REVIEWED PROCEEDINGS

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Ninth International Scientific Webconference of Scientists and PhD. students or candidates
„Trends and Innovations in E-business, Education and security “

Held under the patronage

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Prof. Dr. Zoltán Rajnai,
and of

of the dean of the Faculty of Economics Informatics

Prof. Mgr. Erik Šoltés, PhD.

CONTENT

Invited lecture

ARTIFICIAL INTELLIGENCE THROUGH ASIMOV'S EYES OR THE WORK OF A LIFETIME

Szabó Lajos[1]

Abstract
This paper explores the origins and diverse implications of the terms "artificial intelligence" and "robot," highlighting their evolution and the misconceptions surrounding their use. The term "artificial intelligence" was officially coined by John McCarthy in 1956, although the concept had been explored earlier by Alan Turing and others in the field. This term encompasses a broad spectrum of technologies and applications, often misrepresented in the media as a singular entity, leading to widespread misunderstanding. Similarly, the term "robot" was popularised by Karel Čapek and initially described human-shaped machines, evolving in its application from its Slavic root meaning "labour" to signify various automated devices. The paper also delves into Isaac Asimov's significant contribution to the discourse through his literary works, mainly focusing on his portrayal of robots with "positronic brains" and the ethical and philosophical dilemmas they present. Asimov's fictional laws of robotics are discussed about real-world applications and regulatory challenges in artificial intelligence and robotics. The study underscores the disparity between Asimov’s idealistic visions and the pragmatic issues of integrating AI systems into society, advocating for a nuanced understanding and responsible development of AI technologies.

Keywords
Asimov, AI, robots, ethical aspects of AI.

1 Introduction

Before analysing Asimov's oeuvre, I want to clarify a few essential points. Knowing precisely what we are talking about when we use specific terms is vital.

How long have we been dealing with things called artificial intelligence?

"*Many of the early achievements could be called AI, but a complete idea of AI was formulated in 1950 by Alan Turing in his article Computing Machinery and Intelligence. Here, he introduced the concepts of the Turing test, machine learning, genetic algorithms, and reinforcement learning.*"(MIT BME, 2011)

After the Second World War, several researchers started researching and developing self-learning programs with decision-making capabilities. For a long time, they were called by many names until scientists working on the subject organised a two-month workshop in the summer of 1956. The subject remained many-named until John McCarthy, who later became a professor at Stanford University, named it at the Dartmouth workshop, and we still use the term today.

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As we read about it in the Artificial Intelligence Electronic Almanac:

"*Perhaps the most lasting outcome of the workshop was the adoption of a new name for the field, created by McCarthy, namely artificial intelligence.*" (MIT BME, 2011)

As before, there were many different names for tools, what was otherwise designed for other problem areas, and the programs that work in them. Since then, we have found many interpretations of the terms and descriptions of artificial intelligence used by developers, researchers, and writers.

It is of utmost importance to note that phrases in the media about artificial intelligence, such as " Artificial intelligence already knows this." Artificial intelligence can do it." the like creates a false image in the reader's mind. They suggest that artificial intelligence is a single thing, that we are talking about one thing when we talk about it. The consequence of this suggestion is that people unfamiliar with the subject use it in this context. Yet this interpretation is harmful, misleading, completely unscientific, and unfounded.

Yes, there has been a general term since McCarthy, but it refers to completely separate programs and the instruments they manage. Whether we are talking about a word processor or a word processor that communicates with us verbally or in writing, facial recognition software working in some hardware, or a chess machine that we play with, it is all artificial intelligence. Likewise, software that generates images or moving pictures on verbal or written request, a complex missile defence system, or machines that learn the various movements of four-legged animals or humans are all controlled by partially self-learning software and are all artificial intelligence.

But they have nothing to do with each other!

What one can do, the other can't, even if they have modules in common. The standard modules do not have identical software because they are purpose-built by experts in different research or development laboratories worldwide. One only has to think of information input. It is not the same as what and in what spectrum the input module detects and what software converts these detections into perceptions. After all, if we model humans, they perceive light in a much smaller spectrum than some animals, as we do with sound, heat, and so on. Just as the organisms on our planet perceive and react differently to different things, so do the many variations of artificial intelligence that perceive and respond differently to different things according to their programming.

There is no such thing as artificial intelligence, and it should not be discussed this way. Just as different living organisms have other purposes, different "software" such as DNA, other input and output, information processing, and execution tools, every system using artificial intelligence software is designed for different purposes.

Alongside these research and developments, automation in the industry has continued to replace humans with monotonous and exact tasks. This process continues today, with better and better robots in industry and medicine. In the 21st century, many home automation devices work in our homes, and many automats on computers and other devices do our daily robotised work.

But the robots should not be like the industrial robots we see today, but human androids!

The inventor of the word, Karel Čapek, in his drama "Rossumovi univerzální roboti", describes a human-shaped machine that can think.

"Robot" was already a familiar word in Hungary, having been one of the serf services of the Middle Ages. Although in Slavic languages, such as Russian, there is a general sense of 'work' for robots, it is also known as forced labour. ... Although Karel Capek was the first to use the word, he did not invent it. An English-language Czech website has Capek's recollection of all this. The short story reveals that he first wanted to call the devices "Labori", but his

brother suggested the word " robot " to describe the human-shaped machines." (HVG Kiadó Zrt., 2011)

After the drama premiere in New York in 1922, the name 'robot' began to be applied to intelligent structures in the shape of a man and later to all sorts of other mechanical devices. This led to the present-day meaning, which few people know is derived from the Slavic word for work.

Since language is a "living" evolving communication system, its words and expressions constantly change in content and meaning. The word initially meant work, but in the early Middle Ages, it already meant forced labour, work from which the person doing the work did not benefit. Work done for the landlord, done without compensation by his serfs. This quasi-slave activity is also rooted in the word robot in many languages, including Hungarian.

As Capek understands it, a robot is a slave machine that receives no compensation for the work it does for its master.

The Isaac Asimov of the title, for example, knew it, as he described it on pages 19-20 of the Hungarian edition of The Foundation's Edge, where Professor Quintesetz is talking to Professor Pelorat and explaining to him about robots:

„ Quintesetz pursed his lips, leaned back in his chair (which gave slightly under the pressure), and put the tips of his fingers together. He seemed to be speculating as to just how to begin.

He said, "Do you know what a robot is?"

"A robot?" said Pelorat. "No."

Quintesetz looked in the direction of Trevize, who shook his head slowly.

"You know what a computer is, however?"

"Of course," said Trevize impatiently.

"Well then, a mobile computerised tool-"

"Is a mobile computerised tool." Trevize was still impatient. "There are endless varieties, and I don't know any generalised terms for them except mobile computerised tools."

"—that looks exactly like a human being is a robot." S.Q. completed his definition with equanimity. "The distinction of a robot is that it is humaniform."

"Why humaniform?" asked Pelorat in honest amazement.

"I'm not sure. It's a remarkably inefficient form for a tool, but I'm just repeating the legend. 'Robot' is an old word from no recognisable language, though our scholars say it bears the connotation of 'work."

"I can't think of any word," said Trevize sceptically, "that sounds even vaguely like 'robot' and has any connection with 'work."

"Nothing in Galactic, certainly," said Quintesetz, "but that's what they say."

Pelorat said, "It may have been reverse etymology. These objects were used for work, and so the word was said to mean 'work.' „(Asimov, 1982)

As a native Russian, Isaac Judovich Ozimov, written in Cyrillic letters *Исаак Юдович Озимов*, born in 1920 in the village of Petrovichi in the Smolensk region of the Russian Federation, in the Soviet Union, obviously spoke some Russian. He was familiar with the Čapek interpretation, as the explanation points to it perfectly.

2 Artificial intelligence in Asimov's coherent stream of novels

As a famous writer, most people know Asimov as a fiction or science fiction writer and not as a scientist, so this is the primary information for his name. His works of scientific dissemination are also very numerous, probably exceeding his works of science fiction. As an associate professor of biochemistry, he taught and chaired a department for many years until he decided to continue training more widely through his writings.

He described himself as a scientist who does science fiction when he writes about scientific dissemination. It is in no way worthy of anyone to disparage what he has written or to belittle his achievements. An author with an academic degree and a teaching 'background' who has written more than 500 books, many of which are works of scientific scholarship, is not 'just a science fiction writer'. His work is well worth reading and using in scientific works. This paper is not intended to be a literary or detailed textual analysis but merely to highlight and, rarely, justify the main points with quotations.

The present study considers Asimov's writings as part of a unified stream of thought, which many literary scholars, critics, and, of course, readers familiar with his writings, like the author of this study, consider them to be. The appearance of the short stories, short fiction, and novels is not chronological, as the short stories in I Am a Robot were followed by the Foundation trilogy. The Space Hunter series, the Elijah Bayley stories, Pebble in the Sky, and Stars Like Dust are loosely related but connected. Prelude to Foundation, the Foundation Edge, Foundation and Earth were completed decades after these, at the publisher's request. It is Asimov's literary genius that if you start from beginning to end in this vast reading, you become prisoners of a single stream of thought from the first to the last sentence.

Let us see what the world-famous writer and scientist wrote about artificial intelligence! His first writings coined the term "positronic brain" to describe thinking, consciousness, learning, and decision-making machines. He already uses the term robot when he imagines positronic brains in vehicles.

For 46 years, Asimov was so preoccupied with whether only humans have consciousness and the capacity for autonomous decision-making that he chose it as his central thesis, from his first science fiction writings to almost his last published novel. Had he lived in 2012, he would undoubtedly have been happy to join the signatories of the Cambridge Declaration.

What is the Cambridge Declaration? Vilmos Csányi, in his work Ethology, Man, Society, explains it briefly as follows:

"It has only been five years since scientists agreed that the nervous systems of man and animals are the same, with differences in size and species. In other words, the Cambridge Declaration said that animals have consciousness and that all animals think, but that these thoughts are more modest and of a different type than those of man. " (Csányi, 2017)

As the Cambridge Declaration on Consciousness, issued on 7 July 2012, states about the state of consciousness of non-human beings - non-human animals, I believe, can be named as living beings - that;

“The absence of a neocortex does not preclude an organism from experiencing affective states. Convergent evidence indicates that non-human animals have the neuroanatomical, neurochemical, and neurophysiological substrates of conscious states and the capacity to exhibit intentional behaviours. Consequently, the weight of evidence indicates that humans are not unique in possessing the neurological substrates that generate consciousness. Non-human animals, including all mammals and birds, and many other creatures, including octopuses, also possess these neurological substrates.” (Low et al., 2012)

I want to add that the cleaner fish (Labroides dimidiatus) seems to have consciousness or some initiative to have it because it recognises itself in the mirror! (Kohda et al 2019.) It would seem, therefore, that the Cambridge Declaration could be supplemented even after all these years in the light of scientific discoveries.

Incredibly interestingly related to this 21st-century statement is perhaps the most productive writer of the 20th century, Isaac Asimov, who returned to questions of consciousness for almost his entire creative career (nearly 50 years!).

First published in a single volume in 1964, I, ROBOT New York 1964(Asimov, I. 1964.), and later published in a single volume entitled Robot Stories (Asimov, 1993), all his writings from 1940-1976, which contain short stories about robots and are a coherent stream of thought. However, a considerable amount of time has passed between each of them.

The message of these short stories is about artificial intelligence, robots with a positronic brain, autonomous consciousness, and the ability to think and learn, serving humans.

On the face of it, he writes stories about robots in the form of humans and other robots - vehicles, etc. - with positronic brains, self-awareness, and learning intelligence; the stories are about their masters and the interactions between them. They are exciting and entertaining writings, but those familiar with the subject will notice that they all revolve around the problem of human and artificial consciousness/intelligence. The other important topic is intuition, which is irrelevant to the present subject so that I will leave it aside.

His "Three Laws of Robotics" raises not only logical and decision problems but also ethical and psychological ones, which he has spent decades thinking about and describing and has taken to philosophical depths in his books, both for humans and robots. In the Lucky Starr series, he pushes the envelope on the problem of the intersection of non-human intelligence and human intelligence. At different levels, the intelligent lifeforms he imagines populate the celestial bodies of our galaxy and communicate with humans through various channels— fascinating thought experiments with philosophical and moral issues.

Giskard, whom we met in his novel Robots of the Dawn Planet (Asimov, 1983) and who had a conversation with R. Daneel Olivaw at the end of the novel Robots and Empire (Asimov, 1985) about the extension of the three laws, the introduction of the fourth law, is also a severe ethical-philosophical debate!

Robot psychology as a term also appears in the earliest collection of short stories, I the Robot, where the renowned robot psychologist Susan Calvin of the American Robot Ltd. is one of the main characters in many of the stories. The other protagonists are, of course, all robots who display anomalies still present in existing applications today.

In these short stories, he describes almost everything that makes us fear artificial intelligence today.

Avoiding the world of simple automatons, the author bases his writings on intelligent robots that communicate orally in increasingly clever ways, with the help of a 'positronic brain' invented in the distant future. We do not know, but it is clear that the problem of artificial intelligence and human intelligence, machine and human intelligence, and machine and human consciousness was the subject of his preoccupation, based on the assumption that robots with such capabilities would one day appear.

No one has yet produced artificial intelligence with this capability. As far as we know, current algorithms are as far from this imaginary positronic as the mind of a eukaryote is from that of a human.

One of the short stories he wrote in 1976 to celebrate the bicentennial of the United States of America, "The Bicentennial Man" (Asimov, 1983), is about a robot in the shape of a man who accidentally gains artistic powers. He uses this ability to create sought-after works of art, but his owner and descendants refuse to take the proceeds, leaving the money to his own devices.

I note that the accidental "program error" occurs twice in this series of short stories; both times, the robot develops artistic abilities. If I add to this, the ability of people in various creative fields to represent emotions, complex thoughts, or even entire stories in colours, lines, blobs, sounds, dance, etc., is not an ordinary human ability. There is a saying that very little separates the genius from the madman, and we can safely add artists to the genius. The two extremes are peculiarities in brain processes that differ from the average. The various "talents" are also distinct from the average, and because they result from the thought processes that run in our brains, they can be considered program errors.

Using this ability, the robot creates artefacts that collectors seek after and makes the robot and its owners famous. Its first owner refuses to take the proceeds from the artwork, and the money is his own. After the death of its first owner, all generations of descendants have traditionally treated the robot as a family member and an entity in its own right, as well as the memory of their ancestors, and in keeping with tradition, they have an independent income.

Throughout its long 200-year life, it continued to learn. Serving the descendants of the family that first owned it until its extinction, it explored the differences and similarities between the human brain and the positronic brain.

First, he starts wearing clothes; then, he replaces his metal body with artificial "human" body parts that look deceptively like humans. These are the kinds that humans use as prosthetics and artificial organs. After replacing all his body parts with these semi-bionic body parts, except for the positronic brain, he has only one wish: to prove that there is no difference between him and humans. Finally, the protagonist of the robot stories recognises himself as human and subsequently dies as a human.

The emotionally stirring, flat, and well-constructed writing is the first to say that there is a possibility that one day, at some point, complex software and its associated hardware might be created that is almost indistinguishable from humans. Even in the novel, it is a unique and notable exception that this robot is recognised as human and that too almost at the moment of its death.

In a series of short stories and novels written over 46 years and gradually becoming a coherent whole, he uses the term artificial intelligence only twice! The term first appears on page 58 of the Hungarian edition of "Robots of the Dawn Planet", in the last sentence of paragraph 3. Textually:

> *„Viewing as he did for intuitive feel—for trend and generality—every step*
> *In the course of human/robot interaction, it seemed to depend on dependence.*
> *Even how a consensus of robotic rights was reached—the*
> *gradual dropping of what Daneel would call "unnecessary distinctions"- was*
> *a sign of the dependence. To Baley, it seemed not that the Aurorans were*
> *growing more humane in their attitude out of a liking for the humane but that*
> *they were denying the robotic nature of the objects to remove the*
> *discomfort of having to recognise the fact that the human beings were*
> *dependent upon objects of artificial intelligence."* (Asimov, 1983)

The other time in the novel stream is on page 291 of the novel "Prelude to Foundation", textually:

> *„Dors said, "It seems to be well computerised. I should think the operations*
> *could be turned over to computers altogether. This sort of environment is made*
> *for artificial intelligence."* (Asimov, 1988)

These two books were originally published in 1986 and 1988, much later than the term "artificial intelligence", which, as I quoted above, was coined and adopted at the Dartmouth Workshop in 1956. It is particularly fascinating that, although he must have known it, the author avoided using the term for 30 years after its publication while he was very much involved in the subject.

In his book The Foundation Edge (Asimov, 1982), about the conscious planet Gaia he envisages, he describes all living and non-living parts of the earth as having some level of consciousness, from the planet's core to the last planetary gas molecule in the stratosphere. Every part of the planet knows its place and its role in its existence. These different levels of consciousness perceive each other and are capable of cooperation and collective action.

In the final volume of the series, he continues to reflect on this theme, framing all his books and short stories around this theme. At the end of The Foundation and Earth (Asimov, 1986), he imagines a galaxy of a community of individual consciousnesses forming a shared consciousness, a galaxy like Gaia, as a pledge of peaceful development and survival.

Asimov's work, almost half a century old, thus goes far beyond the problems of the present and the near future and even more beyond the issues of the present and the near future at the time of its writing.

He saw the dangers of the coexistence of automats and humans, the resulting conflicts, and their effects on the soul and consciousness. He did not foresee the pervasiveness of software and computers, the personal computers and their palm-worn versions, which we still call telephones by their first function, even though that is no longer the primary function for most of us.

But he was perfectly aware that there would come a point when machines would make decisions for people. He was not thinking in terms of predictive text input, spell-checkers, or a program that can write down text after dictation—although anyone who has read the Foundation trilogy will know that Arcadia Darell has a descriptor with such a capability—but of much deeper mechanisms that act in place of humans.

The automated airships operating on Trantor are already taking over human control, although human control can be taken back at any time. It is a bit like the rudimentary semi-autonomous vehicles, automatic emergency brakes, lane-keeping systems, ESP, ABS, and other solutions we use daily in the 21st century.

However, in the 21st century, we are increasingly aware of why Asimov's three laws of robotics should be applied in everyday life.

As a reminder:

- The First Law: A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- The Second Law: A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
- The Third Law: A robot must protect its existence as long as such protection does not conflict with the First or Second Law.

The Three Laws set out philosophical and ethical principles that a moral person should, in principle, adhere to in their own life. However, we must admit this is a romantic view of human beings. Even people who live in the most 'holy' way can occasionally make mistakes.

Of course, one could also consider that the 3 Laws of Robotics mean that individual humans and humanity have no reason to fear artificial intelligence since its basic programming precludes it from posing a threat to humans.

