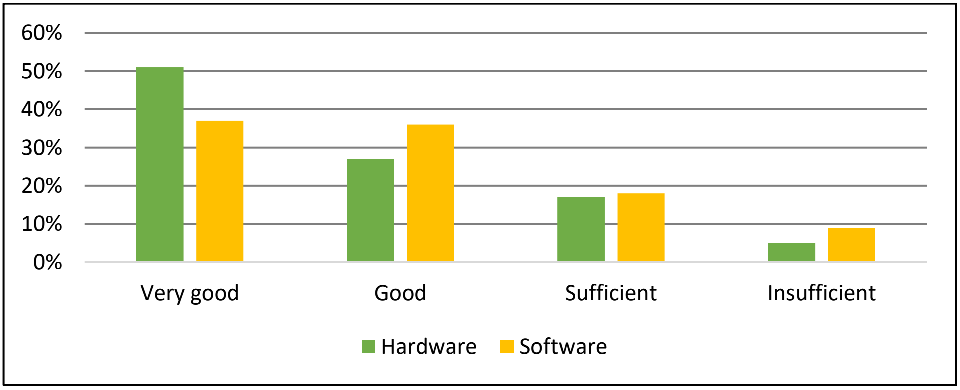
In the next part of the research, we asked about their knowledge in particular areas covering new informatics. First, respondents answered the question: *What is your knowledge in programming and algorithmization?* Most of the respondents, i.e. 86 (42.6%) answered that their knowledge is rather basic. 67 (33.2%) of the respondents are at a good level, i.e. they know at least one programming language, 32 (15.8%) of the respondents are even at a very good level. Only 17 (8.4%) out of 202 respondents have no or only minimal experience with programming and algorithmization. The second question was again used to determine the teachers' knowledge, this time in the field of educational robotics. We also investigated their level of knowledge in educational robotics by asking, *What is your level of knowledge in educational robotics?* All 202 (100%) respondents answered, of which 66 (32.7%) chose "Very Good". Only one less respondent, 65 (32.2%), chose "Good" and 45 (22.3%) teachers chose "Basic". The lowest number of responses, 26 (12.6%), was for "I have minimal/no experience with educational robotics". The last part of this part of the survey was to determine teachers' knowledge of general computer science. All 202 (100%) of the respondents answered the question *What is your knowledge of data handling, coding, and basic computer science?* Respondents chose from four options. The option with the highest number of responses was "Good", with a total of 89 (44.1%). 68 (33.7%) teachers rated their knowledge as "Very Good" and 36 (17.8%) found their knowledge to be at the "Basic" level. 9 (4.5%) respondents rated their knowledge in this area as "Minimal/None". A graphical summary of the findings is presented in the chart below.



Graph 2. On-boarding for the teaching of innovative informatics

It can be seen that most respondents are rather basic in the area of algorithmization and programming. However, the implementation plan took this information into account and therefore offered various types of training and courses related to programming. Thus, the new concept of teaching computer science, specifically the area of programming and algorithmization, is not based on complex programming languages, yet in our opinion it is desirable for the teacher of this subject to know at least 1 programming language. Above all, it is necessary to understand the principles of programming and algorithmization in order to properly convey them to the students. However, less than 16% of the respondents with very good knowledge are very encouraging, but the question remains whether they have a good command of the ability of didactic transformation – i.e. to translate their expertise into learning.

Using the last section of the questionnaire presented here, we collected information about the background of teachers in the area of IT equipment at their workplaces. This section contains two questions, one related to hardware, the other to software. For both questions there were four options to choose from. The question, *What is your opinion about the hardware in your school for teaching upgraded computer science? (computers, data projectors, robotic kits, interactive whiteboards, tablets, etc.)*, more than half of the respondents gave the option "Very good", a total of 102 (50.5%). 55 (27.2%) teachers rated their IT equipment as "Good". 34 (16.8%) of the respondents selected "Sufficient" and 11 (5.4%) of the teachers selected "Insufficient" IT equipment at their place of work. The level of software equipment at the workplace was ascertained by the question, *What is your opinion about the software equipment in your school for teaching innovative informatics? (licenses, programs, study materials in electronic form, etc.)?*, it surveyed the opinion of teachers about the software facilities in the primary schools where they work. 75 (37.1%) teachers rated their software facilities as "Very good", 72 (35.6%) would rate it as "Good". 37 (18.3%) respondents marked the option "Sufficient". According to the survey, the least number of teachers have "Inadequate" software facilities at their place of work. Again, a graphical summary of the findings is presented in the chart below.



Graph 3. Teachers' views on hardware and software equipment at school

If we compare the responses of the respondents in the above chart, we find that the number of "very good" responses has significantly decreased at the expense of the other responses. Thus, we can say that although a large number of schools have very good HW equipment, their SW equipment is rather good or sufficient. This can be attributed to the difference in the purchase of HW and SW equipment. HW equipment very often requires only a one-off purchase and commissioning. The purchase of SW equipment is slightly more complex. Licences for various products are often time-limited and require renewal, which is a significant financial burden for schools.

Conclusion

The aim of the research was to determine the status of implementation of the revised RVP ZV aimed at the development of computational thinking in Czech schools. The sub-objectives furthermore mapped in more detail the attitude of teachers to the changes in the educational area of Informatics and whether they already teach according to the revised RVP ZV, the extent of their knowledge and experience with the new content of this area and finally reveal the state of their working background. On the mentioned objectives we will further note the conclusions resulting from the answers of the respondents. A total of 202 computer science teachers with different levels of education and length of experience participated in the questionnaire survey.

Based on the survey conducted, it can be said that the implementation of the curriculum aimed at developing computational thinking is at a good level. Although there are schools that wait until the deadline to implement, a large number of schools started teaching the new content right from the beginning. In terms of teacher knowledge, most teachers are adequately prepared for teaching. Of course, there are also individuals whose knowledge is at a minimal level, but training on the subject is increasing, so these teachers have the opportunity to acquire new knowledge.

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The Examination of the Popularity and Development of the CodeCup Team Competition

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Abstract

International Informatics Olympiad in Teams (IIOT) is a competition for teams of high school students, organized since 2017. Hungary first participated in 2021. CodeCup, our national qualifier competition, gradually gained popularity over the past three years. In 2023–2024, teams have competed in four qualifying rounds.

The goal of our research was to find means of increasing the number of competitors in CodeCup, and potentially in other national qualifier competitions as well. Primarily, we wanted to measure the effects of recent changes in the competition rules.

We examined trends in the participation of the last three years: the list of involved schools, the age and gender distribution of students, with special regard to the impact of Program'Petition, a lightweight teer of CodeCup, launched in 2023.

The results show that the number of schools has not changed significantly, but the number of competitors and the ratio of girls has increased.

Keywords: CodeCup; Kódkupa; team competition; programming; evolution of competition; IIOT

CodeCup, and its little brother, Program'Petition, are the first team competitions in programming in Hungary, focused on primary (upper class) and secondary school children. The competition is still fresh in the competition calendar, as it has been running for a few years only. Fortunately, however, the examination of the competition is no longer just a possibility, but already an important foundation of its development that helps shape its profile. Our goal, beyond training and developing the communication of competitive programmers (Mhlongo, Oyetade, Zuva, 2020), is to get more students engaged in the world of programming and programming team competitions, because it is difficult to imagine the thinkers of the future without programming skills.

Introduction of IIOT and CodeCup

With goals much like those of the International Olympiad in Informatics (IOI), IIOT was founded in 2017 as an Italian initiative. Teams of up to four students can enter the competition, when all team members attend the same school. The international finals are always preceded by the national finals of every participating country, to which the best teams from the previous rounds qualify. The number of rounds in Hungary has increased steadily in recent years, and this year there were four qualifying rounds, similarly to other participating countries.

The qualifying rounds and the finals collectively have become known as CodeCup (CodeCup, 2021) in Hungary.[1] The winner of CodeCup is rewarded with a place in the international finals, a chance to compete and to represent the country at IIOT. To become a full member of the IIOT organization, a country must have a leader school that agrees to organize the national finals every year. The benefit of full membership is that not one, but two teams can represent the country: the national winner as well as the best team from the leader school. If these two happen to coincide, the second-placed team can also travel to the finals. Sending more than two teams to the international competition is possible but requires a fee to be paid by the delegating country.

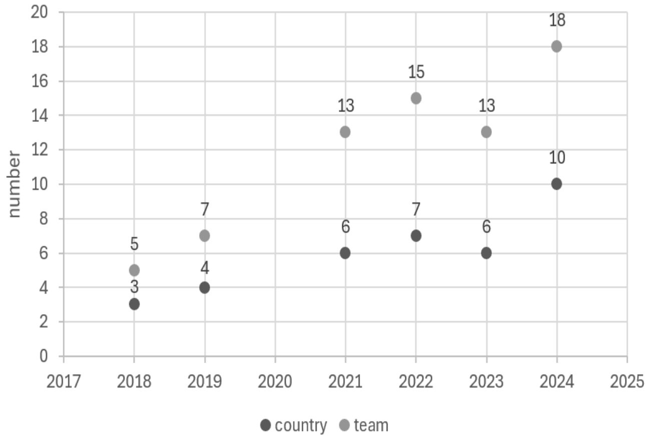

Figure 1. Number of countries and teams participating in the IIOT finals
(https://iio.team/editions)

During the last six years of IIOT, its growth has been uneven. In 2020, the international finals were cancelled due to COVID. In the following year, the competition was organized online. In return, however, more teams from non-

[1] On the website of CodeCup one can find the tasks of the previous years (CodeCup, 2022) and this year (CodeCup, 2024). In Hungary, the qualifying rounds were in Hungarian, and the national finals in English.

member countries were given the opportunity to compete. There are now five full member countries (IIOT, 2024). Figure 1 illustrates the growth of IIOT since the tournament was founded.