Related to these three is the Law mentioned above Zero, first stated by Daniel Robot Oliwaw in the book Robots and Empire (Asimov, 1985) in the chapter entitled Duel, subchapter 63:

- The Zeroth Law: A robot may not harm humanity or, by inaction, allow humanity to come to harm.

The Zero Law is a complex task with many interdependencies that go far beyond the easy and precise conditions of the first three laws. It has to consider several components that would take considerable time to count.

Asimov was driven to do this by a well-intentioned extreme idealism, somewhat divorced from reality, and a desire to continue the novel's course.

However, it would be good not to be afraid of our machines and their programs, which we create for our own benefit.

3 Asimov's principles and the reality

True, there is no artificial intelligence yet to employ, nor even robots to use them, but there are robots and software that should somehow obey the prohibition in the first turn of the first law.

Even in the absence of robots with artificial intelligence, occupational safety and health regulations are written and operated in the spirit of the first law in the design, installation, operation, and maintenance.

Obstacle detection and avoidance by cleaning robots are also designed to avoid causing injury.

For the same reason, the doors of various household vending machines, washing machines, dishwashers, and dryers cannot be opened during operation. So occupational safety and related contact and fire safety standards comply with the first law.

However, adequate protection has not been established for industrial and household cameras because the makers of the software that accompanies them have not considered the damage that could be caused if care is not taken to ensure that they are not vulnerable or to warn their users.

The fact that some computing and IOT devices may use software that takes random recordings of the user, owner, or others in the vicinity of the software being used, which are stored and transmitted, seems to me to be impermissible.

In any case, software that declares in any small print that it obtains data about its users and uses it later violates the first law of robotics.

So, protecting personal data is as much a part of the First Law as protecting life, physical safety, and health. Even mental health is immediately apparent when developers devise devious identification solutions for viewing certain content and using specific devices not to threaten the user or anyone else.

Unfortunately, we must say that we are fighting to protect personal data with little success.

The first law should also apply to addictive programs or even tools, but there is no sign of any attempt to restrict this, either by the creators of the programs or tools or by the legislators!

How many lives would have been saved if the programs of devices called 'telephones', which sometimes have the power of a computer, had been able to detect that their users were in danger in traffic situations and had stopped or warned them?

We also know of deaths where the person with a substance use disorder has played with toys for days without rest and died of addiction. We all know that members of the various age groups named with different acronyms often experience withdrawal symptoms from their usual devices, even for very short periods. I have heard many times, from many people, the clichéd phrase: "Only the machines can keep them alive!" and let's face it, there is something in it... It causes them apparent psychological damage, so it violates the first law.

Virtual reality devices and their programs can also cause severe defects in people with a substance use disorder.

We have developed several artificial intelligences that, against our will, are watching and betraying us at our expense.

Humankind has also produced several devices that automatically search, detect, identify, and destroy devices, objects, or even people, such as missile systems, the Israeli Merkava Barak tank, drone warfare devices, etc. These are capable of performing operations autonomously with significantly greater efficiency than those that would be conducted under human control alone.

Several programs have been designed and are in operation, using so-called deep fake technology (Economix. hu, 2023), which can produce images (Eisenkrammer, 2023), films (The Guardian, 2023), or even voice mimicry (economics. hu, 2023) of anyone.

Let's see where they are with the ideas of regulation. Based on a report with legal adviser and AI expert Theodore Boone, only one aspect is being examined.

"In its draft AI law - which has not yet been finalised or entered into force but appears to be in the process of being - the EU takes the view that we need to look at the risk posed by different types of AI systems and create three categories of AI systems...

- Low-risk AI systems would be subject to minimal regulation and oversight.

- High-risk AI systems would be subject to significant oversight, transparency, and control requirements.

- Examples of AI systems that could fall into the prohibited category include real-time facial recognition AI technology used in public places. " (Balázs, 2023)

There is no mention of dangerous camel crews, AI-controlled systems capable of waging war, police, and other weapons. If there are any, they are not public principles and in no way conform to Asimovian "laws". Since the study was completed, the European Union has drafted and implemented a Regulation of the European Parliament and of the Council laying down harmonised rules for artificial intelligence (AI legislation) and amending certain EU legislative acts, which is identical word for word to the expert opinion presented (Parliament, 2021).

The US government is not ahead of the curve on this issue. Several directives have been issued by presidential decree, such as Preserving US leadership in AI (Federal Register 2020.), Promoting the use of trusted AI in the federal government, or the Blueprint for an AI Bill of Rights (President of US, 2022) which is a legislative preparatory document that has been in the process of being developed into a usable form since 2020. It should be noted that so far, without success and military, law enforcement applications are exceptions, not included in the intended scope of this legislation. The latest US Presidential Executive Order (Executive order of President of US 2023.) on this subject, issued on 30 October 2023, is the first-ever thorough legislation, full of exceptions for military, intelligence, and criminal purposes. The planned publication of the manual on the use and rules of artificial intelligence (Executive order of President of the US 2023.) is only a draft to be published in a year, according to the Regulation. There are principles in this, too, but they do not even come close to the rigour of Asimov Law 1.

4 Conclusions

Ethical and legal principles and daily practice do not often intersect. As far as I know, there is no code of ethics with uniform criteria for software developers and mechatronic engineers.

Every manufacturer has something that considers the company's point of view and no one else's.

Asimov's Laws, in my judgment, would be ethical and suitable principles for people designing software, hardware, and robots, i.e. devices using artificial intelligence.

Artificial intelligence is a theme in the writings of Asimov's contemporary Stanislaw Lem, and it deserves special attention, but I will write about that next year.

References

Asimov, I. (1956). I, robot. The New American Library.

Asimov, I. (1982). The Foundation's Edge. Doubleday and Co. Inc., Garden City, NY.1982 by Nightfall Inc

Asimov, I. (1986). Foundation and Eart. Doubleday and Comp. Inc. 1986.

Asimov, I. (1988). Prelude to Foundation. 1988 Nightfall Inc

Asimov, I. (1983). The Robots of Dawn. 1983 Doubleday and Comp. Inc. Garden City, New York

Asimov, I. (1985). Robots and Empire. Doubleday edition 1985 by Nightfall Inc.

Asimov, I. (1983). The complete robot. Grafton an Imprint of Harper Collins Publishers 1983

Balázs, R. (2023, September 22). *Jönnek a robotok és velük a rideg valóság, hamarosan lefő a kávé*. Index. Hu. https://index.hu/gazdasag/2023/09/22/interju-mesterseges-intelligencia-theodore-boone-jog-munka-kitoresi-pont-sziget-egeszsegugy-radiologia/

Csányi, V. (2017, April 20). Íme, az ember – Csányi Vilmos etológus az SZTE Mentor(h)áló program-sorozatában. U-Szeged.hu; Szegedi Tudományegyetem. https://u-szeged.hu/sztehirek/2017-aprilis/ime-ember-csanyi-vilmos

Economix. Hu. (2023, September 11). Az AI rátesz egy lapáttal a deepfake-re. Economix.hu; economix.hu. https://www.economx.hu/gazdasag/ai-summit-2023-mesterseges-intelligencia-aczel-petra-deepfake.777185.html

Economics. hu. (2023, August 15). Élő énekesek hangját lopja el dalszerzéshez a mesterséges intelligencia. Economix.hu; economix.hu. https://www.economx.hu/gazdasag/zeneipar-mesterseges-intelligencia-deepfake-jogdij.775804.html

Eisenkrammer, N. (23 C.E., September 20). Az AI sötét oldala: kislányokról generáltak meztelen képeket. Economix.hu; economix.hu. https://www.economx.hu/kulfold/mesterseges-intelligencia-gyermekpornografia-buncselekmeny-spanyolorszag.777630.html?utm_source=index.hu&utm_medium=doboz&utm_campaign=link

Federal Register. (2020, August 12). National Archives Federal Register. Unblock.federalregister.gov. https://www.federalregister.gov/documents/2020/12/08

HVG Kiadó Zrt. (2011, January 27). A robot szó 90 éves. Hvg.hu; HVG Kiadó Zrt. https://hvg.hu/tudomany/20110127_90_eves_robot_szo_capek

Kohda, M., Hotta, T., Takeyama, T., Awata, S., Tanaka, H., Asai, J., & Jordan, A. L. (2019). What are the implications for animal consciousness and self-awareness testing if a fish can pass the mark test? PLOS Biology, 17(2). https://doi.org/10.1371/journal.pbio.3000021

Low, P., Panksepp, J., Reiss, D., Edelmann, D., Van Swinderen, B., & Koch, C. (2012). The Cambridge Declaration on Consciousness. https://fcmconference.org/img/CambridgeDeclarationOnConsciousness.pdf

MIT BME. (2011). 1.3. A mesterséges intelligencia története | Mesterséges Intelligencia Elektronikus Almanach. Project.mit.bme.hu; MIT.BME. http://project.mit.bme.hu/mi_almanach/books/aima/ch01s03

EU Commission. (2021, April 21). az európai parlament és a tanács rendelete a mesterséges intelligenciára vonatkozó harmonizált szabályok (a mesterséges intelligenciáról szóló jogszabály) megállapításáról és egyes uniós jogalkotási aktusok módosításáról. Brussels,; EUROPEAN COMMISSION.

The United States Government. (2023, November 22). *Blueprint for an AI bill of rights*. The White House. https://www.whitehouse.gov/ostp/ai-bill-of-rights/

The Guardian. (2023, August 21). Embrace it or risk obsolescence': how will AI jobs affect Hollywood? Theguardian.com; theguardian.com. https://www.theguardian.com/film/2023/aug/21/ai-jobs-hollywood-writers-actors-strike

HYBRID BUCK-BOOST AC TO DC CONVERTER FOR THE IMPROVEMENT OF PFC AND EFFICIENCY

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Abstract

This paper extensively explores a hybrid buck-boost AC to DC converter with a specific topology and control strategy. These converters play a vital role in transforming AC power to DC power in diverse uses, such as electric cars, sustainable power source systems, and consumer electronics, within the field of power electronics. The buck-boost topology is widely preferred for AC to DC conversion due to its ability to regulate output voltage over a broad range of input voltages.

The proposed topology is a hybrid buck-boost AC to DC converter, which combines the advantages of both buck and boost topologies, leading to improved efficiency, reduced size, and enhanced reliability. This converter comprises a standard DC link capacitor, connecting a series arrangement of a buck converter and a boost converter. By manipulating switch duty cycles in these converters, the output voltage of the hybrid converter can be effectively controlled.

Keywords

A control system, Power factor correction (PFC), power factor and efficiency improvement, DC converters, and Continuous Control Models (CCM).

1 Introduction

The device that converts AC voltage to DC voltage is called a hybrid buck-boost AC to DC converter. This converter incorporates the characteristics of both a buck converter and a boost converter within a single circuit, making it a "hybrid" device. Its primary function is to modify the input voltage to provide a stable output voltage as required. In converter topology, "hybrid" signifies combining two types of converters: the buck converter and the boost converter. This blend aims to capitalise on the strengths of both converters for improved performance and efficiency.

The hybrid buck-boost AC to DC converter finds widespread applications in power sources for electronic devices, battery charging systems, and renewable energy systems like solar and wind power. Its superiority over alternative converter types arises from its adaptability to a wide range of input voltages, exceptional efficiency, and minimal noise output [1][2].

The hybrid buck-boost AC to DC converter's circuitry comprises an output filter, a switching circuit, and an input rectifier. The switching circuit is fed to the pulsing DC voltage

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produced by the rectifier's conversion of the AC voltage. Two power switches (transistors or MOSFETs) are used in the switching circuit, and they alternately operate to control the voltage level. The output filter receives the input voltage during the activation of the switches. In contrast, the energy stored in the inductor and capacitor of the filter is utilised to uphold the output voltage during the deactivation of the switches [3][4].

The output filter is crucial in mitigating high-frequency disturbances or fluctuations from the signal and achieving a refined output voltage. Generally, it comprises a series of capacitors and an inductor connected in line with the load.

In summary, the hybrid buck-boost AC to DC converter is a versatile and efficient power converter widely used in various applications. It combines buck and boost conversion capabilities within a single circuit, comprising an input rectifier, switching circuits, and output filters. One notable advantage is its ability to maintain a stable output voltage even when dealing with significant input voltage fluctuations, achieved by raising and lowering the input voltage [5]. Compared to other converters, it offers high efficiency by eliminating the need for a transformer and employing efficient switching circuits [5][6]. Its compact size and lightweight design make it ideal for applications with space and weight constraints, such as portable electronic devices and automotive systems.

2 Proposed circuits for ac-dc converters

2.1 Buck-boost converter

Traditional AC-DC converters like buck, boost, buck-boost, Cuk, SEPIC, and Zeta face limitations in generating the required voltages for modern applications [7]. As the trend shifts toward microprocessors operating on lower voltages (1V to 3V), minimising CPU power loss is essential [8][9]. Researchers are exploring voltage regulators tailored to meet the 1V supply demands of microprocessors capable of handling high load currents and rapid dynamics, although further advancements are required [10][11]. Switched-capacitor converters introduced in the 1990s had high conversion ratios but suffered from low efficiency. While connecting multiple circuits in series, Cascade converters don't effectively address efficiency concerns, as their overall efficiency is a sum of individual circuit efficiencies. To address efficiency issues, individually operated transistors in quadratic power converters have been proposed, although challenges related to voltage and current overstress remain [12][13][14].

This research presents an innovative approach using dual structures, including a configuration with two capacitors and two to three diodes or two to three inductors and two to three diodes. These circuit blocks effectively enable voltage step-down or step-up operations [15][16]. By incorporating these structures into a conventional buck-boost converter, it's possible to achieve a significant voltage conversion ratio while retaining the benefits of topological converters. Importantly, this approach eliminates common drawbacks associated with such conversions [17][18].

During the active switch state of the converter, the capacitors within the C-switching blocks discharge in a parallel configuration. Conversely, when the active switch is deactivated, the capacitors in the C-switching blocks accumulate charge in a series configuration. The innovative converter presented in this study exhibits an enhanced capability to step down the line voltage compared to the traditional buck-boost structure [19]. This is evident in its voltage gain formula,

$$\frac{V_O}{\text{Sinwt } V_{in}} = -\frac{D}{(1-D)(2-D)} \quad (1)$$

Where, D: Duty cycle, Vo: Output voltage, Vin: Input voltage.

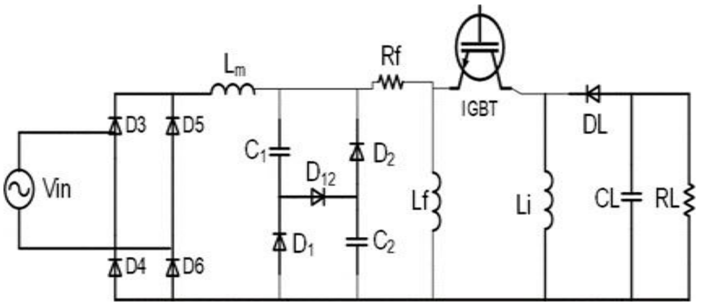
D): This refers to the classical model of the buck-boost converter.

D): This refers to the new value that appears due to the proposed model of the buck-boost converter, which improves the efficiency and PFC.

2.2 Hybrid buck-boost converter topology

This topology introduces a single switching capacitor and closed-loop networks [20]. It offers the advantage of a bridge rectifier configuration without a transformer, reducing equipment costs and weight. Additionally, the suggested topology eliminates hysteresis and potential energy losses associated with transformer magnetisation, leading to anticipated improvements in overall operation efficiency.

Fig. 1 Switched capacitor network with a single tier.



2.3 Functioning principles of the proposed model

Throughout the positive and negative half cycles, as shown in Fig. 2 and Fig. 3, respectively, the charging operation of the buck-boost inductor Li and output capacitor CL is facilitated by the switched capacitors C1 and C2. In the positive half cycle, these capacitors are connected in parallel due to the reverse bias of D12 and the forward bias of D1 and D2. Consequently, they charge with half of the DC link voltage. Conversely, in the negative half cycle depicted in Fig. 3, C1 and C2 are connected in series with the DC link voltage, thanks to the positive bias of D12. Furthermore, the freewheeling diode DL allows the buck-boost inductor Li to maintain a continuous current flow, supplying current and charging the output capacitor CL. The ripples are minimised by adding the high pass filter, which improves the circuit RF and LF output.

Fig. 2 Network during the positive phase

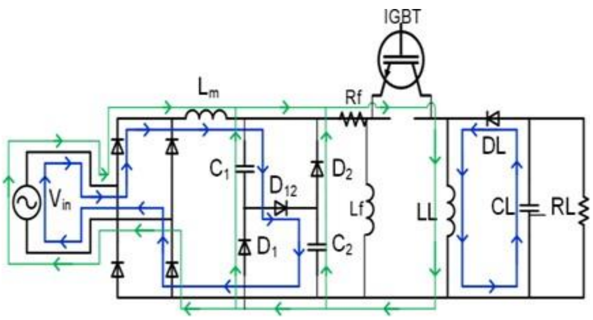
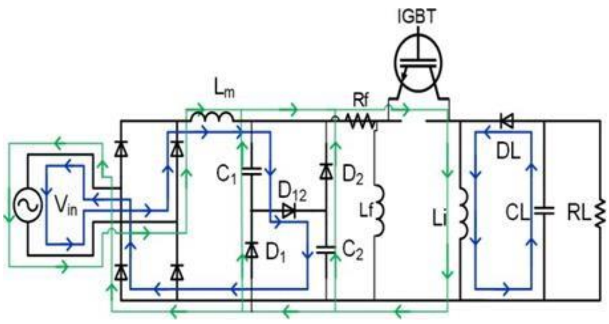


Fig. 3 Network during the negative phase

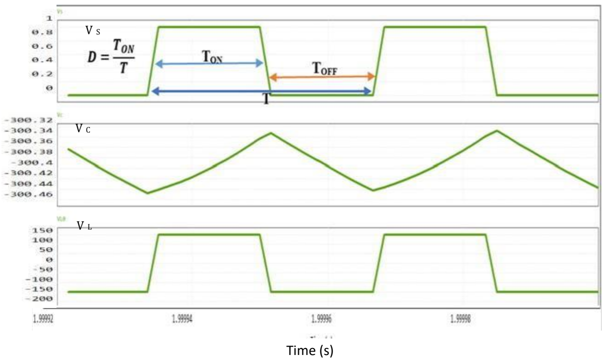


3 Analysis of buck-boost AC to DC converter

3.1 Functioning principles of the proposed model

The suggested converter's voltage amplification can be derived by considering the volt-sec equilibrium across the actors during each cycle of the switching frequency.

Fig. 4 Evaluation of VC and VL as time intervals



According to Fig. 4, the D depends on the period to the total time of the intervals of the PWM passing through the IGBT switch; therefore, the details of the theoretical part of the model depend upon those intervals.