Countries that are full members also commit to organizing international finals themselves a few years after accession. This is no small investment of time, money and energy. There are also countries as guests at the IIOT finals that have not yet joined as full members and do not participate regularly.

This year's finals were held in Syria on 11 May 2024. Most of the students participated online due to military instability in the region. We hope that the IIOT finals will be organized in Hungary in the near future, at Fazekas Mihály Gimnázium in Budapest.

The financing of IIOT is also in line with the economic philosophy of IOI. The cost of the finals of a given year is mainly borne by the organizer. The provision of the competitors (meals, accommodation, local transport), the venue (infrastructure, supervision), the entertainment of the competitors (programs, socialization, quizzes), providing events related to the organization (opening and closing ceremonies, annual meeting) are all the responsibility of the organizer. The other countries are responsible for organizing the national qualifying rounds and finals, and for arranging and covering the costs of the travel for their own competitors to the venue of the international finals.

The long-term perspective of a competition, especially if it is held in a different location every year, can be guaranteed by the stability of the type and flavor of its tasks. The motivation and attention of the competitors can only be maintained by interesting tasks.[2] This can be achieved reliably through a large international and colorful professional committee. This committee currently consists of some 20 people delegated by countries with regular membership: Hungarians, Italians, Romanians. They are usually students who previously have been competitors themselves (source: L. Nikházy). The fact that the tasks for all national and international rounds alike are set by such a committee has the added benefit of significantly lowering the costs of joining the competition for any aspiring country.

Hungarian specialties and our Program'Petition

IIOT's competition rules are very flexible regarding the organization of the national competition and the selection of the winning team. The current recommendation, dating 5 October 2023, is that the national finals should be preceded by four online rounds of three hours each (IIOT, 2023).

Finding a date for four online rounds in our national competition calendar is a challenge. There are probably no four consecutive weekdays on the November–

[2] The tasks so far can be found on the competition website (IIOT, 2018).

February timeline that do not have some kind of competition. With this in mind, we have chosen to hold the rounds on the same dates as the Italians, but rather than limiting the rounds to three-hours each, we have chosen to schedule them over 27-hour periods. With this wider time window, we have been able to offer the students a choice of two consecutive afternoons in every round. Another advantage is that the participants are much less tied to a specific location. For example, they don't have to stay in school, miss classes, or wait in the school for the scheduled start time. Rather, they can compete from the comfort of their homes when it suits them best. Except for some extreme cases (there have been some submissions after midnight, at 00:21), students have always chosen to compete in the afternoons. The average time between two rounds was four weeks and one day. I.e., the first round started at 3pm on Monday and lasted until 6pm on Tuesday, the second started at 3pm on Tuesday, etc. This was chosen so as to spread the workload more evenly throughout the work week and to avoid the same afternoon extracurricular activity being missed every time. The double afternoons in every window also help to reduce conflicts with extracurricular activities.

The top 10 teams from the online rounds go through to the finals, which is held in the Fazekas Secondary School. In the finals, teams solve the problems without Internet or any other external help, using two computers provided by the school.

Students in Italy have been taking part in programming team competitions since 2017. This was their eighth year of the competition. For Hungary, it was the third. Considering the number of competitors in Italy (3911) and Romania (918) (source: L. Nikházy), it is reasonable to predict an increase in the number of participants in our national arena as well. The number of teams participating in the last three years is shown in Figure 2.

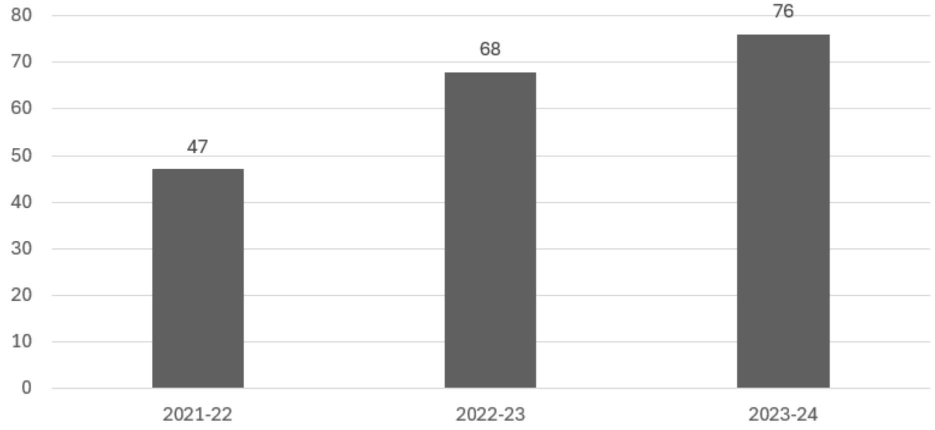

Figure 2. The number of teams participating in the national competition

IT education in Hungary is about to undergo a major change. Not only has the number of lessons increased compared to the previous curriculum, but the emphasis on learning programming has also increased. Last year, students graduating at intermediate level in computer science did not have to program in the practical exam; this year, 15% of the points are given for a programming task. Children's computer science education no longer starts in the sixth grade of primary school, but in the third, so by the eighth grade they would have twice as many computer science lessons as before. The number of regular, four-year secondary school lessons in computer science have increased by a factor of 2.5 (NAT, 2020). We believe that in Hungary we are still in a period of "getting involved" in programming. Our aim is to promote programming and increase the number of competitors. To this end, we have tried to expand the target audience of CodeCup in three areas.

On the one hand, we wanted to give students who are new to programming the opportunity to actively participate in a team competition. But the tasks of CodeCup are not easy for a beginner. In previous years there were several teams that could only solve one or two tasks. This does not mean that they worked on those two tasks for three hours, but rather that they did what they could and then struggled with the rest for a long time.

It has also been a recurring problem in recent years that students have become "isolated". It is not uncommon to have an enthusiastic child learning programming outside of school, and no peers in their school who are similarly knowledgeable in programming. But only teams of students from a single school can enter CodeCup (and later IIOT). This is perfectly understandable, but it would be nice to somehow get these "lone star" students involved in teamwork.

The third question that often arises is how to get more girls on board in (team) programming. This is important because "experience shows that development teams which include women are successful and fruitful" (Vass, 2014), said Szilvia Koleszár in an interview. The (co)founder of Skool and the Equalizer Foundation has also commented on the issue in several interesting interviews (Forbes, 2022; Női Váltó, 2021). However, having a female quota, e.g., mandating that every team should have "at least one girl", can create strange situations. We wanted to make progress in this area, but without the introduction of quotas.

A solution to all three of the above challenges could be competition related to CodeCup, where the tasks are a bit easier, the teammates can come from different schools, and only mixed gender teams can compete. This competition, which is less coding and not so much a cup, is called Program'Petition.

Statistics of the last years

Number of schools

This year, for the first time, it was possible to choose a teer when registerring. Almost 100 students have chosen Program'Petition already in its first year.

As can be seen in Figure 3, on the one hand, there was a “transfer” effect with some students taking advantage of the new opportunity to compete in Program’Petition instead of CodeCup, and on the other, an entirely new group of students became involved with the introduction of the lightweight teer.

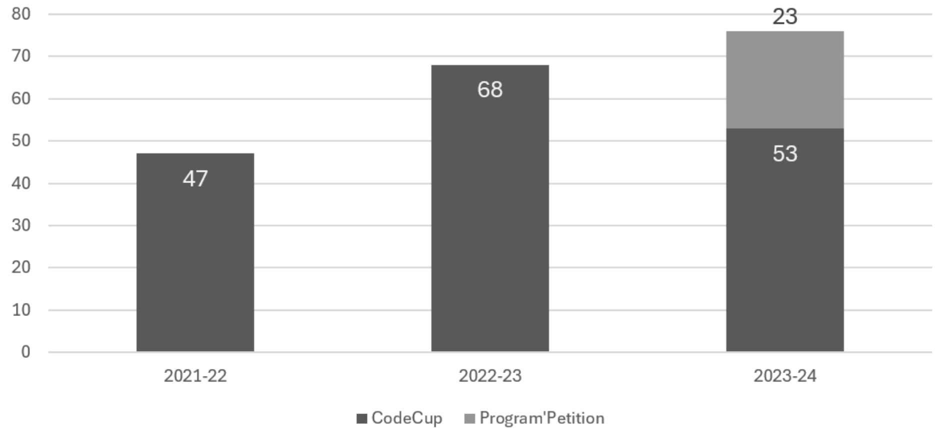

Figure 3. CodeCup and Program’Petition entries

An increase in the number of students does not necessarily indicate the steady expansion of the competition. Another plausible explanation could be that more and more students, even from different schools, try the competition on a single occasion, but do not reenter the following year. To rule out this second explanation, I have looked at how schools have delegated students each year (see Figure 4) and how the specific list of these schools changed from year to year.

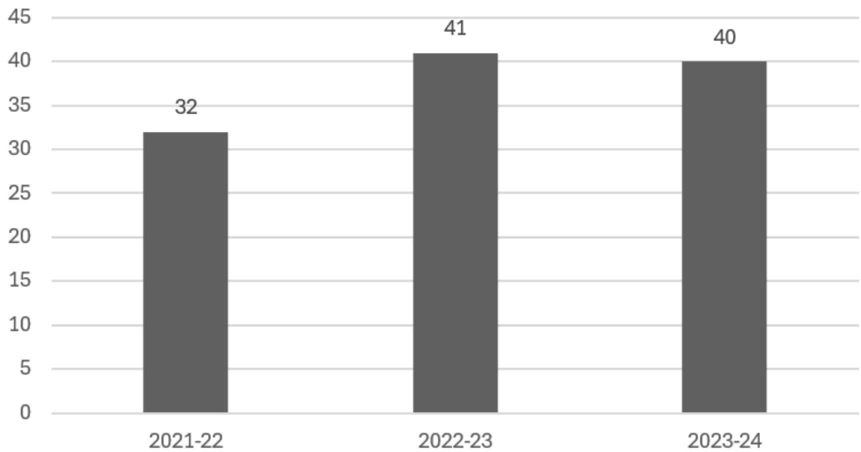

Figure 4. Number of schools entering the competition

The number of participating schools increased in the second year of the competition and remained roughly the same in its third year. Furthermore, the list of participating schools (available on the competition website) did not change significantly between the second and third years. This means that the schools that had been aware of and participated in the competition entered again the following year and delegated more teams and competitors than previously (see Figure 3).

Based on this analysis, we believe that many of the potentially interested schools and students are not yet aware of the competition. Most of the 797 secondary schools in Hungary (168.hu, 2020) have not got involved yet (Figure 5).

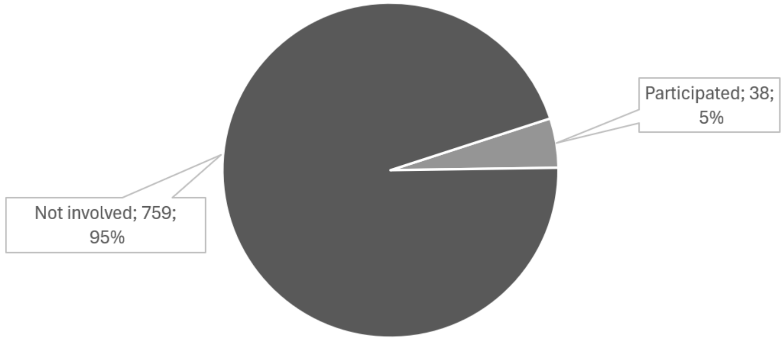

Figure 5. The ratio of the participating secondary schools (2023-24)

Gender ratio

One of the desired effects of the introduction of the new teer, Program'Petition, is an increase in the number of competing girls. Looking at the data, we can see that the number of girls has doubled every year (Figure 6).

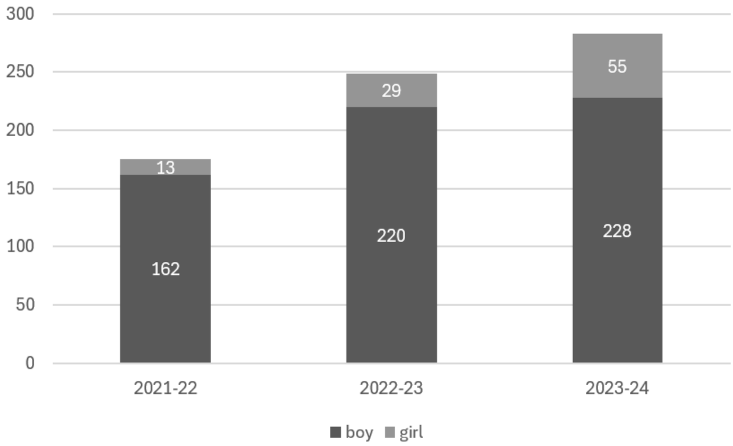

Figure 6. Change in the gender ratio

It should be noted, however, that as the total number of competitors has also increased, almost doubling in two years, it is not the raw number of girls, but rather their ratio in the total population that reflects the progress in this area better. This ratio also shows a steady, albeit slower increase. In the first year (2021–2022), the proportion of girls was 7.43%. In the second year (2022–2023) it rose to 11.65%. And after the introduction of Program'Petition, 19.43% of all competitors were girls, almost one out of every five students (Figure 7).

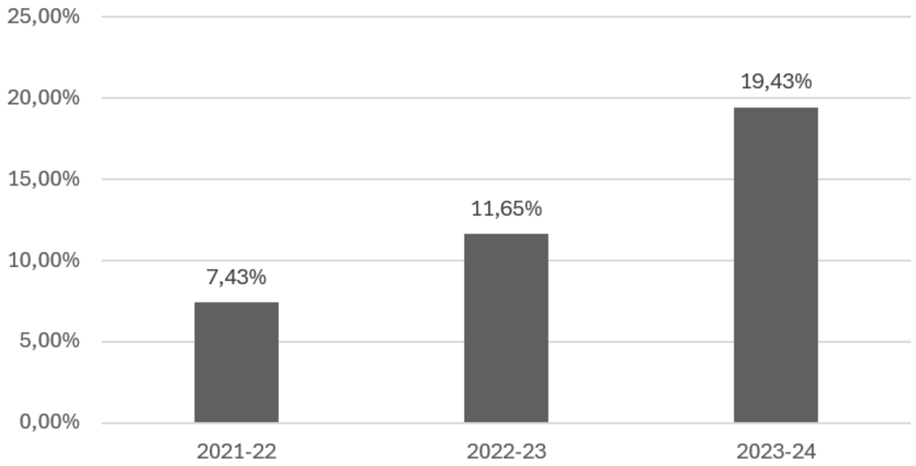

Figure 7. The ratio of girls, as a percentage

Conclusion

In Hungary, the Nemes Tihamér International Programming Competition (Nemes, 1985) has been organized each year for the last 40 years, with more than 200 participating schools and at least 2,500 students per year, all competing individually. CodeCup is a young and less known competition but based on our study and the analogy of the Italian model, we can boldly assume that it has a great future ahead. It is not unrealistic to expect that it can reach the scale of the national individual programming competition in a few years. The long-term impact of IIOT could have a big effect not only on programming skills and programming knowledge, but also on soft skills, such as communication, cooperation, social skills, problem solving, teamwork. Skills that are harder to develop but can be so useful in our lives and professional careers.

Our aim is to get the word out about CodeCup to all potential competitors in Hungary as soon as possible, and to make as many people take advantage of this development opportunity as possible.

The aim of this paper is not only to introduce and promote IIOT, but also to suggest ideas for expanding the competition in the hope of greater involvement.

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The Principle of Polyformity in Mathematics Education

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Abstract

The concept of mathematics is widely used in various societal spheres. As an educational subject, it engages students' logical thinking, contributing to the development of their competencies and thereby equipping them for specific life vocations and future career choices. Mathematics teaches us to be wise and to solve problems step by step. It is to be appreciated for being a logical puzzle, posing a challenge and fostering a readiness to engage with it in various ways. Anyone can learn mathematics; there is no human activity that does not depend on it. Almost all secondary schools and many universities include mathematics as a subject. The significance of the subject extends beyond education, playing a crucial role in shaping one's personality. The objectives and tasks of the educational subject are strictly defined, with primary education aiming at acquiring basic linguistic and mathematical literacy.

Keywords: mathematics, the principle of polyformity, polyformity as a didactic principle, motivation in mathematics education

Introduction. Mathematics and its significance

Mathematics is a dynamic field undergoing rapid development, reaching unprecedented scales. Its applications in the natural sciences and technology are vast, and the progress in these areas of human activity cannot be imagined without mathematics. The utilization of new mathematical disciplines in electronics and atomistics is already significantly transforming the world. The primary objective of modern technology is to replace human involvement in various physical and intellectual activities, improve living conditions, and unleash human energy for new, creative endeavors.

The concept of mathematics is widely used in various societal spheres. As an educational subject, it activates logical thinking in students, contributing to the development of their competencies and preparing them for specific life vocations and future career choices. Mathematics teaches us to be wise and to solve problems step by step (Hilčenko, 2023). It is to be appreciated for being a logical puzzle, posing a challenge and fostering a readiness to engage with it in various ways. Anyone can learn mathematics; there is no human activity that does not depend on it. Almost all secondary schools and many universities include mathematics as a subject (Hilčenko, 2022).

The significance of the mathematics subject is immense, not only as an educational discipline but also in contributing to the development of one's personality. The objectives and tasks of the educational subject are strictly defined, with primary education aiming at acquiring basic linguistic and mathematical literacy. Pedagogical abilities of teachers and the classroom atmosphere are influenced by their personality traits and can be crucial for students' learning and the progression of their education. Teacher behavior shapes the image that students form about them, with the greatest impact occurring in the younger school age. The teacher's personality leaves a lasting impression on the students they teach. The role of a mathematics teacher is one of the most challenging and rewarding professions. Moreover, this profession carries a great deal of responsibility (Dragičević, 1994). Mathematics, as a subject, aims to acquire knowledge, skills, and habits. The process of acquiring knowledge within mathematics education is methodically elaborated, implying a quality and gradual path toward mastering the educational content.

The subject matter of the study. Objectives and tasks of mathematics education

Mathematics, as a subject, aims to acquire knowledge, skills, and habits, with the methodical development of knowledge acquisition within mathematics education signifying a quality and gradual path. The primary objectives of mathematics education in elementary school are to ensure that all students attain basic linguistic and mathematical literacy and participate in achieving appropriate educational achievement standards. Additionally, the goals include:

1. Equipping students to solve problems and tasks in new and unfamiliar situations (Hilčenko, Nikolić, 2022; Hilčenko, Jakovljević, Nikolić, 2021).
2. Enabling students to express and justify their opinions and engage in discussions with others.
3. Developing motivation for learning and interest in the subject matter.
4. Ensuring that students acquire elementary mathematical knowledge necessary for understanding phenomena and laws in nature and society.
5. Preparing students to apply acquired mathematical knowledge to solve diverse tasks in real-life situations.
6. Providing a foundation for successful continuation of mathematical education and self-education.

7. Developing mental abilities, forming a scientific worldview, and contributing to the well-rounded development of students' personalities (Dejić, 2008).