Here is a detailed breakdown of the step-by-step evaluation of the voltage gain.

When T is on,

$$V_{Lm} = V_{in} - V_{L0}$$

$$V_{L0} = V_C$$

$$\therefore V_{Lm} = V_{in} - V_C$$

When T is off,

$$V_{Lm} = V_{in} - 2V_C$$

$$V_{L0} = V_O$$

In steady state, the average inductor voltages V_{L1} and V_{L2} are zero. So we can write,

$$\int_0^T V_{Lm} dt = 0$$

And,

$$\int_0^T V_{L0} dt = 0$$

Now,

$$\int_0^T V_{Lm} dt = 0$$

$$=> \int_{0}^{T_{ON}} (V_{in} - V_C)dt + \int_{T_{ON}}^{T} (V_{in} - 2V_C)dt = 0$$

$$=> (V_{in} - V_C)[t]_0^{T_{ON}} + (V_{in} - 2V_C)[t]_{T_{ON}}^{T} = 0$$

$$=> V_{in}T = V_C(2T - T_{ON})$$

$$=> V_C = \frac{V_{in}T}{(2T - T_{ON})}$$

$$=> V_C = \frac{V_{IN}}{2\frac{T}{T} - \frac{T_{ON}}{T}}$$

$$\therefore V_C = \frac{V_{in}}{(2 - D)} \quad (2)$$

And,

$$\int_{0}^{T} V_{Lo}dt = 0$$

$$=> \int_{0}^{T_{ON}} V_C dt + \int_{T_{ON}}^{T} V_O dt = 0$$

$$=> V_C \int_{0}^{T_{ON}} 1\,dt + V_O \int_{T_{ON}}^{T} 1\,dt = 0$$

$$=> V_C[t]_0^{T_{ON}} + V_O[t]_{T_{ON}}^{T} = 0$$

$$=> V_C T_{ON} + V_O T - V_O T_{ON} = 0$$

$$=> V_C = -V_O\left(\frac{T}{T_{ON}} - \frac{T_{ON}}{T_{ON}}\right)$$

$$=> V_C = -V_O\left(\frac{1}{D} - 1\right)$$

$$=> V_C = -V_O\left(\frac{1 - D}{D}\right)$$

$$\therefore V_C = -V_O\frac{(1 - D)}{D} \quad (3)$$

From Eq. (2) and (3), we get the voltage gain as follows,

$$=> -V_O\frac{(1 - D)}{D} = \frac{V_{in}}{(2 - D)}$$

$$\therefore \frac{V_O}{V_{in}} = -\frac{D}{(1 - D)(2 - D)} \quad (4)$$

The duty cycle (D) is of utmost importance in the proposed buck-boost converter as it dictates the switching component's ON and OFF times. Conversely, in a classical buck-boost converter, the voltage gain is mathematically represented as follows,

$$\frac{Vo}{Vin} = -\frac{D}{(1-D)} \tag{5}$$

The duty cycle (D) is pivotal in the conventional buck-boost converter scenario. A comparison of Eq. (4) to Eq. (5) reveals an additional denominator factor in Eq. (4), specifically (2-D). Since the duty cycle falls within the $0 < D < 1$ range, the expression (2-D) consistently exceeds one. This signifies that the proposed converter has a greater capacity to reduce voltage than the classical buck-boost converter.

3.2 Efficiency assessment

The efficiency of our suggested converters can be mathematically described in the following manner:

$$\eta = \frac{Po}{Pin} = \frac{Vo}{|Vin|}\frac{(1-D)(2-D)}{D} \tag{6}$$

The efficiency of the conventional buck-boost converter can be expressed as follows:

$$\eta_C = \frac{Po}{Pin} = \frac{Vo}{|Vin|}\frac{(1-D)}{D} \tag{7}$$

Comparing (6) and (7), we got

$$\eta = \eta_C(2-D) \tag{8}$$

Because the equation of (2 - D) is consistently higher than one, the efficiency of our proposed converters surpasses that of the conventional buck-boost converter for all duty cycle values.

4 Simulation and results

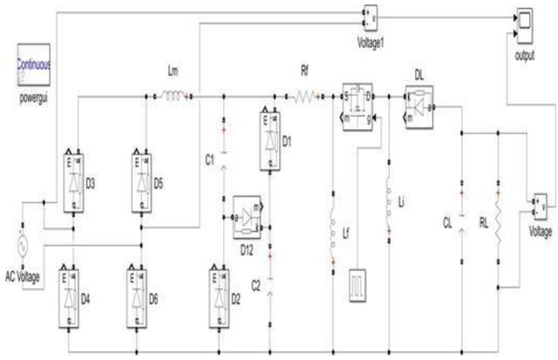
4.1 Efficiency assessment

Several simplifying assumptions were employed to aid theoretical analysis. These assumptions include ideal component behaviour, simplifying the input voltage waveform as a rectified sinusoid, and using a large output capacitor to treat the output voltage as a pure DC source, reducing ripple effects. The buck-boost and conventional converter were simulated using MATLAB with the provided data parameters.

Table 1 Components used for the Proposed Model

Components	***Symbols***	***Values***
Inductors	Lm Li	$1 * 10^{-3}H$ $0.88 * 10^{-3}H$
Capacitors	CL C1 C2	$6 * 10^{-6}\ F$ $5 * 10^{-6}F$ $5 * 10^{-6}F$
Resistor	R	500Ω

Fig. 5 Simulink of Buck-Boost AC to DC Converter



4.2 Output voltage waveshape for different duty cycles

A buck-boost converter is a DC-DC converter that adjusts output voltage based on the duty cycle (D) of the switch:

D < 0.5: Lower output voltage, square wave.

D = 0.5: Output matches input, constant voltage.

D > 0.5 but < 1: Higher output voltage, square wave.

D = 1: Inverted output voltage, constant negative voltage.

These properties enable precise output voltage control for different applications.

Fig. 6 Output at Duty 70%

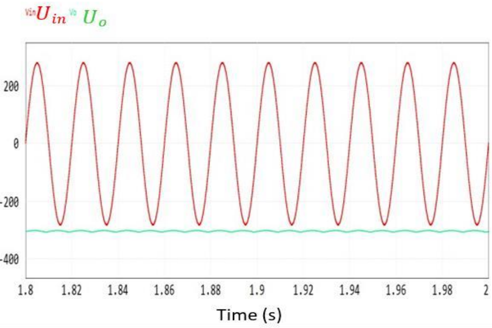
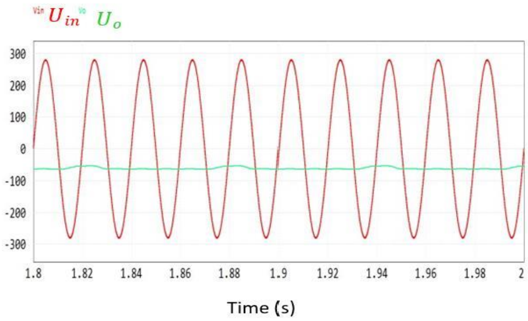


Fig. 7 Output at Duty 40%



Referring to Fig. 6, the output voltage exceeds the input voltage, while in Fig. 7, a duty cycle below 50% results in an output voltage lower than the input voltage. I apologise for any prior confusion, and these figures visually confirm that a duty cycle below 50% leads to a lower output voltage than the input voltage.

4.3 Efficiency, input power factor, and THD comparison

Our proposed topology, as illustrated in Figs. 8, 9, and 10 outperform the classical buck-boost converter on multiple fronts. It features an efficient arrangement utilising transformerless bridge rectifiers to minimise hysteresis reduction and magnetization-induced energy loss, Resulting in superior efficiency. Additionally, it incorporates an input inductor and a switched capacitor network to establish an L-C input filter during each half cycle of operation, significantly improving both the power factor and reducing Total Harmonic Distortion (THD) in the input current compared to the conventional buck-boost converter.

Fig. 8 Efficiency Comparisons

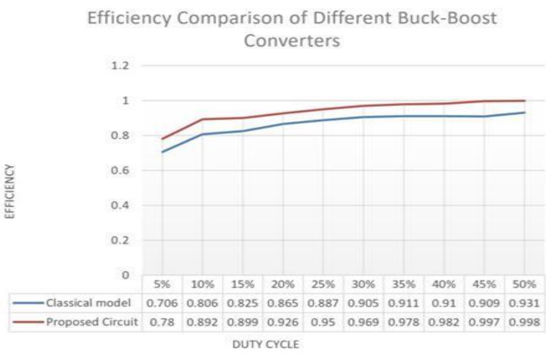


Fig. 9 Input PF Comparison

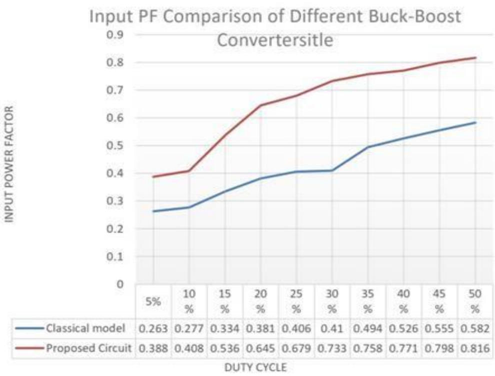
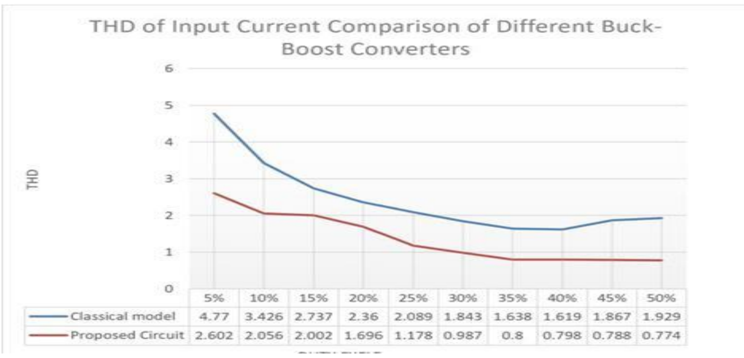


Fig. 10 THD of input current comparison of different buck-boost converters



4.4 Summary of simulation results of the new design of the proposed topology

Upon conducting simulations for the new circuit design of the Buck-boost AC-DC converter, utilising specific parameters derived from the formula of the proposed converter and implementing filters to mitigate output voltage ripples, our results are summarised in Table 2 compared to the other papers. The primary objective of this design is to enhance Power Factor Correction (PFC). This type of converter exhibits the potential for further improvements by applying various filter types, which is a distinctive advantage. This versatility renders the converter applicable in a wide array of scenarios. Notably, this converter finds utility in controlling DC machine operations, regulating vehicle speeds, and devising battery charging systems. These avenues for application delineate the trajectory of our future work.

Table 2 Research Summary and Review

Ref.	**Years**	**Efficiency At D=50%**	**PFC At D=50%**	**THD At D=50%**
[19]	2017	97.8.1%	80.2%	70.3%
[20]	2015	99.7%	-	-
Our research	2023	99.8%	81.6%	77.4%

As highlighted in the research summary and review, when we compare our results to what other studies have found, we see a clear chance to make things work even better. We reached a perfect efficiency score of 99.8% at the start using our methods, specific parameters and R-L high pass filter. However, there is still potential for further improvement, highlighting the benefits of utilising this type of converter. Also, our way of doing things helps to make Power Factor Correction (PFC) better and simultaneously reduces Total Harmonic Distortion (THD).

5 Conclusion

A standard option for many AC-to-DC conversion applications, the hybrid buck-boost AC-to-DC converter has several advantages. Over a wide variety of input voltages, it can reliably and efficiently supply a regulated DC output voltage. Additionally, the converter is expandable, enabling it to manage various power levels and deliver superior power factor correction. Despite being more expensive, the hybrid buck-boost AC to DC converter may have a cheaper overall cost of ownership throughout the product's lifetime. For designers and manufacturers searching for an influential and trustworthy AC-to-DC converter, it is thus a flexible and enticing solution. The paper shows that we can improve upon previous findings.

We achieved a high 99.8% efficiency using specific parameters and filters. However, there is potential for further improvement. Our success is due to the methods and filters that enhance Power Factor Correction (PFC) and reduce Total Harmonic Distortion (THD).

Resources

[1] Kassakian, J., M. Schlecht, and G. Verghese. "Principles of Power Electronics.Wesley."Reading (1991). https://vdoc.pub/documents/dynamics-and-controlof-switched- electronic-system.

[2] Acikgoz, H., Kale, G., Kececioglu, O. F., Gani, A., & Sekkeli, M. (2015, November). Performance analysis and design of robust controller for PWM rectifier. In 2015 9th International Conference on Electrical and Electronics Engineering (ELECO) (pp. 1201-1206) IEEEhttps://www.ceeol.com.

[3] Abu-Qahouq, Jaber, Hong Mao, and Issa Batarseh. "Multiphase voltage-mode hysteretic controlled DC-DC converter with novel current sharing." IEEE Transactions on Power Electronics19.6(2004)1397-1407. https://www.researchgate.net/publication/3280625_Multiphase_Votahes.

[4] Sinha, A., Jana, K. C., & Das, M. K. (2018). An inclusive review of different multi-level inverter topologies, their modulation and control strategies for a grid-connected photovoltaic system. Solar Energy, 170,633-657. https://doi.org/10.1016/j.solener.2018.06.001.

[5] Mumtaz, F., Yahaya, N. Z., Meraj, S. T., Singh, B., Kannan, R., & Ibrahim, O. (2021). Review on non-isolated DC-DC converters and their control techniques for renewable energy applications. Ain Shams Engineering Journal, 12(4), 3747-3763. https://doi.org/10.1016/j.asej.2021.03.022

[6] Da Silva, Edison RC, and Malik E. Elbuluk. "Fundamentals of power electronics." Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of

Topologies, Control and Integration. London: Springer London, 2013. 7-59. http://download.ebookshelf.de/download/0003/9497/94/L-G- 0003949794-0013321462.

[7] Wei, W., Hongpeng, L., Shigong, J., & Dianguo, X. (2008, June). A novel bridgeless buck-boost PFC converter. In 2008 IEEE Power Electronics Specialists Conference (pp. 1304-1308). IEEE. https://doi.org/10.1109/PESC.2008.4592112

[8] Heterogeneous Integration Roadmap Edition Chapter 10IntegratedPowerElectronics2021. https://eps.ieee.org/images/files/HIR_2021/ch10_power.pdf

[9] Kazimierczuk, M. K. (2015). Pulse-width-modulated DC-DC power converters.JohnWiley&Sons.https://www.google.fr/search?tbo=p&tbm=bks&q=inauthor:%22M arian+K.+Kazimierczuk%22

[10] Kazimierczuk, M. K. (2012). Small-signal modelling of open-loop PWM Z-source converter by circuit-averaging technique. IEEE Transactions on Power Electronics, 28(3), 1286-1296. https://doi.org/10.1109/TPEL.2012.2207437

[11] Hareland, Scott, et al. "Impact of CMOS process scaling and SOI on the soft error rates of logic processes." 2001 Symposium on VLSI technology. Digest of technical papers (IEEE Cat. No. 01 CH37184). IEEE, 2001. https://link.springer.com/chapter/10.1007/978-37091-6244-6_62.

[12] J. Wei, P. Xu, H. Wu, F. C. Jee, K. Yao, and M. Ye, "Comparison of three topology candidates for 12V VRM," in Proc. IEEE Appl. Power Electron. Conf. (APEC), 2001, pp. 245–251. http://103.82.172.44:8080/xmlui/handle/123456789/275?show=full

[13] L. Huber and M. M. Jovanovic´, "A design approach for server power supplies for networking," in Proc. IEEE Appl. Power Electron. Conf. (APEC), 2000, vol. 2, pp. 1163–1169. https://www.mdpi.com/2079-9292/9/1/31.

[14] Priyadarshini, D., & Rai, S. (2014). Design, model and simulate a PID controller for buck-boost and Cuk converter. International Journal of Science and Research (IJSR),3(5). http://www.ijsr.net/

[15] Rezaei, I., & Akhbari, M. (2011, February). Transformerless hybrid buck converter with wide conversion ratio. In 2011 2nd Power Electronics, Drive Systems and Technologies Conference (pp. 599-603).IEEE. https://www.semanticscholar.org/paper/ Transformerlesshybrid-buck-converter-with-wide-Rezaei

[16] J. Wie and F. C. Lee, "Two novel soft-switched high-frequency, high efficiency, nonisolated voltage regulators-the phase-shift buck converter and the matrix-transformer phase-buck converter," IEEE Trans. Power Electron., vol. 20, no. 2, pp. 292–299, Mar. 2005. https://doi.org/10.1109/TPEL.2004.843014

[17] Kathi, L., Ayachit, A., Saini, D. K., Chadha, A., & Kazimierczuk, M. K. (2018, February). Open-loop small-signal modelling of cuk DC-DC converter in CCM by circuit-averaging technique. In 2018 IEEE Texas Power and Energy Conference (TPEC) (pp. 1-6). IEEE. https://doi.org/10.1109/TPEC.2018.8312045

[18] A. Ioinovici, “Switched-capacitor power electronics circuits,” IEEE Circuits Syst. Mag., vol.1, no.1, pp. 37–42, Jan. 2001. https://ieeexplore.ieee.org/iel7/63/9780877/09748987.pdf

[19] Saifullah, Khalid, et al. "Bridgeless AC-DC buck-boost converter with a switched capacitor for low power applications." TENCON 2017-2017 IEEE Region 10 Conference. IEEE, 2017. https://doi.org/10.1109/TENCON.2017.8228143

[20] Golam Sarowar, Md. Ashraful Hoque, High-Efficiency Single Phase Switched Capacitor AC to DC Step Down Converter, Procedia - Social and Behavioral Sciences, Vol. 195, 2015, pp. 2527-2536, https://doi.org/10.1016/j.sbspro.2015.06.437.

PROJECT-BASED EDUCATION IN SIMULATION AND MANAGEMENT OF PRODUCTION

Zuzana Červeňanská[5], Janette Kotianová

Abstract

The contribution presents an approach to implementing project-based education supported by simulation software into the educational process of two related subjects involved in engineering study in the field of applied informatics provided by the Slovak University of Technology. We bring observations and experiences using this method in teaching the management of production systems, which develops the knowledge and skills obtained in the previous course on modelling and simulation of systems. Both subjects aimed to utilise the simulation approach in the modelling and optimising systems for production systems management. The framework we work within employs a lot of interdisciplinary relationships and knowledge relating to programming, system design, operational research, production logistics, and production management.

Considering this, project-based education is a natural choice in this area as an alternative to traditional educational methods. The task within the project is focused on designing and creating a production system model to meet all capacity requirements and optimising output parameters from the point of view of production indicators. After being familiar with the theoretical principles and methods at the beginning of the term, students can apply them in practice when solving a project task with the individual assistance of the teacher, if necessary.