Mathematics Education:

1. Creating diverse opportunities for the realization of educational objectives, as well as the goals and tasks of mathematics education, through various contents and teaching methods.
2. Numerical literacy for successful engagement in any profession and achieving a quality life.
3. Acquiring knowledge essential for understanding quantitative and spatial relationships and laws in various phenomena in nature, society, and everyday life.
4. Gaining basic mathematical culture necessary for recognizing the role and application of mathematics in different areas of human activity (mathematical modeling), for successful continuation of education, and integration into the workforce.
5. Developing students' abilities in observation, perception, and logical, critical, analytical, and abstract thinking.
6. Cultivating cultural, work-related, ethical, and aesthetic habits in students, along with fostering mathematical curiosity.
7. Developing the ability to express oneself in mathematical language, ensuring clarity and precision in both written and oral communication.
8. Mastering fundamental facts about sets, relations, and mappings.
9. Mastery of basic operations with natural, whole, rational, and real numbers, along with understanding the basic properties of these operations.
10. Familiarity with essential geometric objects: lines, figures, and solids, and understanding their mutual relationships.
11. Training students for precision in measurement, drawing, and geometric constructions.
12. Preparing students to understand relevant content in natural and technical sciences.
13. Building positive characteristics in students' personalities, such as systematicity, persistence, accuracy, neatness, objectivity, self-control, and a sense of independent work.
14. Developing habits and skills in utilizing diverse sources of knowledge (http://oaji.net/articles/2016/1627-1453802551.pdf).

The teaching of mathematics, in addition to its educational role, also serves a formative purpose. Its significance lies in the development of intellectually robust individuals and the cultivation of work habits that are crucial for acquiring lasting active mathematical knowledge, serving as a foundation for the study of this subject at the next level of education. The aim is to enhance teaching methods that will enable students to independently acquire knowledge and apply it creatively.

Development (analysis of research results).
The principle of polymorphism

The didactic principle of polymorphism is not commonly encountered as a didactic specificity, and if it is applied in some instances, it is very rare, intuitive, spontaneous, singular, and incidental in the teaching of mathematics in primary and secondary schools, as well as at the university level. The essence of applying this principle lies in a continual emphasis on the integral consideration of various approaches to understanding and comprehending the studied teaching phenomena. Therefore, its exploitation in practice requires teachers to have an excellent understanding and skill in applying various pedagogical-didactic-methodological possibilities, inducing intensive cognitive activity in students expressed through quality self-disciplined work and increased motivation. The effectiveness of the polymorphism principle is based on the evident psychological fact that changes and diversity in work refresh the teaching process, while monotony generally induces a weakening of interest and the emergence of passivity and boredom (Marković, 2008). Due to its characteristics, the principle of polymorphism represents a universal teaching, scientific, and philosophical principle, with its epistemological foundation identical to that of the principles of permanence and the law of negation of negation, whereby the principle of polymorphism takes on the characteristic of a dialectical law. As all existing didactic principles are encompassed by the principle of polymorphism, it elevates this principle to the pedestal of universality (Nikolić, 2021). Đ.G. Marković, in his doctoral dissertation "New Perspectives on the Methodology of Teaching Mathematics in the Light of the Didactic Principle of Polymorphism" in 2007, introduced a new concept that combines the didactic principle of diversity and geometric polymorphisms. According to his understanding, the dominance of geometric polymorphisms and combined polymorphisms represents the principle of polymorphism, based on a finite number of conjunctions of logical laws or principles (laws of negation of negation, modus ponens, principles of obviousness, permanence, etc.). Based on the analysis of R. Arnheim's views on visual thinking and L. Vygotsky's ideas about the connection between thinking and speech, viewed in terms of the integrality of M. Marjanović's synthesis of the three-component nature of the concept, and based on personal thirty years of experience in direct teaching of high school mathematics and contemporary didactic tendencies based on dialectical laws, the author of the dissertation comes to the realization that the combination of verbal-textual and illustrative-demonstrative methods, viewed in the light of self-knowledge heuristics, provide unforeseen possibilities for the most effective "illumination" of teaching through the principle of polymorphism. This is especially noteworthy when it comes to the application of this principle in the form of content components of teaching, specifically the geometric polymorphism of the "shariginovsk type," which relates to various solutions to geometric problems using drawings and geometric representations of simple, as regular as possible, shapes such as triangles, squares, circles, etc. In this way, given problems are most simply represented, for example, by pictogrammatic notations, facilitating the easier formation of ideogrammatic representations of mental images, the so-called “aha noticing” of the three-component structure of the concept, types of polymorphism of the principle of obviousness. After all, the principle of polymorphism appears almost as an axiom, whose existence does not need to be separately proven (Nikolić, 2016).

Basic principles of polymorphism

The foundation of the principle of polymorphism, unlike the principle of permanence, lies in the dual or multiple application of the law of negation of negation to the same phenomena, i.e., initial problems or well-known theories. However, polymorphism is not merely a scientific and philosophical principle; it is also an educational principle. The essence of this significant educational principle is also reflected in the continuous emphasis on the integral consideration of various approaches to understanding and comprehending the studied educational phenomena (with the note that, whenever possible, geometric interpretations, i.e., schematizations of these phenomena, should be performed). The effectiveness of the principle of polymorphism is based on the fact that changes and diversity in work refresh the teaching process, while monotony generally induces a weakening of interest and the emergence of passivity and boredom. Due to these characteristics, the principle of polymorphism represents a scientific, didactic-methodological, and therefore philosophical principle, with its epistemological foundation identical to that of the principles of permanence and the law of negation of negation, whereby the principle of polymorphism acquires the characteristic of a dialectical law. As all existing didactic principles are encompassed by the principle of polymorphism, it elevates this principle to the pedestal of universality.

Polymorphism as a didactic principle

Polymorphism as a didactic principle is rarely mentioned in pedagogy, and if applied, it is often done intuitively, spontaneously, haphazardly, singularly, and incidentally in the teaching of mathematics in primary and secondary schools. It became evident very quickly that other forms of polymorphism, especially when combined with geometric and innovative content, have similar effects. This is clear when considering that geometric interpretations of arithmetic or algebraic problems, i.e., their representation through drawings, help students stabilize their internal representations. This is because visual thinking (thinking in images), due to its integral nature, produces “aha experiences” known to psychologists, triggered by a flash of complete clarity. This is evident as icons serve as carriers of information, for which words are often unnecessary translations (Nikolić *et al.*, 2022). The need to classify polymorphic geometric interpretations, whose application in teaching creates an environment that inevitably induces activation and dynamism, in the didactics of mathematics prompted me to reconsider not only geometric but also arithmetic-algebraic polymorphism. It provided a comprehensive review of the entire methodology of mathematics teaching in the "light" of the didactic principles of polymorphism and permanence. Through several years of applying geometric and other polymorphisms in teaching practice, I have become convinced of the specific weight of geometric polymorphism in terms of intensity and importance. Therefore, the discovery of this methodological-didactic innovation is considered a product of both theoretical and empirical components. The practical application of didactic theory initiated the search for the best solutions to activate and dynamize the teaching process, permeating through empirical verification and recognizing polymorphism as a necessity in the educational process, hence the necessity for the complementation of didactic theory. This correlational relationship does not end here; it prompts the need for a theoretical treatment of the given phenomenon, i.e., a thorough theoretical analysis of this significant didactic principle.

Prim application of the principle of polymorphism in mathematics teaching

The essence of the didactic principle of polymorphism lies in the continual emphasis on the integral consideration of various approaches to understanding and comprehending the studied educational phenomena. Its exploitation in practice demands from teachers an excellent understanding and skill in applying various pedagogical-didactic-methodological possibilities, inducing intensive cognitive activity in students through high-quality self-disciplined work and increased motivation. Therefore, in mathematics teaching, the principle of polymorphism should play a universal role, presented by enriching the teaching with diverse content, tools, procedures, and methods (Nikolić, Hilčenko, 2023). When it comes to content, the focus is on selecting tasks that allow a greater variety of approaches to their solution and the use of obvious means. However, organizing such classes requires the adequate application of polymorphism in the forms and details of teaching methods, their variations, and even methodological innovations in the same lesson. The methodological forms and details that a teacher plans and applies during teaching are based on the timely pulsation of didactic principles, manifested in their simultaneous polymorphic-cohesive action, i.e., integral dialectical unity.

Polymorphism as a philosophical principle and direction in art

Polymorphism as a mode of thinking has always been a constant companion of renowned thinkers and artists worldwide. Examples of this include Archimedes, Leonardo da Vinci, Isaac Newton, Nikola Tesla, and others. Polymorphic thinking significantly influenced their brilliant discoveries. Archimedes and Newton attempted and often succeeded in solving all the problems they tackled in multiple ways. Their constant search for different solutions, combined with a persistent emphasis on vivid geometric interpretations, sharpened their diamond-like minds and enabled epochal discoveries. Leonardo da Vinci, besides being a famous painter, anatomist, and architect, was also a leading mathematician of his time. The diversity of fields he engaged in, along with his iconic (visual) thinking expressed through geometric representations and sketches in polymorphic ways of the same phenomena, significantly contributed to all his findings (Marković, 2012). This is now well understood, especially with the results of experiments conducted by Rudolf Arnheim and other representatives of Gestalt psychology on visual thinking. Through drawings, we stabilize our internal representations because visual thinking, due to its integral nature, produces "aha experiences" known to psychologists, triggered by a flash of complete clarity. This is evident as icons serve as carriers of information, for which words are often unnecessary translations. Hence, it almost axiomatically follows why the accurate conclusion is that the same phenomenon studied and solved in a geometrically polymorphic way always triggers that "aha…" flash of complete clarity and integral, i.e., dynamic understanding of the essence of given problems. If we carefully observe the wondrous works of the divine creator – nature, we quickly discover that its most beautiful jewels, crystals, are symphonies of mathematics (Nikolić, 2016). Looking at the structures of snowflakes and other known crystals, the marvelous petals of various types of flowers, the shapes of shells, snail shells, sea stars, various trees and their leaves – in other words, looking anywhere around us, we will realize that nature's imagination in creating diverse forms of symmetry, bathed in a spectrum of incredible shades of colors, surpasses the imagination of even the greatest creators known in the history of art. Therefore, polymorphism is one of the essential natural characteristics or products of nature. Hence, it is not surprising that the universality of polymorphism, including polymorphism as a didactic principle, the phenomenon of polymorphic thinking, and polymorphism as a scientific and philosophical principle, as well as polymorphism as an artistic direction or style in art, is considered natural. Due to all of the above, it is entirely natural that mathematics takes pride in presenting polymorphism as a mode of thinking, polymorphism as a scientific and philosophical principle, and even polymorphism as an artistic direction or style in art.

Conclusions. Motivation in mathematics education

Mathematics, as an academic subject, plays a crucial role in fostering problem-solving abilities and logical reasoning skills among students. It is considered a challenging subject that demands continuous effort, time investment, and dedication. Many students may not always be willing to invest such effort, leading to difficulties in mastering mathematical concepts. However, when there is genuine interest in mathematics and learning occurs with enthusiasm, many obstacles dissipate, and the teaching and learning process unfolds more smoothly and successfully, with content absorption becoming more manageable.

In order to prevent school learning from being perceived as a "chore" or an activity to be completed solely to meet the expectations of teachers and parents, it is essential to motivate students to engage in their studies, i.e., to captivate their interest, awaken their will, and instill a love for the work, particularly in the context of learning mathematics. This can be achieved through special mathematical content, the beauty of its ideas and achievements, various methods, tools, and activities designed to make mathematics education enjoyable and to sustain that love over time. Various educational situations underscore the significant role of motivation in the learning process.

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I'm a Retiree: My Brain After the Age of 60

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Abstract

The work emphasizes that the brain of individuals over 60 years old is more practical than commonly believed. Despite reduced speed inherent in the younger brain, the older brain becomes more flexible, promoting sound decision-making and reducing negative emotions. The peak of intellectual activity in older individuals occurs around the age of 70, accompanied by an increase in myelin, resulting in a 300% improvement in intellectual abilities. With a healthy lifestyle, intellectual capacities do not decline with age but rather grow, reaching their peak between 80 and 90 years of age.

Keywords: older individuals, brain, intellectual abilities, myelin, healthy lifestyle

Introduction

In his study on the aging of the human brain, Alexis Wnuk (2019) highlights that complex changes occur during the aging process of the human brain. Through the analysis of cognitive, structural, neuronal, and chemical changes, the research provides a detailed insight into the diverse aspects of brain aging.

Regarding **cognitive changes**, the research reveals subtle modifications in memory, attention, and working memory during aging (Hilčenko, 2022; Hilčenko, Nikolić, 2022). While certain abilities decline, such as autobiographical memory, other aspects, such as verbal abilities, spatial reasoning, and abstract thinking, may improve in middle age.

Structural changes involve a reduction in brain volume, especially in the frontal cortex, cerebellum, and hippocampus. These changes are not uniform, as different brain regions decrease at different rates. Studying these changes suggests the "last in, first out" theory, indicating that parts of the brain that develop latest during adolescence are the first to suffer from aging.

Neuronal changes include a decrease in neuron size, dendritic retraction, and synaptic reduction, which can impact learning and memory. Specifically, the loss of thin dendritic spines may contribute to cognitive decline, especially in working memory.

Chemical changes encompass a reduction in the synthesis of neurotransmitters, such as dopamine and serotonin, which can have implications for cognitive functions and memory.

Despite these changes, the research points to brain neuroplasticity during older years, meaning the brain can adapt its neural connections to face new challenges. Lifestyle is of great importance in mitigating the negative effects of brain aging: diet, physical, and mental activity (Hilčenko, Jakovljević, Nikolić, 2021).

Aging is a natural physiological phenomenon. Every living being in this universe ages, and as it does, numerous changes occur! Changes are not limited to the external appearance of people but also extend to internal organs and the brain! (Activ Doctors Online, 2018).

The brain changes with age include:

1. **Brain mass** – the mass of the brain decreases, especially in the frontal lobe and hippocampus.
2. **Cortical density** – the outer protruding surface of the brain thins, slowing cognitive functions.
3. **White matter** – the contraction of white matter leads to memory loss.
4. **Neurotransmitter substances** – reduced production of neurotransmitter substances such as serotonin, dopamine, norepinephrine results in various neurological disorders (Figure 1).

Figure 1. What Happens to the Brain as We Age

These are common changes in the brain as we age, and these changes are responsible for age-related neurological changes (Hilčenko, 2015a; Hilčenko 2015b).

But – the surprise has arrived!

Director of the George Washington University Medical School (2022) claims that the brain of an older person is much more practical than commonly believed. At this age, the interaction between the left and right hemispheres of the brain becomes harmonious, expanding our creative possibilities. Therefore, among people over 60 years old, you can find many individuals who have just started their creative activities.

Of course, the brain is no longer as fast as in youth (Gaftandzhieva, Hussain, Hilčenko, Doneva, 2023; Hilčenko, 2023). However, the brain gains in flexibility. Hence, as we age, we tend to make better decisions and are less susceptible to negative emotions.

The peak of human intellectual activity occurs around the age of 70 when the brain begins to function at full capacity. Over time, the amount of myelin in the brain increases, a substance that facilitates the rapid passage of signals between neurons. Consequently, intellectual abilities increase by 300% compared to the average (New England Journal of Medicine, 2023).

It is also interesting to note that after the age of 60, a person can use both hemispheres at the same time. This allows tackling much more complex problems (Figure 2).

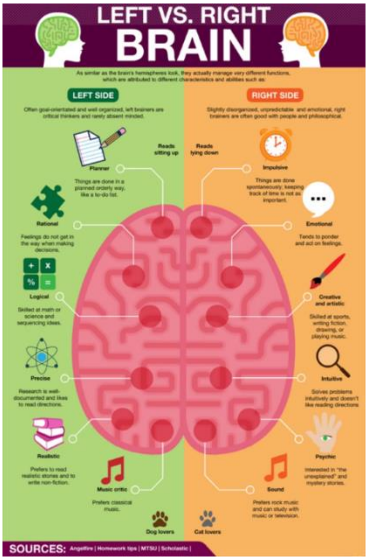

Figure 2. Left vs. Right Brain

Professor Monchi Uri from the University of Montreal (Monchi, 2023) believes that the brain of an older person chooses a path that consumes less energy, eliminates unnecessary elements, and leaves only the right options for problem-solving. A study was conducted involving different age groups. The younger participants were quite confused while undergoing tests, whereas those older than 60 years consistently made correct decisions.

The characteristics of the brain between the ages of 60 and 80 are truly *"rosy."*

Characteristics of the Older Person's Brain

– Neurons in the brain do not die, as everyone around you claims. The connections between them simply disappear if a person does not engage in mental activities (Hilčenko, 2015c; Hilčenko, 2019).

– Disturbances and forgetfulness arise due to an excess of information (Hilčenko, 2009). Therefore, you don't have to focus on unnecessary details throughout your life.

– From the age of 60, a person, when making decisions, uses not only one hemisphere of the brain, like young people, but both.

Health Advice for Individuals Over 60

– Do not fear old age.

– Strive for intellectual development, Solve mathematical puzzles (Hilčenko, 2008).

– Learn new skills, work on the computer (Hilčenko, 2006), create music, learn to play musical instruments, paint pictures! Dance!

– Engage in life, meet and communicate with friends, make plans for the future, travel as much as possible.

– Don't forget to go to stores, cafes, and performances.

– Do not isolate yourself; it is detrimental to everyone.

– Be positive, always live with the thought: "All good things are still ahead of me!"

Conclusion

Research on the aging of the brains of individuals over 60 years old reveals surprisingly positive results. Despite certain changes, such as a decrease in speed, reduction in brain volume, and chemical alterations, the brain of an older person becomes surprisingly practical. Brain flexibility at this age encourages making correct decisions, reducing negative emotions, and expanding creative possibilities. The peak of intellectual activity is reached around the age of 70, with an increase in myelin resulting in significant improvement in intellectual abilities. The importance of a healthy lifestyle, including nutrition, physical and mental activity, is crucial for preserving and enhancing intellectual abilities in old age. Therefore, instead of decline, intellectual abilities grow and reach their peak between 80 and 90 years of age.

Individuals over 60 can expect surprisingly positive brain characteristics by dedicating themselves to healthy habits and continuous intellectual development.

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Music and Technology as Factors of Interdependence in the Mental Health of Students

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Abstract

Since ancient times, music has been an element of people's daily life, so today it is considered a part of companionship, entertainment, relaxation, relaxation and admiration for people. The role of emotions it evokes, the therapeutic effects on mental health, the role of music therapy but also the involvement of artificial intelligence in the production and distribution offer a fertile ground for further research. The aim of the present study is to investigate the music influence in the mental health of a person and generally in the mental health status. Moreover, the role of music therapy will be addressed as well as the crucial role of artificial intelligence in music production and distribution. The type of the research followed was quantitative, using a questionnaire addressed to 177 people. Furthermore, statistical methods are used for the interpretation of the data, and the valid analysis of the findings. The findings highlight the crucial aspect of music and technology in mental health, paving the way for further research in these areas. Overall, the article offers a multidimensional overview regarding the relationship between music, technology and mental health.