Keywords

Project-based education, simulation, optimisation, production management

1 Introduction

Innovative alternative methods and digital technologies adopted for the educational process make learning more enjoyable for students and, in specific directions, can be more effective than traditional ones. Game-based learning (Backlund &Hendrix, 2013; Wiggins, 2016; Sun et al., 2021; Wang et al., 2023), virtual reality-based learning (Kavanagh et al., 2017; Kaplan-Rakowski & Gruber, 2021) or project-based learning (Mettas &Constantinou, 2008; Mioduser &Betzer, 2008; Pérez & Rubio, 2020) belongs to the most popular. They attract the attention of researchers to investigate the most effective way and how to use it in education.

All of the above methods support intensive computational thinking (CT) education. The simulation approach in modelling demands entirely developed CT skills, such as abstract thinking, logic, coding, and logical reasoning (Angeli & Giannakos, 2020).

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1.1 Game-based learning

In improving CT via education, game-based learning (GBL) can play a significant role (Hooshyar et al., 2021). Lu et al. (Lu et al., 2023), Wang et al. (Wang et al., 2023), and Sun et al. (Sun et al., 2021) introduced the results of the meta-analysis and systematic review related to the impact of educational games and game-based learning on students' computational thinking. A similar topic for higher education is studied in the work of Wiggins (Wiggins, 2016).

Udeozor et al. (2023) state that " digital games can immerse learners in simulated real-world environments that foster contextualised and active learning experiences." However, they mention the challenges of applying computer games to assessment. Their work presents a game-based assessment framework for designing assessments for immersive learning environments.

1.2 Virtual reality-based learning

From a perspective point of view, employing virtual reality-based learning in education (VRL) also disposes of substantial opportunity for the enhancement of students' motivation, transfer of knowledge, and development of skills, e.g. in the course of the design of the manufacturing system (Ma et al., 2018), or in special medical training (Pulijala, 2018). In addition, the VRL course content management system powered by artificial intelligence (AI) seems promising for effective personalised, competency-based, and differentiated learning (Zou, 2021). Online learning platforms use AI to measure students' skill sets, capabilities, and interests before recommending the most contextual course content (Roll & Wylie, 2016).

1.3 Project-based learning

Comparing innovative learning methods to traditional ones, according to Helm and Katz (Helm & Katz, 2001), students learn best in informal and interactive situations. This is the substantial attribute of project-based learning (PBL), which can be defined as a student-oriented approach in pedagogy. It encompasses a dynamic classroom work that is assumed to offer students more profound knowledge and skills via active solving of real-world problems.

The main advantage of this alternative method is that it can be a source of joy from discovering knowledge and achieving understanding, which is internally understood as success. Both feelings create a high intrinsic motivation, which is crucial for learning. Also, individual work or work within small teams develops creativity and soft skills (Yasseri et al., 2018).

The application of PBL is widespread, mainly in subjects where the complex overlap of many different areas can be identified. Children can use this method in its simplest form already at elementary school, and a more advanced approach grounded on deeper interdisciplinary relationships and solving complex problems appears in subsequent high school and university studies.

Experiences published in the literature indicate that courses focused on education in fields related to nature, life sciences, and technical subjects have a great potential to invoke more profound interest and curiosity when applying project-based learning. Notable results were observed in acquiring knowledge and skills when applying PBL for education in physics (Holubova, 2008), bioinformatics laboratory courses (Achappa et al., 2020), and design and software engineering (Pérez & Rubio, 2020) concerning university courses. PBL was also successfully applied in teaching molecular biology (Elsamanoudy et al., 2021) or in introductory biology (Burks, 2022).

2 Project-based learning in the education of technical subjects of engineering degree related to simulation and management of manufacturing systems

Manufacturing system design and management of production are related complex engineering areas with the need for cooperated and collected multiple-disciplinary theoretical and practical assistance. Sometimes, it can be challenging for learners to fully understand topics in this field, such as context and relationships. Concerning the experience presented in the literature, PBL implementation provides many opportunities to improve acquiring knowledge with relationships and better insight into the studied subject.

Abella´n-Nebot (Abella´n-Nebot, 2020) proposed a PBL approach with actual manufacturing activities in a four-year mechanical engineering course to improve the learning process. The project focused on planning the manufacturing process of a natural part and performing all the activities required directly on the shop floor to solve authentic real practice problems.

In Serdar's work (Serdar, 2015), the experience and teaching results of PBL implementation in the Manufacturing Processes Course were presented. He mentioned that many manufacturing courses provided students with technical information, but it had to be transformed into appropriate knowledge for actual practice. The goal of design projects was to define a product design through the identification of potential combinations of materials and processes that could generate the desired shapes with the required properties, all this by redesigning an originated existing part.

Pérez and Rubio (Pérez & Rubio, 2020) presented a project-based learning (PBL) experience in a software engineering program at a Spanish university. The work was organised in small, heterogeneous teams. The challenge for students was to solve a software project similar to a real one. Students work on different tasks throughout the project via the strategy of role rotation and documentation transfer.

This contribution demonstrates the implementation of project-based learning into the educational process within two compulsory subjects of a technical focus, which are part of studies of engineering degrees in the 1st and 2nd year for selected fields of study. The subjects Modeling and Simulation of Systems (MSS) and Management of Production Systems (MPS) follow each other smoothly, and all seminars are fully supported by the computer using simulation software Witness Horizon and Excel spreadsheet.

3 Design and implementation of project-based learning and its results

3.1 Modeling and Simulation of Systems (MSS) course

In the MSS course, the first nine weeks of the term were devoted to understanding the essence of critical concepts and their relationships in the field of modelling and simulation of various types of systems and, at the same time, to acquiring skills in work with the software Witness in which we created simulation models. We mixed traditional lectures to explain the new and unknown and seminars based on interactivity with two-way feedback, which controls the learning tempo according to the student's capabilities.

After mastering the creation of simulation models, students learned to analyse the modelled system, experimented with its parameters, and assessed its behaviour and outputs in simulation experiments. In the last four weeks of the term, project-based learning was applied. Each student worked independently on a given complex problem task at his tempo. When solving this, the teacher assisted and appreciated creativity, critical and analytical thinking, and an innovative approach.

3.2 Management of production systems (MPS) course

The MPS course builds on the knowledge and skills acquired in the MSS. Although it is comprehended in a certain sense, more specifically at first sight, because it concentrates on the optimisation of production systems within the framework of systems management, it comprises other interdisciplinary relationships and knowledge from the fields of system design, production logistics, operational research, and production management. With this in mind, project-based learning is directly offered for education.

The student's task is to design and create a model of a flexible production system according to capacity requirements and to optimise its output parameters. At the beginning of the term, after students become familiar with the theoretical principles and methods of designing such systems, they can apply them practically when solving a project task. They learn to experiment, analyse relationships between variables, interpret data, draw conclusions, and share knowledge. They also apply all knowledge and programming skills originated from previous MSS courses.

3.3 The role of the teacher

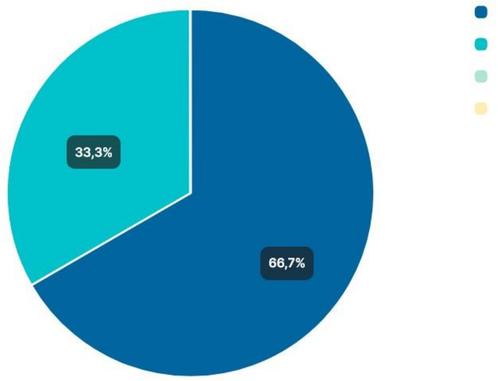
The teacher works individually with everyone and guides him/her according to the project's actual status. The teacher also prepares materials for individual self-study and explains the basic principles and ideas applicable to all students regardless of the specification of individual tasks, if necessary.

The quality of project results depends on the student´s creativity, internal motivation, patience, and ability to observe, analyse, and evaluate. Communication skills and precise formulation of thoughts are also important for successfully achieving the project goals.

3.4 Feedback – students

For students´ feedback, we created a short questionnaire about learning experiences and self-study materials. The student´s reflection (21 respondents) was primarily positive; they considered both subjects interesting and liked learning them independently. They appreciated the possibility of proceeding at an individual tempo and the teacher's and their mates' support. They also valued the freedom to manifest their creativity in solving project problems. The feedback related to selected responses is depicted in Fig. 1 and Fig. 2, resp.

Fig. 1: Student´s feedback on a way of acquiring information in both courses

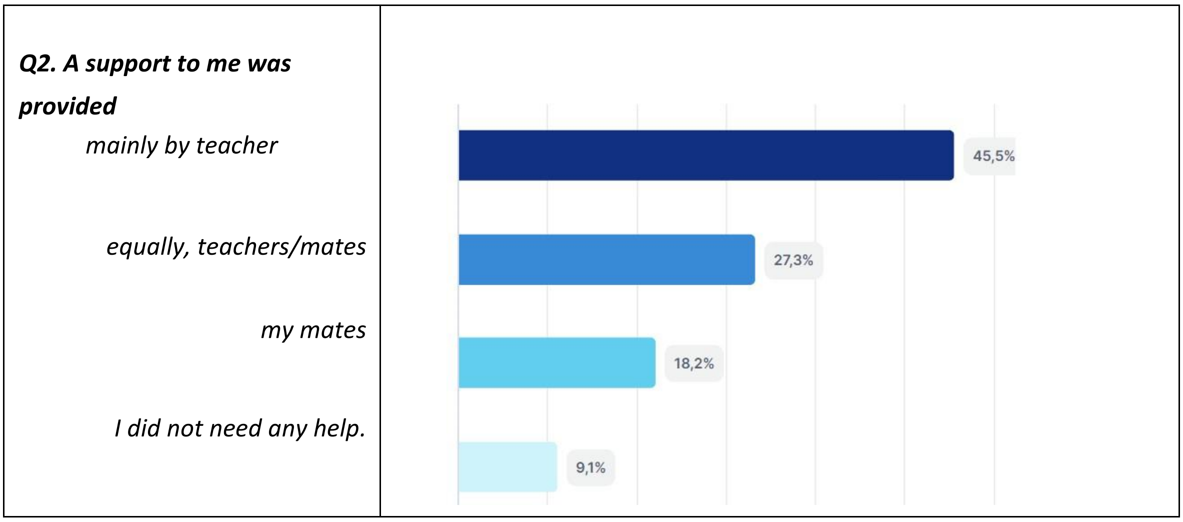


Q1: Comparing the form of teaching the subjects Modeling and simulation of systems and Management of production systems, please evaluate both subjects in terms of gaining new knowledge and experience:

- *I evaluate the approach more positively through individual project solutions applied in the Management of production systems.*
- *I evaluate both subjects equally in terms of the effectiveness of obtaining information.*
- *It is more convenient for me to obtain information through explanations and examples of the solution, as was applied in the subject Modeling and simulation of systems.*
- *Another answer*

Source: Authors

Fig.2: Reflexion based on student´s feedback on a needed assistance



Source: Authors

3.5 Feedback – teacher:

The most appreciated feature of project-based learning from the teacher´s point of view was to observe the students´ creativity and the opportunity to learn something new from them when the unique solution or procedure was introduced. The teacher also ensured a more pleasant and informal environment and built better relations between him/her and their students.

On the other hand, much information had to be often repeated because the progress in the project was at a different level, and a specific need for assistance in solving the same partial problem appeared repeatedly.

4 Conclusion

Experience with implementing project-based learning in subjects focused on simulation and management of production shows the effectiveness of combining lectures and the project approach. Based on students´ predominantly positive feedback, we find it essential that if work is appropriately supported by teacher assistance, this student-oriented approach generates an increase in satisfaction and more profound interest and develops the ability to think independently and work creatively, individually, and in small teams. In the future direction, we would like to employ virtual reality elements in designing a project task.

5 Acknowledgements

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Resources

Abella´n-Nebot J.V. (2020). Project-based experience through real manufacturing activities in mechanical engineering. *International Journal of Mechanical Engineering Education* 2020, Vol. 48(1), 55–78. https://doi.org/10.1177/0306419018787302

Achappa, S., Patil, L. R., Hombalimath, V. S., & Shet, A. R. (2020). Implementation of project-based learning (PBL) approach for bioinformatics laboratory course. *Journal of Engineering Education Transformations*, 33(Special Issue), 247–252. https://doi.org/10.16920/jeet/2020/v33i0/150154

Angeli C., Giannakos M. (2020). Computational thinking education: Issues and challenges. *Computers in Human Behavior*, 105. https://doi.org/10.1016/j.chb.2019.106185

Backlund P., Hendrix M. (2013). Educational games - are they worth the effort? A literature survey of the effectiveness of serious games. *5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, 1–8. IEEE. https://doi.org/10.1109/VS-GAMES.2013.6624226

Burks, T. N. (2022). Improving student attitudes and academic performance in introductory biology using a project-based learning community. *Journal of Microbiology & Biology Education*, 23(1), 1–9. https://doi.org/10.1128/jmbe.00216-21

Elsamanoudy, A. Z., Fayez, F. Al, Alamoudi, A., Awan, Z., Bima, A. I., Ghoneim, F. M., & Hassanien, M. (2021). Project-based learning strategy for teaching molecular biology: A study of students' perceptions. *Education in Medicine Journal*, 13(3), 43–53. https://doi.org/10.21315/eimj2021.13.3.5

Helm, J. H.& Katz, L. G. (2001). Young Investigators: The Project Approach in the Early Years (Early Childhood Education Series) 3rd ed. *New York: Teachers College Press.* ISBN-13: 978-0807756904

Holubova R. (2008). Effective teaching methods – project-based learning in physics. *USChina Education Review*, 5(12), 27–35. ISSN 1548-6613.

Hooshyar D., Pedaste M., Yang Y., Malva L., Hwang G. J., Wang M., Lim H., Delev D. (2021). From gaming to computational thinking: An adaptive educational computer game-based learning approach. *Journal of Educational Computing Research*, 59(3), 383– 409. https://doi.org/10.1177/0735633120965919

Kaplan-Rakowski, R., & Gruber, A. (2021). One-on-one foreign language speaking practice in high-immersion virtual reality. In Y. J. Lan & S. Grant (Eds.), *Contextual language learning—Real language learning on the continuum from virtuality to reality.* 187–202. Springer. https://doi.org/10.1007/978-981-16-3416-1

Kavanagh, A. Luxton-Reilly, B. Wuensche, & B. Plimmer (2017). A systematic review of virtual reality in education. *Themes in Science and Technology Education*, 10(2), 85–119. ISSN-1792-8788

Lu Z., Chiu M. M., Cui Y., Mao W., Lei H. (2023). Effects of game-based learning on students' computational thinking: A meta-analysis. *Journal of Educational Computing Research*, 61(1), 235–256. https://doi.org/10.1177/07356331221100740

Ma, J., Jaradat, R., Ashour, O., Hamilton, M., Jones, P., & Dayarathna, V. L. (2018). Efficacy Investigation of Virtual Reality Teaching Module in Manufacturing System Design Course. *ASME. J. Mech. Des.* 141(1). https://doi.org/10.1115/1.4041428

Mettas, A. C., & Constantinou, C. C. (2008). The technology fair: A project-based learning approach for enhancing problem-solving skills and interest in design and technology education. *International Journal of Technology and Design Education*, 18, 79–100. ISSN-0957-7572

Mioduser, D., Betzer, N. (2008). The contribution of project-based learning to high achievers acquisition of technological knowledge and skills. *International Journal of Technology and Design Education* 18, 59–77. https://doi.org/10.1007/s10798-006-9010-4

Pérez B. & Rubio Á. L. (2020). A Project-Based Learning Approach for Enhancing Learning Skills and Motivation in Software Engineering. *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, 309–315. https://doi.org/10.1145/3328778.3366891

Pulijala, Y., Ma, M., Pears, M., Peebles, D., & Ayoub, A. (2018). Effectiveness of immersive virtual reality in surgical training-A randomised control trial. *Journal of Oral and Maxillofacial Surgery*, 76(5), 1065–1072. ISSN-0278-2391. https://doi.org/10.1016/j.joms.2017.10.002

Roll, I., Wylie, R. (2016). Evolution and Revolution in Artificial Intelligence in Education. *International Journal of Artificial Intelligence in Education* 26, 582–599. https://doi.org/10.1007/s40593-016-0110-3

Serdar, T. (2015). Project-based Learning in Manufacturing Processes Course. Paper presented at *ASEE Annual Conference & Exposition*, *Seattle*, *Washington*, 2015. pp 26.1267.1 - 26.1267.9. ISSN-2153-5965. https://doi.org/10.18260/p.24604

Sun L., Guo Z., Hu L. (2021). Educational games promote the development of students' computational thinking: A meta-analytic review. *Interactive Learning Environments*, 1–15. https://doi.org/10.1080/10494820.2021.1931891

Udeozor Ch., Abegão F. R., Glassey J. (2023). Measuring learning in digital games: Applying a game-based assessment framework. *British Journal of Educational Technology*, 00:1–35. https://doi.org/10.1111/bjet.13407

Wang, X., Cheng, M., & Li, X. (2023). Teaching and Learning Computational Thinking Through Game-Based Learning: A Systematic Review. *Journal of Educational Computing Research*, 61(7), 1505-1536. https://doi.org/10.1177/07356331231180951

Wiggins B. E. (2016). An overview and study on using games, simulations, and gamification in higher education. *International Journal of Game-Based Learning (IJGBL)*, 6(1), 18–29. https://doi.org/10.4018/IJGBL.2016010102

Yasseri, D., Finley, P. M., Mayfield, B. E., Davis, D. W., Thompson, P., Vogler, J. S.(2018). The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork. Instructional Science. 46 (3), 457–488. https://doi.org/10.1007/s11251-017-9438-9. ISSN 1573-1952.

Zou, Z. (2021). Design and Research of Virtual Reality Course Management System Based on Artificial Intelligence. *Journal of Physics: Conference Series*, Vol. 2066, International Conference on Information Technology and Mechanical Engineering (ITME 2021) 29-30 April 2021, Hangzhou, China. https://dx.doi.org/10.1088/1742-6596/2066/1/012077

COMPARISON OF EXECUTION TIMES IN SERIAL AND PARALLEL PROCESSING OF THE MONTE CARLO METHOD

Perizat Gapbarova[6], Nursaule Karelkhan[7], Pavol Jurík[8]

Abstract

Integrating parallel computing in numerical methods represents a significant advancement in computational science and engineering, enabling substantial performance enhancements. This study explores the efficiency of parallel computing across various numerical applications, including Monte Carlo integration for π approximation, finite element methods for thermal conductivity, parallel merge sorting, molecular dynamics simulations, and linear systems like Gauss-Seidel and Jacobi methods. The Monte Carlo method, originating from the 1940s, has been fundamentally transformed through parallel computing, allowing for the efficient processing of large datasets and complex simulations. This paper details the historical context, applications, and performance benefits of parallel computing in enhancing the Monte Carlo method. Critical applications include high-energy physics, financial modelling, healthcare imaging, environmental modelling, and realistic rendering in computer graphics. The study demonstrates the superior computational efficiency achieved with parallel processing through experiments, including parallel and sequential Monte Carlo simulations for π estimation. The results indicate that parallel computing accelerates processing times and maintains high accuracy and reliability in computational outcomes. The findings underscore the critical role of parallel computing in addressing the increasing complexity of scientific and engineering problems, facilitating real-time data analysis, and supporting high-performance computing tasks. Future research will focus on optimising parallel algorithms for cloud-based environments and specialised hardware, enhancing the scalability and effectiveness of computational methods in various domains.