Keywords: music, music therapy, mental health, emotional intelligence, artificial intelligence

Introduction

The presence of music in people's daily lives is obvious. In this respect, questions that are worth raising is how can music stimulate people emotionally? How can it affect people mentally? Many studies have shown the positive effects of music and its form of therapy (music therapy). Typical emotions observed when listening to a melody are joy, calmness, nostalgia, love, sadness, excitement, etc. (Juslin, Sloboda, 2001). Hanslick (2003), points out that the effect of a melody on our mood has been adequately explained by physiology. Music has strong effects on human psychology and can stem from various factors such as rhythm, melodies, lyrics and the overall atmosphere it creates. These effects cover a wide range of emotions and situations. The field of emotional intelligence includes the verbal and nonverbal evaluation of emotion expression, its regulation in self and others, and the utilization of emotional content in problem solving (Salovey, Mayer, 1990). For instance, jazz music presents a complexity in music composition which matches individuals who seek complex and spiritual stimuli (Chamorro-Premuzic, Furnham, 2007). In the evolution of music, artificial intelligence is emerging as a powerful force in the world of music, radically influencing the way sound art is produced, created and perceived (Stephanidis, Antona, Ntoa, 2021).

The aim of the present study is the investigation of the music influence in a person's emotional state but on their mental health in general, the role of music therapy and the contribution of artificial intelligence to music production and distribution. The research questions of the study are as follows:

Question 1. How is the type of music chosen according to the emotional states experienced by the person and how does this contribute to mental health?

Question 2. How does music affect emotional intelligence and what is the role of music therapy?

Question 3. How does artificial intelligence influence the evolution of music production and distribution?

Literature Review

It is worth analyzing to distinguish and define the notions of emotion and music in order to record the character of the emotions caused by the music. According to the American Psychological Association (American Psychological Association, 2020), emotion is "a complex pattern of reactions that includes experiential, behavioral and physiological elements".

According to Cooke (2008) music phrases constitute a special language of emotions, like the one of speech. For Panksepp and Bernatzky (2002) most people who listen to music connect and create bonds with the various situations they experience. The first studies and research on emotions in music are observed in the 19th century, forming the springboard for the existence and subsequent creation of film music around the end of the 1980s (Cohen, 2010). In our attempt to include the notion of mood in music and emotion it is observed by Panksepp and Bernatzky (2002) that the mood is directly affected by the music of the listeners. Of course, this is getting weaker and weaker since everyone's mood is something that the person himself carries while constantly changing.

Researchers talk about the theory of general intelligence, based on the aforementioned intelligence general intelligence is an indicator of the degree of success of a person in his/her academic career (Neofytou *et al.*, 2006). The first theorists and researchers who talk about emotional intelligence are Wayne Payne in 1985 and later Keith Beasly (Salovey *et al.*, 1989–1990). Mayer *et al.* (2000a), define emotional intelligence as a type of social intelligence that involves one's ability to monitor one's own emotions as well as those of others in order to understand and manipulate emotions to facilitate thinking (Mayer *et al.*, 2000a). According to Bar-On, (2000) and Mayer, Salovey and Caruso (2000b) emotional intelligence can be shaped and developed constantly through the stimuli that the person receives but also through his continuous education.

In Tiffany Field's research (as it is referred in Gottman, 2011) the mental health carried by the parents directly contributes to the development of the central nervous system and emotional intelligence of the infant. The effects of music on humans become apparent from the fetal age both in their physiology and psychology. Research shows that until nowadays music affects: heart rate and pulse, electrodermal reaction, breathing rate, blood pressure, muscle tension, blood volume, skin temperature, gastric movement, pupillary reflexes eye, blood oxygenation, hormonal secretions (Sakalak, 2004).

These effects cover a wide range of emotions and conditions such as expressiveness of emotions, effect on mood, improvement of concentration, therapeutic action, social connection, enhancement in the fight against stress and depression, improvement of physical recovery, enhancement of brain functions, combat of distraction and overwhelm (MacDonald, Kreutz, Mitchell, 2012).

The relation between music and a person's personality, it is linked to their character and neurotism. Depending on the kind of choice certain aspects of it in both physiology and psychology will also be revealed. For instance, jazz music exhibits a complexity in musical composition that matches individuals who seek complex and spiritual stimuli (Chamorro-Premuzic, Furnham, 2007).

For the International Music Therapy Association, music therapy is defined as the application of music to the needs of individuals for the purpose of mental and physical health (Kartasidou, 2004). Within these definitions that of the American Music Therapy Association could not be missing, where it defines music therapy as the clinical and documented use of musical interventions with the aim of achieving individual goals in a therapeutic relationship where the therapist has completed a validated music therapy program. Music therapy is a form of psychotherapy which uses music as a means of achieving psychological goals. Furthermore, it can be used for the therapy to treat a wide variety of mental disorders, including depression, anxiety, post-traumatic stress disorders (PTSD), schizophrenia, and personality disorders. (Saarikallio, Erkkilä, 2019). Music can be utilized as a means of communication and expression of feelings that may be difficult or impossible to express with words. This can be very important for people with mental disorders who find it difficult to communicate their feelings to others. The aforementioned can be particularly important for people with psychological disorders who find difficulty in expressing their emotions with others. For instance, music can be used by people who deal with depression so as to express their feelings of sadness, hopelessness or isolation. It can also be used by people with anxiety to express their feelings of fear, panic or tension (Koelsch, 2014).

According to Papanikolaou (2011), music therapy is divided into two categories: the interactive one based on musical improvisation and the receptive one, where listening techniques are used. Music therapy is capable of bringing out and helping to express the most hidden and difficult emotions (Koukourakis, 2010).

Music from the perspective of Artificial Intelligence

Modern music production continues to evolve with the rapid development of technologies. Advances in computing power, sophisticated sound processing algorithms, and the use of artificial intelligence have enabled the creation of innovative musical expressions (Yang, Nazir 2022).

Artificial intelligence emerges as a strong force in the world of music, influencing radically the mode of production, creation and perception of the arts of sounds (Stephanidis *et al.*, 2021). Algorithms can analyse the patterns of popular music genres, predict audience preferences, and even create original pieces of music (Hernandez-Olivan, Beltrán Blázquez, 2022). "Artificial Intelligence (AI) refers to systems that exhibit intelligent behavior, analyzing their environment and taking action with some degree of autonomy to achieve specific goals" (European Commission, 2018). The applications of Artificial Intelligence in music production include composition, deciphering, transcribing existing music, and even playing instruments using robotic technology (Stephanidis *et al.*, 2021).

Platforms such as Pandora and Spotify use artificial intelligence algorithms to keep listeners engaged with modern music (Williams, Hodge, Wu, 2020). Artificial Intelligence can also create personalized videos, soundtracks and live event recommendations. Moreover, Artificial Intelligence plays a crucial role in copyright and rights management, a task made more complex by the proliferation of digital content (Venkatesh *et al.*, 2022).

The ethical implications of Artificial Intelligence such as creativity, property rights and its impact on artists and industry professionals will also be a focal point in the near future (Williams *et al.*, 2020).

Research Methodology

1. Method

For this present research, the quantitative research methodology was followed which helped us in its objectivity and effectiveness. According to what was studied in a literature review, primary quantitative research was conducted using Likert scale questionnaires on 177 undergraduates, postgraduates, doctoral candidates, and participants in training programs at the University of Patras (Athanasiou, 2000; Creswell, 2016).

The research tool that was used for the present study was the construction of a questionnaire as it has a flexible, effective and non-particularly expensive way of collecting and analysing inexpensive ways of collecting and analysing data (Athanasiou, 2000; Creswell, 2016).

Relevant studies that contributed to our study were the following ones: Bar--On, (1997), Perlovsky, (2010), Nowak and Bennett, (2020), Gabrielsson and Lindström (2001), Gardner, Santos and Schmidt, (2023). The aforementioned studies explore the nature of emotions (emotional intelligence), music and emotions (effects – therapy), and artificial intelligence with its contribution to music production, distribution and development. In this respect, our questionnaire's questions emerged from the findings of the above studies. To be more precise, the questionnaire consists of 18 questions with three demographic data (age, gender, marital status), the remaining questions were divided into questions related to music, mental health and artificial intelligence. As mentioned earlier the data were collected on a Likert scale.

The indicator that proves questionnaire and research's reliability is the Cronbach's alpha coefficient, where it calculates the internal consistency of a test or a scale with values from 0 to 1. The internal consequence describes the degree of relativity that the objects in the research tool have. Research is considered reliable with value greater than 0.7 both overall and in individual groups of questions that govern it (Field, 2009). In that case, the internal consistency coefficient ranged at the limit of 0.7. It is also worth mentioning that a pilot study was carried out so as to design the final form of the questionnaire. The present study was given to three experts with relevant research background knowledge and work in order to evaluate the appropriateness of the research questions while a pilot application followed in terms of the final form of the questionnaire.

2. Selection of data

For the implementation of the statistical analysis, the questions from question 1 (age group) to 3 (marital status) are considered as demographic characteristics and general data.

The research sample consisted of 26% (n = 46) men and 74% (n = 131) women who were the majority of the sample. The sample of age groups of the research was divided as follows: from 18–25 years old made up the largest percentage of the whole 47.5% (n = 84), while the age group from 26–45 years old followed with 37.3% (n = 66) and finally from 46 and over with 15.3% (n = 27). As far as the marital status of the sample is concerned, the majority were unmarried with 70,1% (n = 124), divorced with 4,0% (n = 7) and finally married with 26,0% (n = 46). The research axes of the present study are related to:

1. The assessment of the importance of music for the sample population as well as the daily interface that exists with music.

2. Music therapy, people' ability of emotional intelligence and the levels of mental health that people think they have according to their own assessment.

3. The examination of the knowledge of Artificial Intelligence as well as the ways and means by which this technology affects the production and distribution of music.