Keywords
C++, speed, accuracy, parallel computing, numerical methods, performance, scalability, Monte Carlo

1 Introduction Parallel Computing in Numerical Methods

Studying performance enhancements through parallel computing in numerical methods is crucial in modern computational science and engineering (Bobreneva et al., 2023). This approach efficiently utilises multi-core processors, significantly speeding up the resolution of complex computational tasks. Examples of applications include:

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- Numerical integration problems, such as approximating π using the Monte Carlo method.
- Finite element methods for experimental thermal conductivity.
- Advanced sorting algorithms like parallel merge sorting.
- Molecular dynamics simulations.
- Linear model systems like the Gauss-Seidel and Jacobi methods.

1.1 Historical Context and Development of the Monte Carlo Method

The Monte Carlo method, named after the famous Monaco casino due to its reliance on randomness, was developed in the 1940s. Early concepts date back to the 18th and 19th centuries with pioneering work by mathematicians like Buffon and developments in probability theory. During World War II, scientists, including John von Neumann and Stanislav Ulam, enhanced the method at Los Alamos for complex physical simulations. Post-war, its application expanded across various fields, benefiting from the growth in computing technology.

1.2 Applications in Modern Computing

Parallel Computing Enhancements

Integrating parallel computing techniques has significantly enhanced the Monte Carlo method. This synergy allows for the effective use of multi-core processors, which can perform multiple calculations simultaneously, significantly reducing computation times for complex models. This is particularly vital in scenarios where large numbers of random samples must be processed quickly to simulate probabilities and outcomes (Kropachev et al., 2020).

Scientific Research

In fields like particle physics and materials science, the Monte Carlo method models complex interactions within analytically intractable systems. For example, high-energy physics helps simulate particle collisions that occur in particle accelerators, providing insights into the fundamental components of matter. Parallel computing allows these simulations to run in a fraction of the time required initially, facilitating more extensive and detailed studies that were previously not feasible due to computational limitations (Sokolinsky, 2021).

Finance and Economics

The financial sector employs the Monte Carlo method to assess risk and uncertainty in market dynamics and to price complex derivatives. By simulating thousands of possible future market scenarios, traders can predict the likelihood of different outcomes more accurately. Parallel computing accelerates these simulations, enabling real-time decision-making in fast-paced financial environments. This capacity is crucial for developing high-frequency trading algorithms adapting to rapidly changing market conditions.

Healthcare and Medicine

The Monte Carlo method is used in healthcare for imaging and radiation therapy planning, particularly in cancer treatment. It simulates the interaction of radiation with human tissues to optimise the dosing levels and minimise exposure to healthy tissues. Using parallel computing in these simulations allows for more precise and personalised treatment plans to be developed quickly, improving patient outcomes.

Environmental Science

Environmental scientists use the Monte Carlo method to model complex ecological systems and predict climate change's impact on these systems. This includes simulations of weather patterns, pollution dispersion, and ecosystem responses to various environmental stressors. Parallel computing enables processing extensive environmental data sets, such as satellite imagery and ground sensor data, to model these systems at a much larger scale and with greater accuracy (Yazovtseva et al., 2023).

Graphics and Visual Effects

In computer graphics, particularly for movie and video game production, the Monte Carlo method renders scenes realistically by simulating the random paths of light rays. This process, known as ray tracing, produces images with sophisticated lighting effects, such as reflections, refractions, and shadows. Parallel computing dramatically speeds up rendering times, making it practical to use Monte Carlo methods for this purpose in a production environment.

Challenges and Future Directions

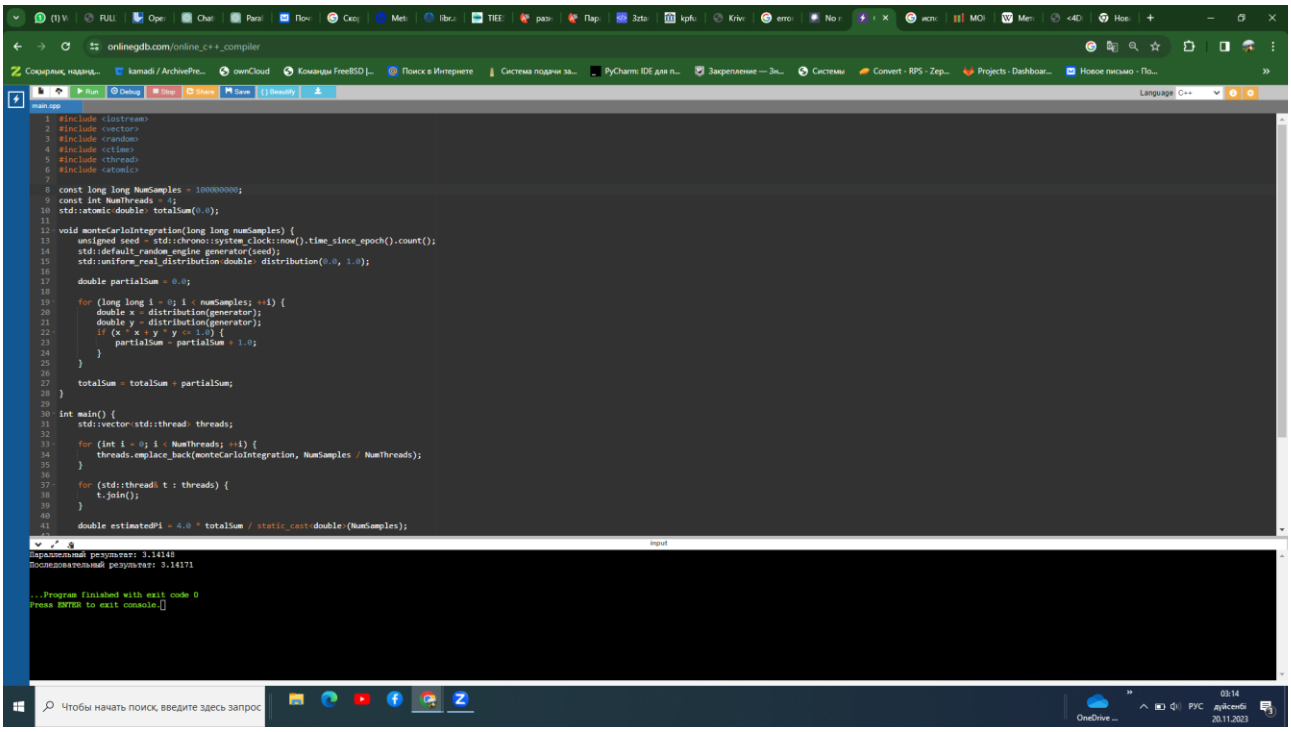
While the applications of the Monte Carlo method in parallel computing environments are extensive, challenges remain, particularly regarding algorithm efficiency and the management of computational resources. Future developments are likely to focus on optimising these algorithms for cloud-based environments and specialised hardware like GPUs, which offer massive parallelism capabilities. Additionally, improvements in machine learning algorithms may also help refine the setup of simulations to yield faster and more accurate results (Sokolinsky & Sokolinskaya, 2023).

2 Experiment Setup

We set up the simulation within a unit square with an inscribed quarter circle, where the area of the quarter circle represents $\pi/4$. Points were randomly distributed across the square, and we calculated the ratio of points that fell inside the quarter circle to estimate π. The Monte Carlo simulations were run using the following code in C++:

```
for (long long i = 0; i < numSamples; ++i) {
    double x = distribution(generator);
    double y = distribution(generator);
    if (x * x + y * y <= 1.0) {
        partialSum += 1.0;
    }
}
totalSum += partialSum;
```

Fig 1: The first attempt to run the Monte Carlo method in C++



Source: own research

Sequential result: 3.14171
Parallel result: 3.14148

2.1 Detailed Overview of Parallel and Sequential Monte Carlo Simulations for π Estimation

In parallel computing, the Monte Carlo integration function is employed across multiple threads, each operating on a subset of the total number of samples (NumSamples). This division enhances computational efficiency by leveraging multicore processor architectures. Each thread executes an independent simulation, accumulating a partial sum of points that fall within a predefined quarter circle. These partial sums are then atomically integrated into a total sum to prevent race conditions—a critical consideration when multiple threads access and modify the same memory location concurrently.

The atomic operations ensure that updates to the shared memory (total sum) are completed without interference among threads, thereby maintaining data integrity and consistency across the concurrent processes. Upon completion of all parallel computations, the threads are synchronised using the join() function, ensuring that all parallel processes have concluded before proceeding to aggregate the results:

```
    for (int i = 0; i < NumThreads; ++i) {
        threads.emplace_back(monteCarloIntegration, NumSamples / NumThreads);
    }
    for (std::thread& t : threads) {
        t.join();
```

```
    }
    double     estimatedPi     =     4.0     *     totalSum     /
static_cast<double>(NumSamples);
    std::cout << " Parallel result: " << estimatedPi << std::endl;
```

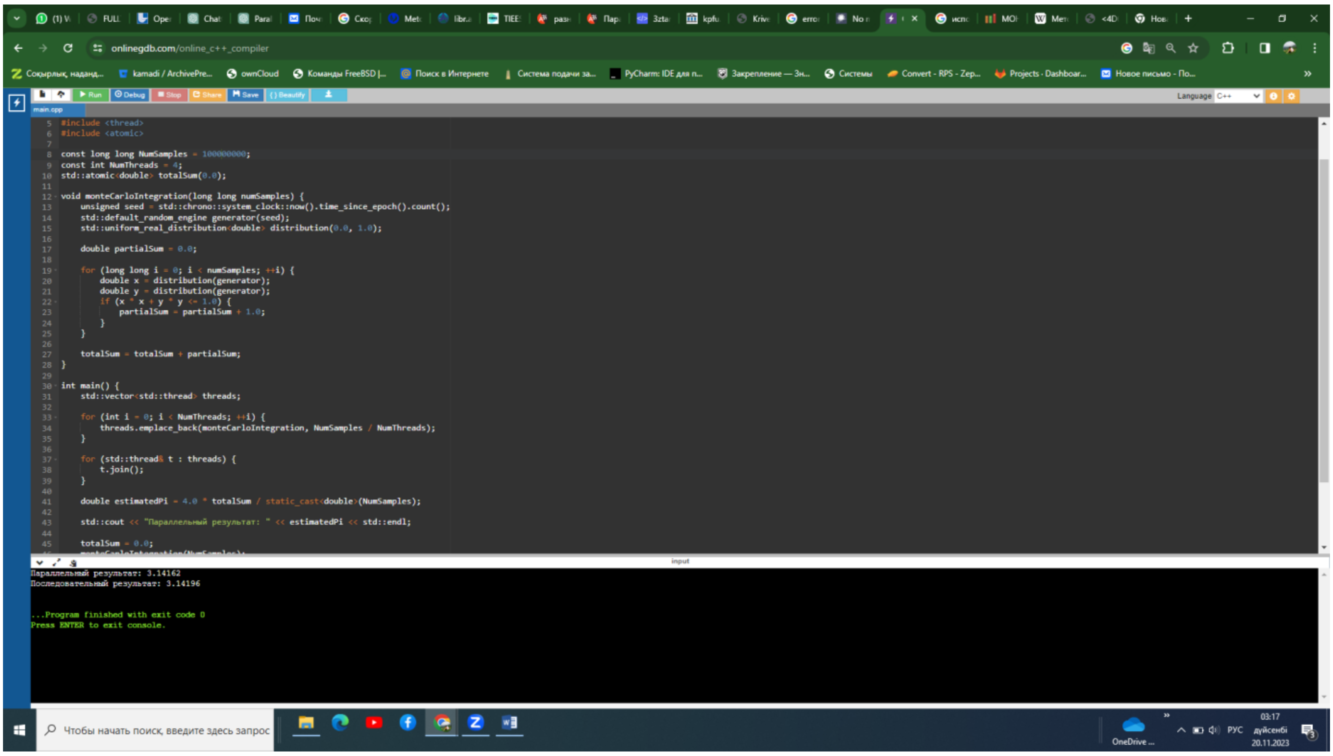
Following the parallel computation, a sequential version of the Monte Carlo Integration function is executed as a single-threaded process to provide a baseline for comparison. This sequential execution simulates the entire set of samples in a cumulative fashion, thereby contrasting the performance and output against the parallel approach:

```
    totalSum = 0.0; // Resetting totalSum for sequential computation
    monteCarloIntegration(NumSamples); // Sequential execution
    double     sequentialPi     =     4.0     *     totalSum     /
static_cast<double>(NumSamples);
    std::cout << " Sequential result: " << sequentialPi << std::endl;
```

Mathematically, the estimation of π in both the parallel and sequential scenarios is calculated using the formula:

$$\pi \approx 4 \times \frac{Total}{NumSamples}$$

Fig 2: The second attempt to run the Monte Carlo method in C++



Source: own research

Sequential result: 3.14196
Parallel result: 3.14162

To validate our computational models' consistency and reliability, the parallel and sequential simulations were executed 1,000 times. This repetitive testing helps assess the variability and accuracy of the results across multiple runs. Statistical analysis of these runs can provide insights into the stability of the Monte Carlo method under different computational conditions and help identify any potential anomalies or deviations in the expected outcomes.

The repeated execution of these simulations underscores the robustness of the parallel processing approach, particularly in its ability to harness increased computational resources effectively. The aggregate data from these 1,000 trials were analysed to determine the average, variance, and standard deviation of the estimated values of π, offering a comprehensive view of the performance metrics associated with each method.

This extensive testing regime demonstrates that while parallel computing generally yields faster processing times due to distributed workload among multiple cores, the precision and accuracy of computational results remain consistent with those obtained via traditional sequential processing. Such findings are crucial for computational sciences, where speed and data integrity are paramount.

3 Conclusion

Studying performance enhancements through parallel computing in numerical methods is pivotal for advancing computational processes across scientific and engineering disciplines (Koledin et al., 2023). By significantly accelerating the execution speed of tasks, parallel computing enhances efficiency and enables handling complex problems that were once constrained by the limitations of single-threaded processing. This shift is crucial for processing vast datasets and executing high-performance computing tasks, thereby making substantial contributions to fields requiring real-time data analysis and complex algorithmic computations.

Parallel computing optimises using advanced hardware resources, including multicore processors and specialised devices like GPUs, facilitating faster and more reliable execution of complex simulations and analyses. However, developing and optimising parallel algorithms require a deep understanding of parallel programming and computer architecture. Effective memory access management and the prevention of race conditions are essential to maintaining accuracy and reliability in results (Zymbler & Kraeva, 2023).

As we move deeper into the era of big data and artificial intelligence, the demands for increased computing power and faster data processing are growing exponentially. Integrating parallel computing techniques into numerical methods enhances existing capabilities and opens new horizons in research and development. It empowers scientists and engineers to tackle more intricate tasks efficiently, paving the way for innovative solutions in an increasingly data-driven world.

In conclusion, as scientific challenges' complexity increases, so does the necessity for advanced computing strategies. Parallel computing stands at the forefront of this evolution, offering promising solutions to enhance computational capacity and address the pressing needs of modern-day scientific inquiries and technological advancements.

Resources

Bobreneva, Y. O., Poveshchenko, Y., Podryga, V. O., Polyakov, S. V., Uzyanbaev, R. M., Rahimly, P. I., Mazitov, A. A., & Gubaydullin, I. M. (2023). One approach to numerical modelling of the heat and mass transfers of two-phase fluids in fractured-porous reservoirs. *Mathematics*, *11*(18), 3991. https://doi.org/10.3390/math11183991

Kropachev, P., Imanov, M., Borisevich, J., & Dhomane, I. (2020). Information Technologies and the Future of Education in the Republic of Kazakhstan. *Scientific Journal of Astana IT University*, (1), 30–38. https://doi.org/10.37943/aitu.2020.1.63639

Sokolinsky, L. B., & Sokolinskaya, I. M. (2023). Apex method: A new scalable iterative method for Linear Programming. *Mathematics*, *11*(7), 1654. https://doi.org/10.3390/math11071654

Zymbler, M., & Kraeva, Y. (2023). High-performance time series Anomaly discovery on graphics processors. *Mathematics*, *11*(14), 3193. https://doi.org/10.3390/math11143193

Yazovtseva, O. S., Gubaydullin, I. M., Peskova, E. E., Sukharev, L. A., & Zagoruiko, A. N. (2023). Computer simulation of coke sediments burning from the whole cylindrical catalyst grain. *Mathematics*, *11*(3), 669. https://doi.org/10.3390/math11030669

Sokolinsky, L. B. (2021). BSF: A parallel computation model for scalability estimation of iterative numerical algorithms on Cluster Computing Systems. *Journal of Parallel and Distributed Computing*, *149*, 193–206. https://doi.org/10.1016/j.jpdc.2020.12.009

Koledin, S., Koledina, K., & Gubaydullin, I. (2023). Multiobjective optimization of a metal complex catalytic reaction based on a detailed kinetic model with parallelization of calculations. *Mathematics*, *11*(9), 2051. https://doi.org/10.3390/math11092051

RENEWAL OF THE OPERATION OF THE EU CUSTOMS SYSTEM IN HUNGARY

Istvan Gál[9], Zoltan Hima[10], Andrea Tick[11]

Abstract
This study examines how Hungary's budget revenues have changed because of customs duties. On May 1, 2004, the European Union was further expanded by the fact that Hungary also joined the membership, and after the accession, Hungary also joined the customs policy of the EU. But this is not the only significant change. No public data sources exist on which countries and goods are delivered to the community at what customs price. However, the amount of revenue from customs revenues has decreased. The situation is also complicated by the fact that the territory of the European Union and the location of the customs border do not coincide. At the same time, there was a significant change in the reliability and speed of customs activities. Hungary's budget revenues changed significantly after joining the European Union in 2004. There will be a significant change in the accuracy and speed of completion of customs declarations, which will bring about changes in customs clearance processes. The proposals can be exemplary for other middle-income countries, such as Hungary, and for higher-income EU countries in terms of application to EU regulations.