Table 1. Descriptive statistics for the sample data (Mean, Standard Deviation, and Median)

	N	Missing	Mean	Median	Mode	SD	Minimum	Maximum
4. Do you choose the type of music according to your mood?	177	0	3.825	4	4.00	1.070	1	5
5. How do you choose a song:	177	0	2.661	3	3.00	0.729	1	3
6. Do you play a musical instrument?	177	0	0.294	0	0.00	0.457	0	1
7. Do you think that music contributes to changing a person's mental mood / health?	177	0	4.525	5	5.00	0.565	2	5
8. To what extent can music help in the treatment of people with mental problems?	177	0	4.198	4	4.00	0.776	1	5
9. Do you know the role of music therapy?	177	0	3.034	3	3.00	1.167	1	5
10. How important do you consider the ability to recognize and understand other people's feelings?	177	0	4.610	5	5.00	0.594	3	5
11. How often do you recognize and express your own feelings?	177	0	1.215	2	2.00	0.959	0	3
12. How much does emotional intelligence influence the decisions you make on a personal and professional level?	177	0	3.938	4	4.00	0.854	1	5
13. How much do you think music affects emotional intelligence?	177	0	3.915	4	4.00	0.818	1	5
14. Do you know what Artificial Intelligence is?	177	0	3.887	4	4.00	1.016	1	5
15. Have you used apps that incorporate Artificial Intelligence?	177	0	2.661	3	1.00	1.335	1	5
16. To what extent do you think Artificial Intelligence affects music?	177	0	3.232	3	3.00	0.952	1	5
17. Could Artificial Intelligence replace the way we listen and share music?	177	0	2.915	3	4.00	1.157	1	5
18. Do you think that Artificial Intelligence can contribute to improving mental health?	176	1	2.938	3.00	3.00	1.127	1	5

The analysis of the table above reveals interesting observations on the participants' relationship with music, their emotional intelligence and artificial intelligence.

First, we observe that most participants choose the type of music according to their mood, as indicated by a mean of 3.825 and a median of 4. However, the choice of a particular song appears less defined, with a mean of 2.661 and a median of 3. Of note is also the fact that few participants play a musical instrument, as it is stated by the low mean of 0.294 and median of 0.

As far as the sector of emotional intelligence is concerned, participants show a moderate ability to recognize and express emotions, with a mean of 1.215 and a median of 2. On the contrary, the impact of music on mood and mental health is particularly highly valued, with a mean of 4.525 and a median of 5, which shows the positive perception of music in people' lives. In addition, many people believe in music's ability to heal mental problems, with a mean of 4.198 and a median of 4. Regarding music therapy knowledge, participants have a moderate awareness, as indicated by mean 3.034 and median 3.

Understanding participants' emotions is considered extremely important with a mean of 4.610 and a median of 5, while emotional intelligence seems to play an important role in their decisions, with a mean of 3.938 and a median of 4. At the same time, music is estimated to have a significant effect on emotional intelligence, with an average of 3.915.

In the sector of Artificial Intelligence, participants present a sufficient level of knowledge with a mean of 3.887 and a median of 4, but little experience in using applications incorporating artificial intelligence, as shown by a mean of 2.661. The impact of artificial intelligence on music is moderately rated, with a mean of 3.232 and a median of 3, while there seems to be an idea that artificial intelligence might affect the way we listen to and share music, although not to a large extent, with a mean of 2.915. Finally, the belief that Artificial Intelligence can improve mental health status is moderate with a mean of 2.938 and a median of 3, indicating a restrained optimism of the participants.

Overall, the standard deviations ranged from 0.457 to 1.335, indicating the variability of participants' views on the various research topics.

3. Results

Regarding <u>the first research question</u> which refers to these answers, it appears that 71.1% of the respondents choose the music they listen to depending on the emotional state they experience at the time of the choice. The above percentage results from the sum of the answers "Quite" and "Very", while if this percentage is added to the people who answered "Average" then it follows that 87.5% choose the type of music they listen based on the emotional of the situation, in the majority of choices (at least 3 out of 5 times).

Based on the result of the correlation, it is found that the more time someone spends listening to music, the more carefully they choose their music based on the emotional state they are experiencing (r_s (175) = 0.691, p-value < 0.01). Regarding the second part of the first research question, the aim is to evaluate the contribution of music to the level of mental health that characterizes a person. Taking into consideration the answers we can clearly state that approximately 90% consider music as a fairly or very important dimension of influence on mental health.

As far as the second research question is concerned, the influence of music is examined in terms of sharpening people's emotional intelligence but also evaluating the role of music therapy in improving the living conditions and emotions experienced by a person.

According to the quantitative data obtained for this question, 75% consider the effect of music on emotional arousal as high or very high.

According to the statistically significant prices, we observe that there is a small correlation (r_s (175) = 0.164, p-value < 0.05) between the frequency of expressing personal feelings and the opinion about the influence of music in terms of aggravating emotional intelligence. At the same time, we realize that there is a medium strength effect between how important participants consider the ability to recognize and understand other people's emotions and how much they believe music affects emotional intelligence (r_s (175) = 0.376, p-value < 0.01).

Regarding the third research question, we find out that all the correlation coefficients calculated are statistically significant, as they note p-values less than 0.05. More specifically, the findings are summarized as follows:

1. There is a medium to high correlation ($r_s(175) = 0{,}545$, p-value < 0,01) between participants' use and understanding of the evolving capabilities of AI applications for music production and sharing and how important the development of such applications and their use is perceived to be for mental health difficulties.
2. There is a medium impact($r_s(175) = 0{,}33$, p-value < 0,01) regarding the level of AI's influence in music and the degree of importance of corresponding applications for dealing with mental health problems.
3. Finally, strengthless seem to be the correlations between whether participants know or have been in contact with an Artificial Intelligence application and how important they consider their contribution to mental health programs, the Spearman correlation values are equal to 0.148 and 0.276 respectively.

Discussion – Conclusion

Significant points that were addressed in our study were the role of music in the development and expressiveness of emotional intelligence. More specifically, we touched upon topics such as the ability to recognize, understand and manage emotions. Of note is also the therapeutical power of music when it comes to mental health, emphasizing on how music can affect mood, the expression of emotions and studying how the emergence of technology and especially artificial intelligence has changed music production and distribution, as well as the effects it can have on people's lives. More specifically, regarding the music choice and mood, the convergence of the research with the research of Panksepp and Bernatzky (2002) was evident, where, as they argue, the mood is directly influenced by the music of the listeners. Similarly, Hanslick (2003), points out that the effect of a melody on our mood has been adequately explained by the physiology of the human organism. The contribution of music to the individual's mental mood was consistent with all our literature reviews, while in dealing with mental problems our research showed that the largest percentage agreed with 45.8%. Although, there was uncertainty regarding the aforementioned. The studies of Zheng *et al.* (2021), Troubat *et al.* (2021) and Fancourt and Perkins (2018), reveal the direct action that music has in combating stress and depression. As also research by Boyd-Brewer (2003) and Choi, Lee and Lim (2008) refer to the improvement of physical recovery and the enhancement of brain functions respectively, brought about by music.

The role of music therapy for the research sample was shared in various percentages, a fact that shows the connection and knowledge that participants have with this type of therapy. From a bibliographical point of view, the beginnings of music therapy as well as its therapeutic properties have been evident throughout time and since ancient times, just like the history of music. According to Karafas (2005), music affects the physiology as well as the psychosynthesis of a person. Regarding the emotional intelligence, participants mostly show that they are influenced for the decisions they make in the various issues of everyday life (personal, professional) and this is logical as it is proven in the research of Goleman (1998), where there are certain abilities that are emotional intelligence by dividing them into two categories.

Of note is the condition where survey participants were asked about their knowledge of artificial intelligence and 44.1% said "Very". This is contradicted when in the next question asking if they have used apps that incorporate artificial intelligence only 17.5% said "Very". The aforementioned is contradicted when in the next question asking if they have used apps that incorporate artificial intelligence only 17.5% said "Very". They should definitely, after knowing the concept of artificial intelligence, realize that most applications and programs that use AI, they incorporate it. According to the literature review, platforms such as Pandora and Spotify use artificial intelligence algorithms to keep listeners engaged with updated music (Williams *et al.*, 2020).

Regarding the last three questions that were addressed to the participants of the *research (16. How much do you think AI affects music? 17. Could AI replace the way we listen to and share music? 18. Do you think AI can help improve* *mental health?)* a variety was observed in the responses and the percentages obtained. The literature review does not directly answer these as it is an evolving topic that requires continuous and thorough study. However, the ethical implications of AI, such as creativity, property rights, and its impact on artists and industry professionals, will be a focal point (Williams *et al.*, 2020).

With reference to the first research question, the research respondents showed that music is important to them, while the reasons for listening to music outweighed entertainment, relaxation, expression and finally relaxation. The largest percentage showed that they choose the type of music according to the lyrics and music that characterize it. Regarding the first research question, the survey respondents showed music is important to them, while the reasons for listening to music outweighed entertainment, relaxation, expression and finally relaxation. The largest percentage showed that they choose the type of music according to the lyrics and music that characterize it. Thus, the person participates more actively in the musical process, leading him/her to connect with the emotional states he/she experiences. The contribution and change of the individual's mental health and mood is determined to be very important for the participants. In these terms, music and emotion interact both directly and indirectly. For each individual this interaction may be different depending on time, space, exposure and lived situation.

Regarding the second research question, it appears that music is linked and can influence a participants' emotional intelligence. Participants showed that the influence of emotional intelligence on the decisions of everyday issues (personal, professional) is enough. On the other hand, the role of music therapy was not so evident as well as the answers given by the people had a diversity regarding the distribution of percentages. The aforementioned distribution of percentages may indicate a confusion that individuals had about this form of therapy, its knowledge, relationship and role. A small percentage of participants had a clear view of exactly what music therapy is and what its implications are for mental health.

In the third research question, the number of participants showed that they know what artificial intelligence is, of course it contradicts when only 11.3% answered that they have used applications that integrate it. The participants agreed however to the fact that the impact of Artificial Intelligence in music is medium to high, the same applies regarding the production, distribution and the contribution of music. The stronger the belief that Artificial Intelligence will replace the way we listen to and share music, the stronger the contribution of these technologies to the treatment of mental health problems.

Research's conclusions highlight the importance of music and technology in mental health, suggesting further research in those fields. Overall, the present research offers a multidimensional look at the relationship between music, technology and mental health.

Research Limitations – Further Suggestions

Suggestions for future research could be to conduct interviews with music and mental health experts, where a more specific and specialized view on the subject would be revealed. Another proposal is the creation of a psycho-educational music therapy program for children or teenagers in order to manage and deal with mental problems (e.g. severe anxiety, depression).

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Selected Methods in the Process of Teaching a Chronically Ill Child at the Early School Stage

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Abstract

The article discusses the definitions and models of chronic disease, and lists examples of diseases that are considered chronic diseases and fit into the classification of students with special educational needs. The role of chronically ill student in early school education and the goals that a teacher should set when working with a child are explained. The article contains considerations on selected methods of therapy for a child with a chronic disease.

Keywords: therapy, work as a teacher, chronically ill child, special educational needs

Introduction

Among students with special educational needs, chronically ill children can be distinguished. The term "chronic disease" is not unambiguous, as many researchers and specialists categorize and define this term differently in the literature. According to Maciarz (2001), the key characteristics of a chronic disease are:

– long duration, lasting more than four weeks;
– milder symptom intensity compared to the acute phase of the disease;
– the possibility of permanent, irreversible changes in the patient's body;
– chronic diseases require long-term medical care and the use of therapeutic and rehabilitation support.

According to Pilecka (2002), a chronic disease should be seen as a potential factor that changes the individual's and their family's previous situation, requiring changes in attitudes and behaviors from both the patient and their family members, which allow them to cope with this new and difficult life situation. The variety of definitions and the inability to develop consistent guidelines arise from the fact that chronic diseases and their defining characteristics are strongly dependent on the individual's condition, the specifics of the disease's occurrence, and its type. They may be characterized by sudden onset, a slow process of initiating changes in the body, significant or only slight deterioration in health, a long period without symptoms, or a sudden worsening requiring hospitalization. Examples of chronic diseases include:

- cancer;
- respiratory diseases;
- obesity;
- diabetes;
- osteoporosis;
- epilepsy;
- autoimmune diseases;
- diabetes.

Models of Chronic Disease

Models of chronic disease help to understand what it means to adapt to life with specific limitations resulting from the presence of particular diseases in an individual. Their development is based on assumptions that explain the origin of the disease, its consequences, as well as the role and position of the sick person in society.

1. **Biomedical Model** – Focuses on the origin, course of the disease, prevention, and treatment. This model primarily refers to biological factors that determine how the student functions.
2. **Bio-psycho-social Model** – Assumes a holistic approach to both the disease and the patient, significantly expanding the structure of adaptation. It not only includes the negative consequences of the disease but also emphasizes the positive psychosocial aspects of human functioning. The student, as part of society, is subject to its influences. The person is treated as a system that functions in accordance with the principles of self-regulation and regulation.
3. **Cognitive Models of Disease** – These models focus on an individual's beliefs about the disease, its causes, consequences, their situation as a patient, and their future. Adapting to life with a chronic disease is viewed here as a process aimed at maintaining a positive self-image and worldview in the face of health-related problems (Plichta *et al.*, 2018, p. 159).

The Chronically Ill Child as a Student in Grades 1–3

Starting education at the early school stage is undoubtedly a stressful and significant change in the life of every new student. Changing schools, facing different requirements, and often leaving behind the preschool group and peers presents a considerable challenge for seven-year-olds, especially considering that each child undergoes the adaptation process in a new environment in their own way. Taking all these aspects into account and analyzing the situation of a chronically ill child, we can infer that this may be an even greater challenge for them, as the limitations caused by the illness and the potential for exclusion from the peer group contribute to additional stress, reluctance, and fear of starting education at the early school stage. Particularly since not all children attend integrated schools, as, according to educational law, chronically ill children have the option of attending mainstream schools. Antoszewska (2020, pp. 60–64), as a way of fulfilling the school obligation or the duty to learn for a chronically ill child, suggests an approach tailored to the student's health condition and the stages of the disease:

- attending primary schools in healthcare institutions;
- individual teaching;
- home education;
- mainstream primary schools.

According to the Act of April 12, 2019, on healthcare for students, the care of a chronically ill or disabled student in school is provided by a community nurse or a school hygienist. This care must be based on cooperation with the parents, the primary healthcare physician, the school principal, and the school staff. This cooperation includes determining the way the student is cared for, administering medications with the written consent of the parents, and adapting the student's stay at school to their abilities and limitations resulting from the illness.

In the case of teaching a student with a chronic illness, the teacher is required, in order to achieve the most effective results in working with the student, to cooperate with the child's parents, ensure the child's position in the class, maintain a positive attitude and relationships with peers, and also adhere to the principles of working with a chronically ill child. These principles include, among others (Plichta *et al.*, 2018, p. 170):

- plasticity and complexity of action;
- the principle of subjectivity and individualization;
- minimizing unnecessary effort;
- therapeutic activation;
- functional reintegration and social rehabilitation;
- valuing the family environment.

Goals Set During Work with a Chronically Ill Child

When working therapeutically with a chronically ill child, the teacher should primarily focus on the goals that need to be set in order for the rehabilitation process to be meaningful and bring positive outcomes. The goals that the teacher should follow during their work with a chronically ill child include (Plichta *et al.*, 2018, p. 170):

– “Getting to know the chronically ill child, making them aware of the nature of their illness and the need to accept it;

– Increasing the child’s self-confidence and sense of self-worth;

– Raising awareness in the ill child and their family about the necessity and methods of ongoing treatment;

– Educating the child on what they can do on their own to reduce the effects of the illness;

– Adapting the environment so that the child can move independently (if they have limited mobility);

– Presenting content in a way that makes it fully accessible to the student;

– Adjusting educational and therapeutic goals to meet the child’s individual needs;

– Using activating methods and forms of therapeutic work;

– More frequent use of information technology in education (if the child has limited mobility);

– Organizing the student’s work time both in school and at home (taking into account necessary breaks) and understanding how much time it takes the child to complete individual educational tasks;

– Recognizing symptoms of poorer well-being (the teacher should know how to help the child);

– Encouraging the child to engage in frequent social interactions and make friends;

– Providing assistance in catching up with schoolwork missed due to absences;

– Offering opportunities for the child to demonstrate independence;

– Taking a holistic and multi-faceted approach to the problems and needs of the chronically ill child;

– Utilizing the body’s ability to compensate;

– Developing preserved skills;

– Adapting the family, school, and physical environment to the needs of the ill child;

– Helping the child adapt to the situation created by their specific illness;

– Teaching proper emotional regulation and boosting self-esteem;

– Encouraging the child’s active participation in treatment and rehabilitation”.

Selected Therapy Methods

Working with a child with special educational needs involves more than just teaching and conveying content that the child must learn. The work requires not only knowledge of the specifics of the illness and the ability to set goals for working with the child, but also conducting therapy that, when woven into daily teaching activities, will help achieve results both in terms of academic progress and improvements in the emotional, psychological, and social aspects of the child's life. Working with a student requires constant searching and adapting the type of therapy to their abilities and needs, particularly during the early school education stage. When selecting the type of activities, the teacher must keep in mind that children at this stage are still primarily in need of play, and, considering their life and health situation, they need relaxation and a suitable way to release frustrations that may often accompany them. Here are some examples of therapy methods (Żelazkowska, 2016, pp. 223–232):

1. **Play** – Encourages taking part in joint activities, is a form of providing pleasure to the child, and is their natural form of activity. It allows for the development of prosocial behaviors, teaches active listening, observing, expressing one's own feelings, boosts self-esteem, and teaches the principles of healthy competition. Cooperation during play and the possibility of setting rules and guidelines fosters integration, showing that teamwork can be fruitful, enjoyable, and open to new ideas and solutions. Choosing appropriate games and activities helps meet the chronically ill child's need for positive interactions with their environment, overcoming difficulties, concentrating, and seeking new solutions.
2. **Artistic expression** – Develops skills of creative imagination, visual sensitivity, and motivates the child to express their own feelings and relieve tension. Between the ages of 9 and 12, chronically ill children often experience significant social challenges. In such cases, creating puppets and acting out dramas or scenes can help address the issues the child is currently facing.
3. **Fairy tale therapy** – Fairy tales break down shyness, teach expressing and discussing feelings through situations that are present in the story. There are many therapeutic books on the market that address problems in various contexts. By identifying with literary characters, students learn valuable patterns of behavior, social conduct, problem-solving strategies, and a new perspective on their own situation.
4. **Music therapy** – This form of therapy is considered one of the oldest. It primarily serves therapeutic and educational goals, aims to improve the self-image, develop motivation in children, and enhance skills such as motor coordination, auditory skills, and communication abilities. Therapeutic activities using music are enjoyable and relaxing for students, offering a means of releasing unwanted emotions, expressing oneself, and sharing their problems and emotional state through music.

Conclusion

The occurrence of a chronic illness in an adult or daily life with the awareness of limitations caused by the disease's consequences is burdensome for everyday functioning, pursuing education, or personal development. If being chronically ill is challenging for adults, we can only imagine how it affects children living among healthy peers or family members. For a child with such limitations, establishing relationships with peers and attending a general education school largely depends on the child's health condition and on building a strong sense of self and belief in their capabilities.

A teacher working with a chronically ill child at the early school stage must step out of their comfort zone, overcome their internal barriers, and make an effort to transcend these challenges. Therefore, it is justified to state that their work cannot focus solely on teaching but must primarily involve supporting the child, integrating them into their environment, and implementing therapeutic activities that positively influence the child's social, physical, psychological, and emotional functioning.

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