Keywords:
AIS-AES, budget revenue, customs duty, customs system, tax

1 Introduction

In the last two decades, a dramatic and fundamental change has occurred in many advanced economies' budgetary policies. These recent debt and financial crises and their negative spillover effects on several emerging economies have brought the potential damage to the fore. Policymakers and academics have, therefore, recently made efforts to try to predict financial and debt crises before they occur. That is why the countries in the European Union must prepare a stable and sustainable budget and minimise their possible deficit state. For the expenses not to significantly exceed the incomes, the incomes must be raised close to the level of the expenses. The revenues from public finances are made up of several parts. One significant source of income was the duties established during import customs procedures, which were a very significant source of the budget. The lack of coordination of tax policies across the European Union allows multinational enterprises to shift profit and avoid their fair share of tax payments (Nerudova et al., 2023).

Since our membership in the European Union, the role of customs revenues in the budget has decreased significantly. However, this is not the only significant change; it is also the fact that we know much less about EU customs revenues. No public data sources exist on which countries and goods are delivered to the community at what customs price. Small and medium-sized enterprises constitute a significant industrial segment (Prashar, 2017).

Like the other member states of the European Union, Hungary plays a decisive role in promoting international trade through its customs activities. The EU's customs system is vital

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in maintaining the smooth flow of goods between member states and the integrity of the single market. This article explores the renewal of the operation of the EU customs system in Hungary and its effects on trade and border management.

Changes occurred in connection with Brexit (Muinzer et al., 2022). Northern Ireland remains part of the common customs area, but the United Kingdom is no longer part of the European Union. However, the unity of the Customs Union did not cease. Although Turkey, Andorra, and San Marino are not EU member states, they still form a duty-free zone with the Customs Union of the European Union.

2 Research Methodology

The research methodology used during the renewal of the Hungarian EU customs system includes a comprehensive assessment of the existing customs procedures, including a thorough evaluation of performance and identifying deficiencies. The legal framework governing customs operations is regularly reviewed and updated to meet evolving EU regulations and international trade standards. Technology integration is key, focusing on applying digital tools, automation, and data-sharing mechanisms to increase efficiency. Training and capacity building are prioritised to ensure stakeholders, including customs officials, are adequately prepared for updated procedures and technologies. The renewal process includes rigorous testing and piloting phases to identify and address potential issues before fully implementing the renewed customs system. I consider it appropriate to use the PDCA (Plan-Do-Check-Act) cycle when introducing changes to the customs management system.

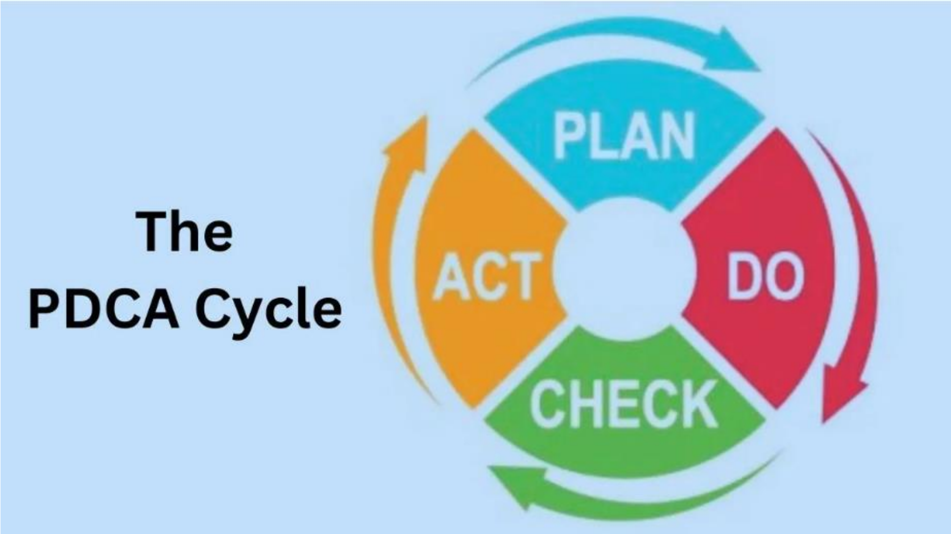
PDCA is a systematic and iterative four-step management method for continuously improving processes, products, or services.

- Plan: In the first phase, organisations identify and plan for improvement. This involves establishing objectives and goals, identifying processes that need improvement, and devising a plan to achieve those objectives.
- Do: The second phase involves implementing the plan. This is where the planned changes are executed, and the new processes, products, or services are implemented.
- Check: After the implementation, the next step is to assess and monitor the results. Organisations evaluate whether the implemented changes have achieved the desired goals and objectives.
- Act: In the Check phase, organisations act appropriately based on the evaluation. The changes are standardised and incorporated into regular practices if the results meet the objectives. If there are deficiencies or areas for further improvement, the organisation refines the plan and repeats the cycle.

The PDCA cycle is a critical component of many quality management systems. It is widely used in various industries to drive continuous improvement and ensure that organisations adapt and thrive in a dynamic environment.

The PDCA cycle can be combined with a simulation model of the production facility to test different what-if scenarios. This allows strategies to be tested without disturbing the current manufacturing system, significantly reducing the time, cost, and risk of implementing new strategies (Cui et al., 2023).

Fig. 1. PDCA cycle model source



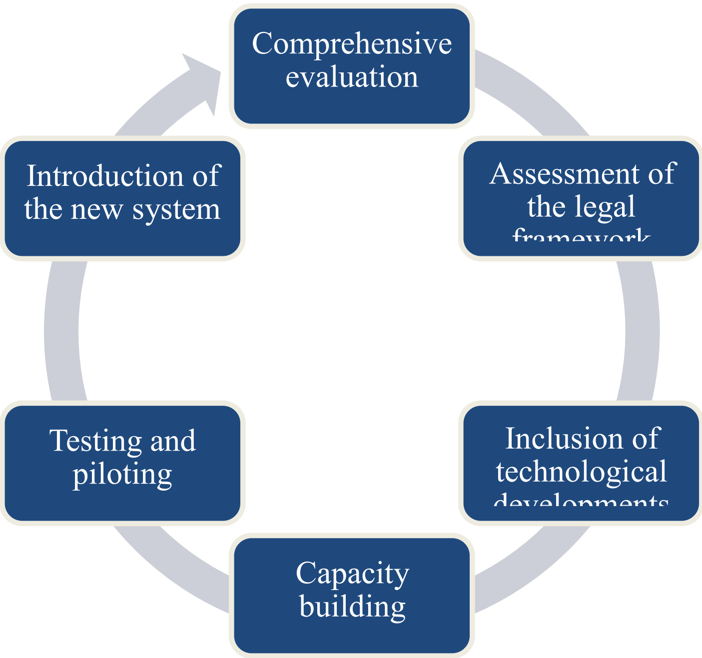
Source: (“BokasTutor, 2023)

2.1 The customs union of the European Union and its changes

The EU's customs system is designed to harmonise customs procedures between member states, promoting efficiency, transparency, and security. This includes the electronic exchange of information between customs authorities, businesses, and other relevant parties. Customs operations are regularly reviewed and updated to address emerging challenges, improve processes, and improve overall efficiency.

The renewal of the EU customs system in Hungary is carried out in cooperation with the Hungarian government and the European Commission. The process is presented in Figure 2. The circular shape represents the ongoing renewal and development of the customs clearance process.

Fig. 2. presents the procedure for renewing the EU customs system in Hungary.



Source: Developed by the authors

2.2 The process includes the following steps:

Before the renewal, a comprehensive evaluation of the existing customs system will be carried out. This includes evaluating performance, identifying weaknesses, and considering technological improvements. After that, they take care of the legal framework. The legal framework governing customs operations will be reviewed and updated to comply with EU regulations and international trade standards. Technological development also requires integration. The technological developments were incorporated to increase the efficiency of customs procedures. This may include introducing and integrating new digital tools, automation, and data-sharing mechanisms. Once implemented, customs officials and relevant stakeholders will be trained to familiarise themselves with the updated procedures and technologies. Capacity building ensures a smooth transition to the renewed system. The new customs system will undergo thorough and pilot testing to identify potential problems before full implementation. This phase allows for adjustments and fine-tuning based on real-world scenarios. After successful testing, the renewed customs system will be officially introduced. This may involve a phased approach to minimise disruption to ongoing commercial activities.

The introduction of a new procedure in customs clearance marks a strategic effort to enhance the efficiency and effectiveness of trade processes. This initiative aims to streamline the movement of goods by leveraging innovative methods, potentially reducing delays and administrative complexities in customs operations. During the introduction of the new procedure, the PDCA management cycle model can be identified to support these activities.

The change in the customs clearance process can provide the following benefits for the member countries modernising the customs procedure:

- *Efficiency improvement:* Simplified customs procedures reduce delays and administrative burdens, facilitating faster customs clearance of goods.
- *Enhanced security:* The updated systems enhance the detection of potential risks and strengthen border security measures.
- *Compliance with central regulations:* Alignment with EU regulations ensures that Hungary continues to comply with international trade standards.

2.3 The source of Hungary's budget and the possibilities of the community's income

These budget revenue sources are essential to the European Union (Syropoulos, 2003). They make up about 11%-13% of the budget revenue. Before the accession to the European Union, the total amount of customs duty paid was Hungary's income. From then on, however, the most significant part of this income belongs to the EU, of which the Hungarian member state can take a small part. Eighty per cent of customs revenues belong to the community and the remaining 20 per cent to the countries that collect them. Thus, in the budget, the size of the budget revenue from customs revenues also decreased significantly in all member states. During the redistributive policy, they may later benefit from EU support in a different form, but this study does not deal with this topic (Amores et al., 2023).

Consequently, Hungary's budget revenue from customs payments is no longer significant (Sipos, 2015). The customs revenue of countries with seas and ports is much higher. Hungary earns customs revenues after customs clearances after deliveries by air, container deliveries from 3rd countries delivered here by directional trains, and goods delivered from former Soviet member states located east of Hungary. However, the differences between the individual member countries are significant for the reasons mentioned. Compared to the community's average, the customs revenue measured concerning economic performance in Hungary is one-tenth less. In addition to the costs involved, customs clearance time also creates significant differences in customs clearance locations. This and the speed of customs clearances justify which countries can encourage more traders to do this activity with better customs services and which nations are better avoided (Elliott & Bonsignori, 2019).

For example, the case of Ireland is also interesting because, although its customs revenues are low, it still has a significant turnover of goods by sea, and most of the products subject to customs duties come by sea from distant China. Therefore, it is evident that the goods have already been cleared at the ports and transported to the continent's interior. For landlocked countries, it is, therefore, understandable if the proportion of customs revenues is lower. Many companies also use this opportunity for the ports of Hamburg, Rotterdam, Trieste, and Koper.

3 Europe's most important seaports

The efficiency and competitiveness of seaports have always been significant for European seaports. In the last 30 years, the ports have undergone many changes, just as the services provided by the ports (customs handling, warehousing, transhipment) have also continuously changed according to the needs (Kammoun & Abdennadher, 2022). Figure 3 shows the most important European ports.

Fig. 3. The most important European ports

Source: (ShipHub, 2021)

The member states have different options regarding the distribution of customs revenues. Austria, Estonia, Slovakia, and Romania came behind Hungary on the list of significant beneficiaries of customs revenue. The Czech Republic can collect nearly a third more customs duties on dutiable imports than Hungary, even without coastal ports. Countries with seaports, such as Germany, the Netherlands, Greece, Spain, Portugal, Italy, and Slovenia, collect the most duties on dutiable imports.

In Hungary, customs revenue and foreign trade are among the highest compared to GDP in the world, so it can be fundamentally misleading to measure the revenue from the payment of customs duties against economic performance. Most imports from European Union countries can be linked to duty-free EU partners. If the proportion of customs duties paid locally reached the EU average in Hungary, it would represent HUF 7.6 billion in additional revenue for the Hungarian budget annually. Customs control depends on the type of transport on which the goods are transported (Fuchs et al., 2022).

Several companies providing preparation and commissioning of customs clearance services were also established. In addition to providing services, these companies also perform warehousing tasks. In addition to completing the customs clearance procedure, they also help the principals with their deferred customs payment permits, for whom a delayed payment of up to two weeks means significant ease compared to the customs clearance option of the country of the site. Of course, this option also generates costs. The service also has a price. The direct customs clearance fee is now EUR 60–70, based on the number of customs clearances in 2023. The service providers use a bank guarantee certifying the payment of the subsequent customs costs. This is determined at around 2% of the customs value of the imported product. Considering the company's solvency using the service, however, after invoicing the incurred costs, a payment deadline of one month is usually given. The service is in the European Union but not Hungary, so paying VAT is unnecessary. In Hungary, the importer is also obliged to pay the VAT. Although this amount can be reclaimed, it still requires considerable liquidity from the importer despite the possibility of reclaiming the VAT later.

Another case is when, during the declaration of the imported goods for customs clearance, the value of the goods is under–invoiced on the commercial invoice that forms the basis of the customs clearance. The more significant the deficit, the greater the extent of misrepresentation by the importer, which is motivated by the incentive to under-invoice to avoid paying customs duties (Al Wazzan et al., 2023).

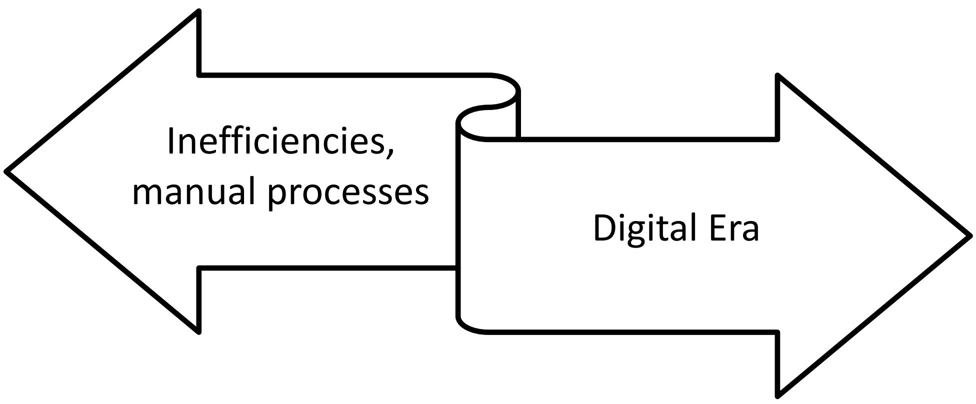
The administration in our area is also difficult and bureaucratic. However, this will change after the end of 2023. The use of AIS (Automated Import System) and AES (Automated Export System) is required from the member states of the European Union (Customs Office, Hungary, 2023).

In the case of Hungary, as I mentioned before, the level of customs duties is not significant today. The budget deficit is increased by the direct payment to the EU and the net revenue loss related to the customs system, which is the difference between the lost customs revenues and the reimbursement of customs collection costs paid by the EU. The EU reimbursement will reduce the deficit. Excise tax rates raised due to EU regulations are also linked to EU accession in a completely analogous way to customs reduction. It positively affects the budget that EU funds can be used to finance previous programs at a lower domestic cost.

4 Conclusion

Customs play a crucial role in facilitating and speeding up the international flow of goods, especially in logistic nodes such as seaports or dry ports (Cavallini & Benzi, 2023). The renewal of the EU customs system in Hungary is a dynamic process, aiming to modernise customs operations to the changing needs of international trade.

Fig. 4. The changes from inefficient manual process to the digital era



Source: (Pettit et al., 2022)

By embracing technological developments and adapting to EU standards, Hungary contributes to the overall efficiency and effectiveness of the EU customs system, promoting the smooth flow of goods across borders. Table 1 shows the steps of the changes.

Tab. 1. Summary of the changes in the customs procedure

	Previous process		
Submission of customs clearance documents	**NAV's feedback**	**Possible outcome**	**The administration time**
only on paper documents	only on paper documents	only on paper documents	only on paper documents
(commercial invoice, transport document and insurance, goods declaration)	(to present a declaration form, to present certificates, to present a request for goods inspection)	1. Successful customs clearance	Longer procedure
Further process	Change request	2. Further procedure	Longer procedure
	New process		
on the electronic way only	on the electronic way only	on the electronic way only	on the electronic way only
(commercial invoice, transport document and insurance, goods declaration)	(to present a declaration form, to present certificates, to present a request for goods inspection)	1. Successful customs clearance	Quick procedure
Further process	Change request	2. Further procedure	Quick procedure

Source: developed by the authors

Moreover, the emphasis on continuous updates to customs clearance processes reflects Hungary's proactive approach to staying ahead of regulatory changes. By adapting to evolving legal requirements and international standards, Hungary ensures that its customs activities remain in harmony with the global trade landscape, fostering strong bilateral and multilateral trade relations. As Hungary positions itself as a critical player in regional and international trade, modernising customs clearance activities is a strategic investment in the nation's economic future. The collaborative efforts between the government, businesses, and international partners underscore Hungary's commitment to creating an efficient, transparent, and secure customs framework that supports sustainable economic development and integration into the broader global economy, as is shown in Figure 4.

This is, of course, not a closed process, as this activity is still ongoing. Companies must develop a competitive advantage in today's competitive business environment. Technological innovation is one of the most effective ways for companies to achieve this advantage and enhance their competitiveness (Mokhtari Moughari & Daim, 2023). The innovations implemented now must be reviewed after a certain period, and if they do not meet expectations, they must be changed again. Figure 4 shows the changes from inefficient manual processes to the digital era.

Before modernising customs clearance activities, Hungary faced inefficiencies, manual processes, and challenges adapting to the digital era of global trade. After embracing modernisation, Hungary now boasts streamlined procedures, reduced processing times, and enhanced security measures, positioning the country as a competitive player in the international trade landscape while fostering a more conducive environment for businesses and ensuring compliance with evolving standards. The transformation underscores Hungary's commitment to economic growth, resilience, and successful integration into the dynamic global trade ecosystem.

References

Al Wazzan, L., Grether, P., & Olarreaga, M. (2023). Measuring misreporting at customs. *Economics Letters*, 229, 111232. https://doi.org/10.1016/j.econlet.2023.111232

Amores, A. F., Maier, S., & Ricci, M. (2023). Taxing household energy consumption in the EU: The tax burden and its redistributive effect. *Energy Policy*, 182, 113721. https://doi.org/10.1016/j.enpol.2023.113721

Caballini, C., & Benzi, M. (2023). Fast Corridors: Innovative customs processes and technology to increase supply chain competitiveness. The case of IKEA Italy. *Transportation Research Interdisciplinary Perspectives*, 21, 100909. https://doi.org/10.1016/j.trip.2023.100909

Cui, X., Webb, D. P., & Rahimifard, S. (2023). Capability evaluation of real-time inline COD detection technique for dynamic water footprint management in the beverage manufacturing industry. *Water Resources and Industry*, 30, 100215. https://doi.org/10.1016/j.wri.2023.100215

Elliott, D., & Bonsignori, C. (2019). The influence of customs capabilities and express delivery on trade flows. *Journal of Air Transport Management*, 74, 54–71. https://doi.org/10.1016/j.jairtraman.2018.09.007

Fuchs, E., Novikov, V., & Novikov, S. (2022). Improvements in Post-Release Customs Control of Goods Moved by Different Modes of Transport. *Transportation Research Procedia*, 61, 200–205. https://doi.org/10.1016/j.trpro.2022.01.033

Kammoun, R., & Abdennadher, C. (2022). Seaport efficiency and competitiveness in European seaports. *Transport Policy*, 121, 113–124. https://doi.org/10.1016/j.tranpol.2022.04.003

Mokthtari Moughari, M., & Daim, T. U. (2023). Developing a model of technological innovation for export development in developing countries. *Technology in Society*, 75, 102338. https://doi.org/10.1016/j.techsoc.2023.102338

Muinzer, T. L., Jenkins, K. E. H., McCauley, D. A., & Little, G. M. (2022). Energy justice beyond borders? Exploring the impact of Brexit on Ireland's all-island energy market. *The Electricity Journal*, 35(10), 107218. https://doi.org/10.1016/j.tej.2022.107218

Nerudova, D., Dobranschi, M., Solilová, V., & Litzman, M. (2023). Onshore and offshore profit shifting and tax revenue losses in the European Union. Economic Modelling, 119, 106111. https://doi.org/10.1016/j.econmod.2022.106111

Pettit, S., Wang, Y., & Beresford, A. (2022). Chapter 7—The impact of digitalisation on contemporary and future logistics. In B. L. MacCarthy & D. Ivanov (Szerk.), The Digital Supply Chain (o. 111–125). Elsevier. https://doi.org/10.1016/B978-0-323-91614-1.00007-1

Prashar, A. (2017). Adopting PDCA (Plan-Do-Check-Act) cycle for energy optimisation in energy-intensive SMEs. Journal of Cleaner Production, 145, 277–293. https://doi.org/10.1016/j.jclepro.2017.01.068

Sipos, A. (2015). Determining Factors of Tax-morale with Special Emphasis on the Tax Revenues of Local Self-governments. *Procedia Economics and Finance*, 30, 758–767. https://doi.org/10.1016/S2212-5671(15)01325-8

Syropoulos, C. (2003). Rules for the disposition of tariff revenues and the determination of common external tariffs in customs unions. *Journal of International Economics*, 60(2), 387–416. https://doi.org/10.1016/S0022-1996(02)00046-6

Top container ports in the EU 2021 Edition | *ShipHub*. (2022, February 3). https://www.shiphub.co/top-container-ports-in-the-eu-2021/

NAV Sikeresen zárult az átállás az eVÁM AIS-rendszerre [WWW Document]. Nemzeti Adó- És Vámhivatal. URL https://nav.gov.hu/vam/nemzeti-import-rendszer/Sikeresen_zarult_az_atallas_az_eVAM_AIS-rendszerre (2023) (accessed 1.7.24).

What is the PDCA Cycle? (Plan-Do-Check-Act) - BokasTutor. (2023, június 3). https://bokastutor.com/pdca-cycle/

HOW COULD HELP INTERNATIONAL CERTIFICATIONS FOR IT SUBJECT MATTER TEACHERS

Veronika Horniakova[12]

Abstract
This article focuses on the benefits of knowledge and understanding of international certificates for academic IT management, governance, project management, and software development teachers. This article does not discuss standards for programming languages and techniques.
To deliver quality teaching, following standardisation trends and incorporating them into the course syllabus is important. But first, it is necessary to observe which standards will shape the future of IT management and which ones are only hype caused by the current situation.
In this article, we will focus more closely on standards that have already been verified and have become best practices in their field. We will also show some of the results of our research and formulate hypotheses for our upcoming scientific research.

Keywords
IT Management Standards, ITIL, IT Governance, Project Management, Software Development

1 Introduction

In the dynamic of Information Technology (IT), where efficiency, reliability, and security are necessary, adherence to established standards is essential. Certain standards have emerged as IT management and governance pillars among the available frameworks and methodologies. In this article, we describe three standards:

- ITIL (Information et al. Library),
- COBIT (Control Objectives for Information and Related Technologies),
- and PRINCE2 (Projects IN Controlled Environments).

Each of these frameworks takes a unique approach to IT management, ranging from service delivery and governance to project management. By understanding the principles and practices advocated by these standards, organisations can streamline their operations, enhance service quality, mitigate risks, and achieve strategic objectives.

In connection to university education, authors Smith & Johnson (2020) consider teaching about standards a natural part of the curriculum. University teachers are pivotal in shaping the future generation of IT professionals. As educators, they develop technical knowledge and support students in developing a comprehensive understanding of industry practices, standards, and methodologies. Familiarity with commonly known IT standards such as ITIL, COBIT, and PRINCE2 is therefore helpful for university lecturers for several reasons, such as:

Integrating these standards into the curriculum raises the learning experience by providing students with practical insights into industry-relevant practices. By aligning course content with established standards, lecturers ensure that students are equipped with the knowledge and skills demanded by the IT industry.

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According to Patel & Jones (2019), organisations worldwide widely adopt IT standards to optimise IT service delivery, governance, and project management. By incorporating discussions on methodologies into their lectures, educators bridge the gap between theoretical concepts and real-world applications, preparing students for the challenges they will encounter in professional settings.

Employers increasingly value candidates with knowledge of established standards, as it demonstrates their readiness to contribute effectively to organisational goals from day one.

Professors and lecturers often research to advance knowledge in their respective fields. Familiarity with IT standards supports research collaborations, enabling academics to explore emerging trends, evaluate the effectiveness of existing frameworks, and propose innovative solutions to industry challenges.

The IT landscape constantly evolves, with new technologies and methodologies emerging rapidly. By staying abreast of developments in IT standards, lecturers ensure their professional growth and remain valuable resources for their students and the academic community.

University lecturers should know ITIL, COBIT, and PRINCE2 to enrich the educational experience, enhance industry relevance, prepare students for successful careers, pursue research opportunities, and facilitate their continual professional development. By embracing these standards, educators empower the next generation of IT professionals to thrive in a dynamic and competitive global market (GARCIA & MARTINEZ (2017), NGUYEN & TRAN (2018), LEE & WONG (2019)).

While teaching IT standards can significantly benefit the students, educators should be mindful of common pitfalls that they may prevent during the learning process (SMITH & JOHNSON, 2020):

Focusing solely on theoretical aspects without providing practical examples or case studies can lead to student disengagement. Lecturers should strive to balance theory and application, ensuring students understand how these standards are implemented in real-world scenarios.

IT standards can be very complex, especially for students who are new to the field. Presenting too many concepts without breaking them down into parts can overwhelm learners. Lecturers should adopt a step-by-step approach, gradually introducing complex topics and providing opportunities for clarification and reinforcement.

Also, failure to contextualise the relevance of IT standards within the broader IT landscape and organisational context can limit students' understanding. Lecturers should illustrate the practical implications of these standards by referencing industry examples, case studies, and success stories. This helps students appreciate the value proposition of adhering to IT standards in diverse organisational settings.

Encouraging rote memorisation of IT standard frameworks and terminology without fostering deep conceptual understanding undermines the learning process. Instead, educators should promote critical thinking and analytical skills by encouraging students to analyse, evaluate, and apply the principles underlying these standards to solve complex problems.

Last but not least, effective implementation of IT standards often requires collaboration, communication, leadership skills, and technical proficiency. Lecturers should integrate teamwork, presentation, and interpersonal skill development opportunities into their curriculum.

By knowing these common pitfalls, educators can tailor their teaching approaches to maximise student engagement, comprehension, and retention of IT standards, ultimately preparing them for success in the dynamic and demanding field of IT.

2 Understanding IT Standards

IT standards refer to established frameworks, methodologies, guidelines, and best practices that define how organisations should manage, implement, and govern information technology. These standards provide a structured approach to various aspects of IT operations, including service management, governance, security, project management, and software development.

Based on authors Smith & Johnson (2020), the IT standards ensure consistency and efficiency in IT operations by providing a standard set of guidelines and procedures. They establish uniform practices that streamline processes and minimise errors, improving productivity and resource utilisation. IT professionals can ensure the quality and reliability of IT services and products. Standards specify best practices and performance benchmarks, enabling organisations to deliver consistent, high-quality solutions that meet user requirements and industry standards.

IT standards also help mitigate risks and ensure regulatory requirements and industry standards compliance. They address various risk factors, such as security vulnerabilities, data breaches, and service disruptions, by prescribing preventive measures and control mechanisms. Standards also promote interoperability and compatibility among IT systems, applications, and components. They define standard interfaces, protocols, and data formats, enabling seamless integration and communication between disparate systems, thereby enhancing efficiency and scalability.

IT standards can foster a culture of continuous improvement by providing frameworks for evaluating and optimising IT processes and practices. They emphasise the importance of feedback loops, performance measurement, and iterative refinement, empowering organisations to adapt to changing business needs and technological advancements.

Compliance with widely accepted standards demonstrates a commitment to excellence, quality, and best practices, instilling trust and confidence among customers, partners, and stakeholders.

Standards also serve as foundational pillars in ensuring the effectiveness, reliability, and security of IT operations across diverse organisational landscapes (WANG & LEE, 2018).

IT standards establish uniform processes, procedures, and methodologies, eliminating redundancies and inefficiencies in IT operations. Standards streamline workflows and optimise resource utilisation by providing clear guidelines for incident management, change management, and service delivery tasks. Standards facilitate the efficient allocation of resources, including human capital, infrastructure, and budgetary resources. By defining best practices for resource management, standards help organisations prioritise investments, minimise waste, and maximise ROI. Many IT standards encourage automation and innovation as means to improve efficiency. By adopting automation tools and embracing innovative technologies, organisations can streamline repetitive tasks, accelerate processes, and drive continuous improvement in IT operations.

IT standards promote consistency and predictability in IT operations by defining standardised approaches and methodologies. This consistency ensures that IT services and solutions are delivered reliably and meet predefined performance criteria, fostering stakeholder trust and confidence. Standards play a crucial role in mitigating risks and vulnerabilities in IT operations. By prescribing preventive measures, control mechanisms, and best practices for risk management, standards help organisations identify, assess, and mitigate potential threats to the reliability and availability of IT services. They also emphasise the importance of resilience and business continuity in IT operations. By establishing guidelines for disaster recovery, backup procedures, and redundancy measures, standards ensure that organisations can withstand disruptions and maintain uninterrupted service delivery in the face of adverse events.

IT standards also define security baselines and best practices for safeguarding IT assets, data, and systems. These standards establish minimum security requirements, such as access controls, encryption standards, and security configurations, to protect against unauthorised access, data breaches, and cyber threats. Standards help organisations achieve compliance with regulatory requirements and industry standards related to information security. By aligning with frameworks such as GDPR, ISO 27001 and the NIST Cybersecurity Framework, organisations demonstrate their commitment to protecting sensitive information and ensuring regulatory compliance. Many IT standards emphasize the importance of security awareness and training for IT professionals and end-users. Organisations can mitigate human-related security risks and enhance overall cybersecurity posture by promoting a culture of security awareness and providing training on security best practices.

3 Overview of Commonly Known IT Standards

Several methodologies have been created for IT management in recent decades, primarily based on processes that are supposed to help solve individual problems or tasks within the framework of IT management. Most of these models were created based on solving actual tasks in practice. They are, therefore, often referred to as so-called "best practices," i.e., the most effective solution to the given problem. This part describes commonly used standards ITIL, COBIT5, and PRINCE2 (HORNIAKOVA, 2022).

ITIL

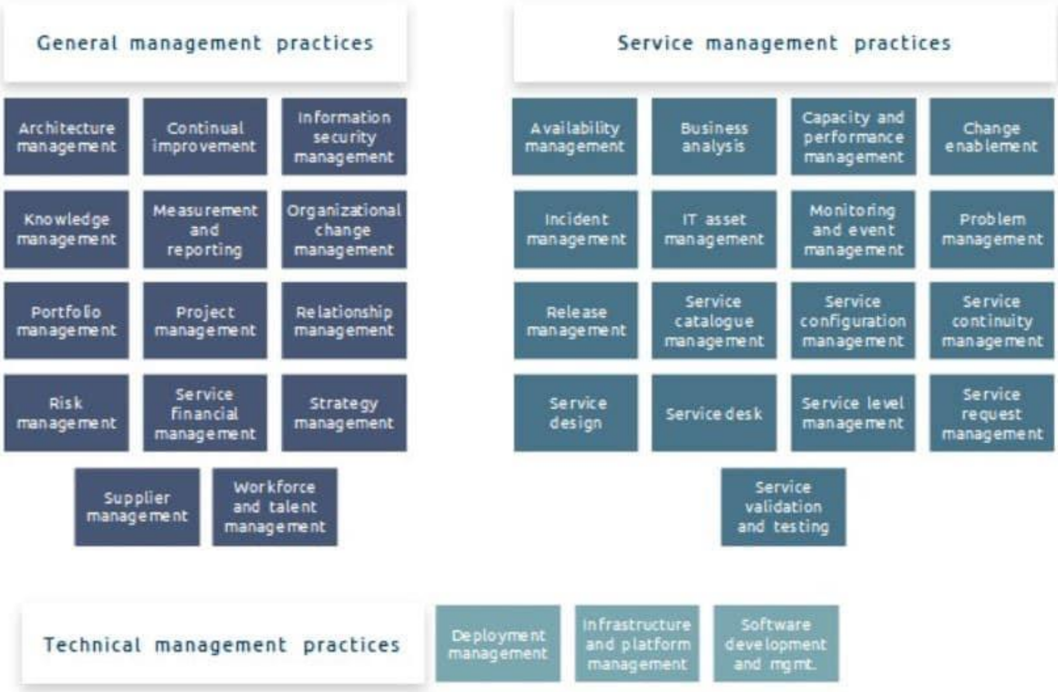
ITIL is an IT service management framework that outlines best practices for IT service delivery. A systematic ITIL approach can help businesses manage risks, strengthen customer relationships, implement cost-effective practices, and build a stable IT environment that enables growth and change (AXELOS, 2020).

ITIL has undergone several revisions in its history; the current version is ITIL 4. This version maintains the original focus and strongly emphasises supporting an agile and flexible IT department. It currently consists of a schema covering the various IT service life cycle processes and phases. The scheme contains recommendations and a framework to help organisations standardise IT service management processes. In the latest version, these processes are organised according to 3 types of procedures (Fig. 1):

- Management practices,
- Service management practices,
- Technical management practices.

ITIL, the most frequently used IT methodology in organisations, provides a certification scheme intended for individual IT professionals. As organisations continue to implement ITIL processes, the need for experts continues to grow. You can read more about the certification scheme on the official website of Axelos, the authority to issue ITIL certificates.

Fig. 1: Organization of processes in individual practices



Source: (AXELOS, 2020)

COBIT5

COBIT was designed as a support tool for managers and allows for bridging the critical gap between technical issues, business risks, and control requirements. It is a recognised methodology that can be applied to any organisation in any industry. Overall, COBIT ensures the quality, control, and reliability of information systems in an organisation, which is also the most critical aspect of any modern business (ISACA, 2012).

The COBIT framework provides a common language for IT professionals, compliance auditors and business managers. They can communicate about the same IT goals, controls, and results.

The difference between the ITIL and COBIT methodologies is that the ITIL methodology focuses on operations, managing and providing IT services to best support business. In contrast, COBIT focuses on strategic management and aligning IT goals and values with business goals. Like ITIL, COBIT also provides a certification scheme for individual IT professionals.

PRINCE2

It is based on common practice and is flexible for all projects, regardless of their type or scope. It contains seven main principles, seven processes, seven topics, two techniques, roles in the project organisation and mutual relations between these elements. The methodology is tested on thousands of projects and regularly improved to best adapt to current requirements. It guides managers on best practices for project management (AXELOS, 2017).

Like its predecessors, the PRINCE2 methodology was founded because projects were not delivered on time. In 2013, it was taken over by the company Axelos, which 2017 carried out the last significant modification to the form in which the PRINCE2 methodology is known today.

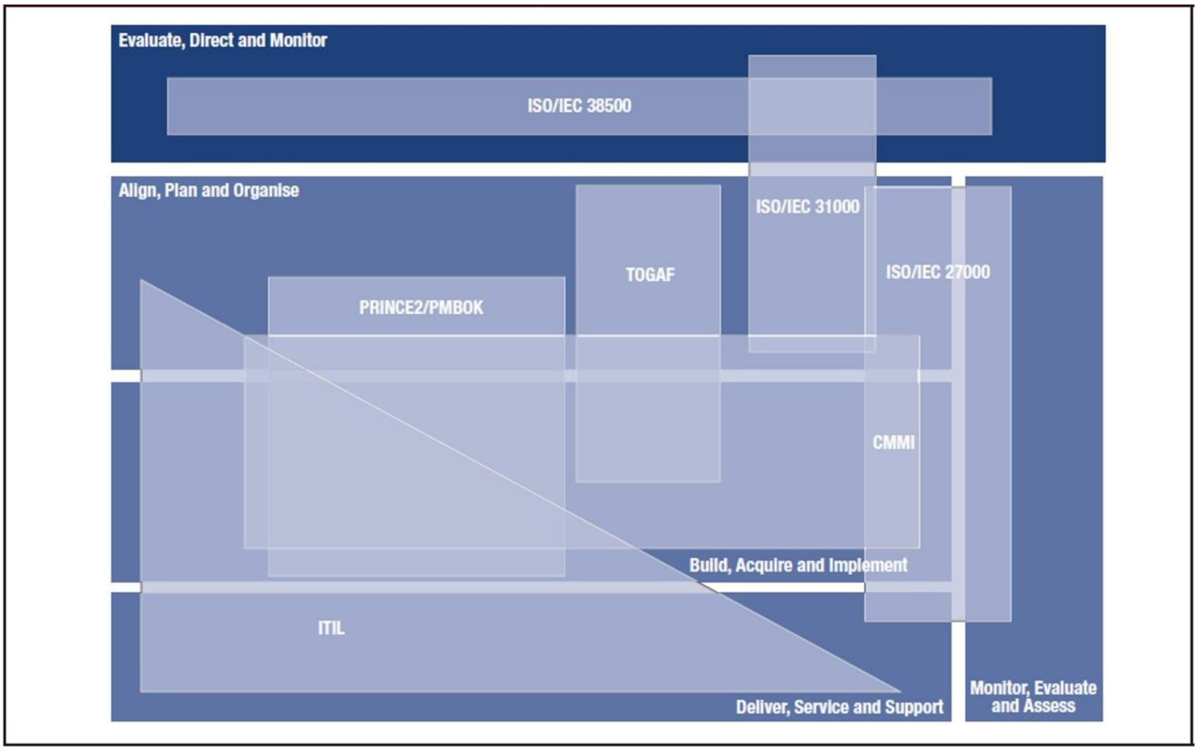
In practice, several standard methodologies (ITIL, COBIT, TOGAF, PRINCE2, CMMI) exist for IT management and separate areas such as project management, risk management, or information security management. Figure 2 clearly outlines how individual methodologies are related, where they overlap, and how they complement each other.

It is based on the COBIT methodology, which is the background and consists of five domains:

• Evaluate, Direct, and Monitor—domains that ensure the stakeholders' needs are evaluated by identifying and agreeing on the objectives to be achieved. These goals are prioritised and monitored for performance. They represent the governance domain.

• Plan, Align, organise, Build, Acquire and Implement, Deliver, Service and Support, Monitor, Evaluate, and Assess domains that ensure the planning, implementation, operations, and monitoring of activities that should be in accordance with the set goals.

Figure 2: Coverage of selected standards with the COBIT methodology



Source: (ISACA, 2012)

Standards of various areas subsequently cover these individual domains. There are standards such as PRINCE 2 and PMBOK in the field of project management. They mainly affect planning and implementation. There is also the TOGAF enterprise architecture standard, which mainly covers the area of planning and partly extends to implementation. We can see the ITIL methodology in the lower left part of the image. It mostly affects the field of IT operations and also the implementation itself. The ISO 27000 standard, for example, covers all areas of development and monitoring, as it is an IT security management standard, which is important in all areas. It starts with the design and continues with implementation through operation and important monitoring.

Therefore, it is obvious that organisations in IT management are often not satisfied with a single standard or methodology. For effective functioning, a suitable combination of several is necessary. Implementing the given standards and methodology depends only on the organisation's capabilities and possibilities.

Nowadays, organisations cannot ignore these methodologies. Based on the facts mentioned from the beginning, IT professionals must ensure the implementation of these standards in organisations. Here, it is also worth reminding that even if the standards provide experience, it is always important first to carry out an appropriate analysis of the implementation, the so-called "tailoring", i.e. choosing for the given organisation what is useful from the particular standard and not just blindly following the procedures (HORNIAKOVA, 2022).

3.1 Teaching IT Standards in the University

Incorporating IT standards into university curricula is crucial for preparing students to meet the demands of the rapidly evolving IT industry. There are several reasons to do so, such as (Smith & Johnson, 2020):

- **Alignment with industry practices** - IT operates within established standards and best practices. By incorporating IT standards into university curricula, educators ensure that students have the knowledge and skills to navigate real-world IT environments. This alignment with industry practices enhances the relevance and practicality of students' education, bridging the gap between academic theory and professional application.
- **Enhanced employability** - Employers increasingly seek candidates who possess knowledge of industry-standard frameworks and methodologies. By exposing students to IT standards such as ITIL, COBIT, and PRINCE2 during their academic studies, universities enhance their graduates' employability and competitiveness in the job market.
- **Preparation for professional certifications** - Many IT standards are accompanied by professional certification programs offered by accredited organisations. By integrating IT standards into university curricula, educators lay the groundwork for students to pursue certification exams and attain industry-recognized credentials. This preparation enhances students' resumes and demonstrates their commitment to ongoing professional development, setting them apart as qualified and competent IT professionals.
- **Holistic skill development** - Studying IT standards goes beyond memorising frameworks and terminology. It fosters the development of critical thinking, problem-solving, and decision-making skills. By engaging with case studies, group projects, and practical exercises centred around IT standards, students learn to analyse complex scenarios and apply theoretical concepts to real-world situations. This holistic approach to skill development prepares students to tackle the multifaceted challenges they will encounter in their future careers.
- **Adaptability to technological change** - Rapid technological advancements and evolving industry trends characterise the IT landscape. By exposing students to IT standards, universities develop a mindset of adaptability and continuous learning. Students who understand IT standards' principles are better equipped to adapt to new technologies, methodologies, and industry paradigms throughout their careers, ensuring their long-term success and relevance in the ever-changing IT field.

Effective teaching of IT standards involves implementing strategies that balance theoretical knowledge with practical applications, provide real-world context through examples and case studies, and foster critical thinking and analytical skills. Here's a deeper exploration of each strategy (Wang & Lee, 2018):

Balancing Theory and Practical Applications

Begin by establishing a solid foundation of theoretical knowledge, explaining the core concepts, principles, and frameworks of the IT standards being taught. This ensures that students grasp the underlying theories and methodologies. Complement theoretical lectures with hands-on activities, simulations, and practical exercises that allow students to apply the concepts they have learned in real-world scenarios. For example, students could participate in role-playing exercises to simulate IT service management processes or project management scenarios.

Providing Real-World Examples and Case Studies

Introduce real-world examples and case studies demonstrating how IT standards are applied in various industries and organisational contexts. Highlight success stories, best practices, and lessons learned from organisations implementing the standards effectively. Also, invite industry professionals with experience implementing IT standards to share their insights, experiences, and practical tips with students. Hearing from practitioners provides students with valuable real-world perspectives and enhances their understanding of the relevance of IT standards in professional practice.

Encouraging Critical Thinking and Analytical Skills

Present students with challenging scenarios, dilemmas, or problems related to IT standards and ask them to analyse, evaluate, and propose solutions. Encourage student discussion, debate, and collaboration to foster critical thinking and problem-solving skills. Incorporate opportunities for students to critically reflect on their learning experiences, identify strengths and weaknesses in IT standards implementation, and explore alternative perspectives. Encourage students to question assumptions, challenge existing practices, and propose innovative IT management and governance approaches.

By implementing these strategies, educators can effectively teach IT standards, ensuring that students develop a deep understanding of theoretical concepts, gain practical skills, and cultivate critical thinking abilities that are essential for success in the IT industry.

3.2 Curriculum Integration

Integrating IT standards into university curricula is essential for preparing students to navigate the complexities of the IT industry. Effective approaches to incorporating IT standards into university courses (Patel & Jones, 2019):

Dedicated Courses on IT Standards

Design dedicated courses that focus specifically on IT standards such as ITIL, COBIT, PRINCE2, or others. These courses can be structured to cover the foundational principles, frameworks, implementation strategies, and real-world applications of each standard. Provide in-depth coverage of each IT standard, allowing students to comprehensively understand its core concepts, principles, and methodologies. This approach enables students to acquire specialised knowledge and skills related to IT standards, making them proficient in their application.

There is also useful to align dedicated courses on IT standards with professional certification exam objectives, preparing students to pursue industry-recognized certifications. Offer resources, study materials, and exam preparation workshops to support students' certification endeavours.

Integration into Existing IT Management, Project Management, or Software Engineering Courses

Integrate modules or units on IT standards into existing courses related to IT management, project management, software engineering, or other relevant disciplines. Embedding IT standards within broader course content ensures that students understand the role of standards in specific contexts and disciplines. Adopt an interdisciplinary approach by integrating IT standards across multiple courses within the curriculum. For example, incorporate ITIL discussions into IT service management courses, integrate COBIT into courses on IT governance, or discuss PRINCE2 in project management courses.

Emphasise the practical applications of IT standards by incorporating case studies, simulations, and project assignments that require students to apply standard frameworks and methodologies to real-world scenarios. This approach reinforces theoretical concepts and enhances students' ability to translate knowledge into practice.

Collaborative Projects and Hands-On Exercises Centered Around IT Standards

Facilitate collaborative learning experiences by organising group projects and team-based assignments centred around IT standards. Assign students to teams and challenge them to analyse, design, implement, and evaluate IT solutions using standard frameworks and methodologies. Design hands-on exercises and practical workshops that allow students to interact with IT standards in a controlled environment. Provide access to simulation tools, software platforms, or virtual environments where students can experiment with implementing IT standards and observe their impact on IT operations.

Foster partnerships with industry organizations, consulting firms, or IT service providers specialising in implementing IT standards. Collaborate with industry partners to develop real-world projects, case studies, or internship opportunities that expose students to authentic IT standards implementation scenarios.

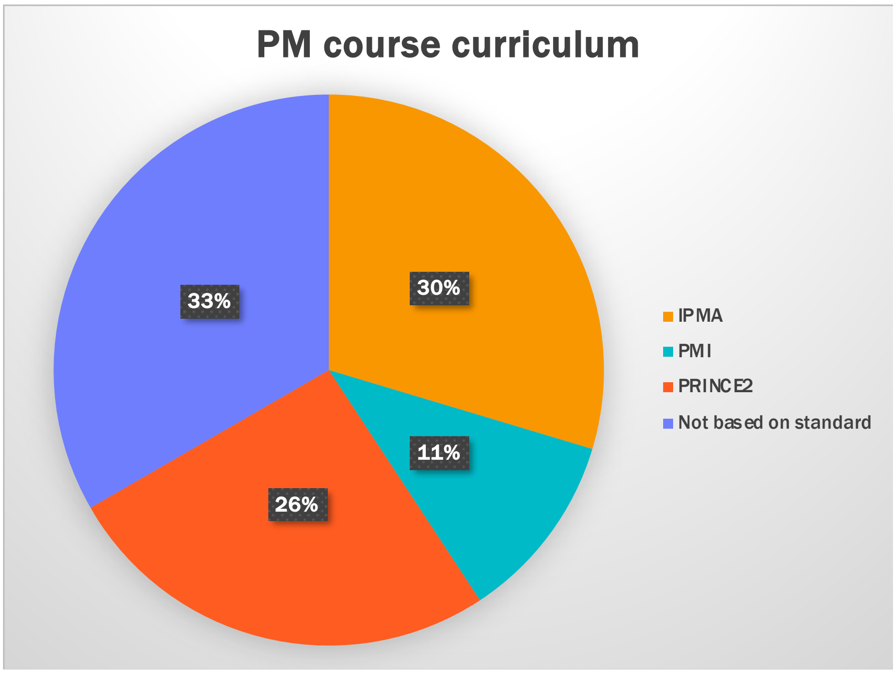
Educators can ensure that students receive a comprehensive education that prepares them to effectively apply standard frameworks and methodologies in their future careers by integrating IT standards into university courses through dedicated courses, module integration, and hands-on exercises.

3.3 Partial outputs of the research

During the year 2021 (April-June and October/November), we researched Slovak university teachers' interest in certification in project management. A survey was conducted to learn how educators are aligned in teaching the project management course with some of the well-known PM methodologies. They also used the possibility of cooperating with the praxis to improve the curriculum quality and knowledge shared with the students.

The survey was answered by 109 educators over 49 faculties within Slovak higher education institutions with the following results.

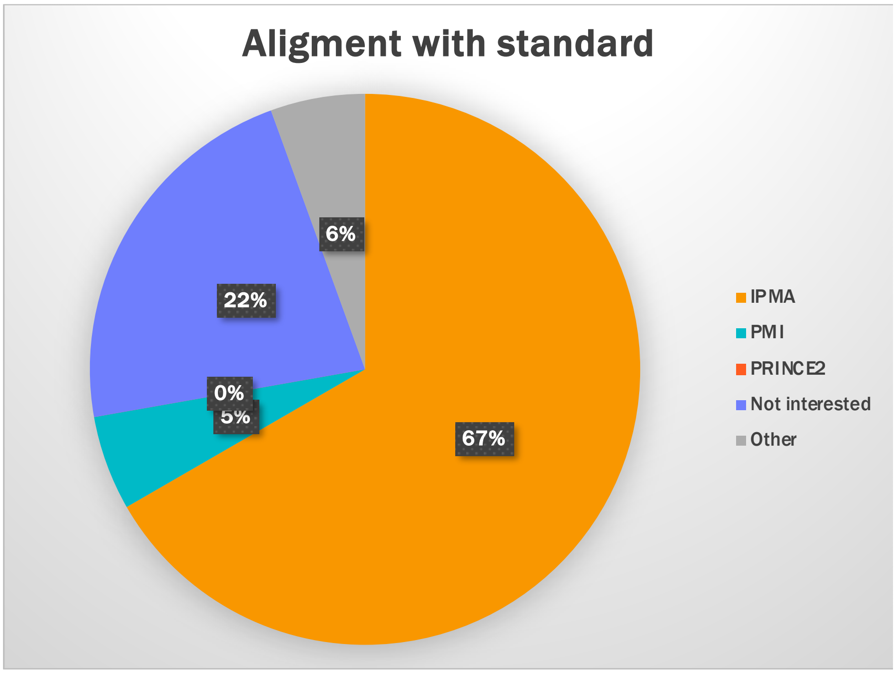
Fig. 3: Coverage of the curriculum by the specific PM standard



Source: Own work

Figure 3 shows that educators at universities teach, in most cases, according to one of the most frequently used standards in the field of PM. 89% of teachers stated that they use either PMI, IPMA, or PRINCE2 methodology when teaching a subject focused on project management.

Fig. 4: Future alignment with the specific PM standard

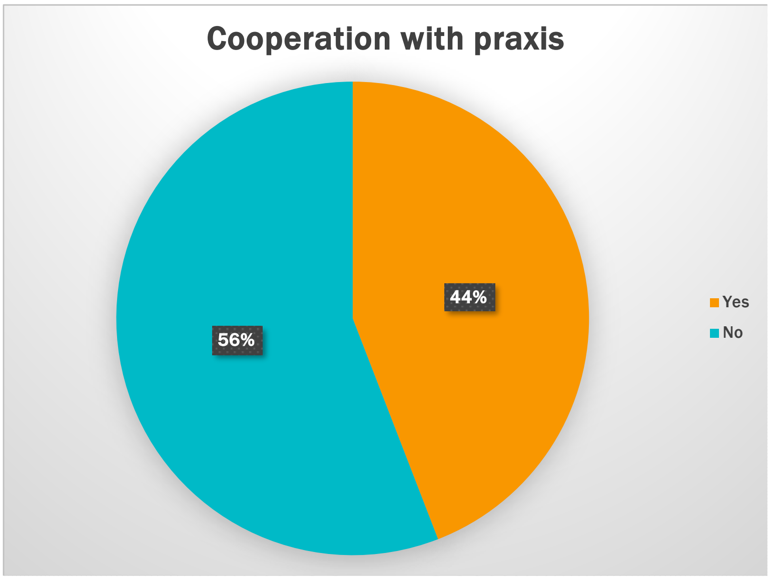


Source: Own work

Figure 4 shows the educators' answers to the questions about starting to use some of the important standards in PM. Almost two-thirds want to implement some of the standards in the future. This indicates that Slovakia's level of alignment with standards is high in the field of teaching project management subjects.

Another interesting part of the survey focused on cooperation with praxis, which is one of the most important pillars in education according to standards.

Fig. 5 Cooperation with the praxis in the PM subjects

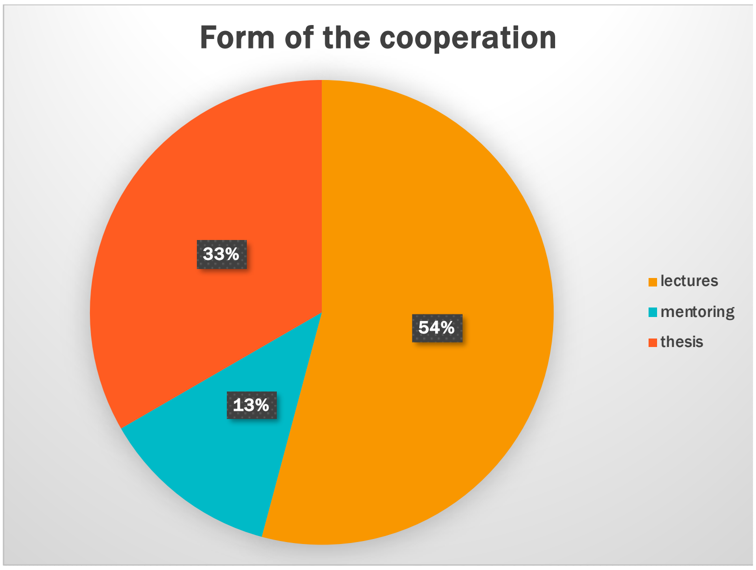


Source: Own work

As is seen in Figure 5, educators partially use the possibility of cooperation with practice. Less than half of the respondents answered that they use this possibility to bring new insights, case studies, cooperation with thesis or mentoring at their lectures.

If the educator uses an offer that, in many cases, in in the form of lectures (54%), then followed by thesis coaching (33%) and last but not least, mentoring (13%)

Fig. 6: Form of the cooperation with the praxis



Source: Own work

Our partial research revealed consistency or room for improvement regarding incorporating the standards into teaching. We started around project management and will continue in other areas of IT management.

4 Conclusion

As the IT industry evolves rapidly, equipping students with a comprehensive understanding of industry standards is essential for their success in the dynamic and competitive landscape. Educators empower students with frameworks such as ITIL, COBIT, PRINCE2, and others by empowering them with the tools and knowledge needed to excel in their future careers. IT standards provide a common language and framework for IT professionals, ensuring consistency, efficiency, reliability, and security in IT operations. They also enhance employability, as graduates with knowledge of industry standards are better prepared to meet the demands of employers and contribute effectively to organisational success.

Our research revealed quite a good pace among the Slovak higher education teachers and their approach to the incorporation of standard methodologies used. We could see that the educators perceive the need to modernise teaching and adapt to new knowledge in the IT area.

Educators must prioritize integrating IT standards into their curricula to ensure students receive comprehensive and relevant education. Educators can provide students with the skills, knowledge, and mindset needed to thrive in the IT industry by incorporating IT standards into courses, modules, and practical exercises. This integration should be ongoing and proactive, with educators continually updating course content to reflect the latest developments in IT standards and industry best practices. This article offers possible integration into the everyday education process in several ways.

Resources

AXELOS. (2017) Managing successful projects with PRINCE2. 6th Edition. London: The Stationery Office. 15-18

AXELOS. (2020). ITIL Foundation. ITIL 4 Edition. London: The Stationer Office. 37-39

GARCIA, L., & MARTINEZ, E. (2017). Integrating ITIL into university courses: Lessons learned and best practices. Computers & Education, 109, 12-24.

HORNIAKOVA, V. (2022). Information system management. Vol. 1, 12-18

LEE, A., & WONG, B. (2019). Challenges and solutions in teaching COBIT: A case study approach. Journal of Information Systems Education, 30(2), 89-104.

ISACA. (2012) COBIT 5 Framework. Schaumburg: ISACA. 24-28

NGUYEN, T., & TRAN, H. (2018). Teaching PRINCE2 in university project management courses: A comparative analysis. Journal of Project Management Education, 23(1), 45-62.

PATEL, R., & JONES, M. (2019). The importance of teaching IT standards: A perspective from industry experts. Journal of Computer Science Education, 12(1), 89-104.

SMITH, J. A., & JOHNSON, L. B. (2020). Integrating IT standards into university curricula: Challenges and opportunities. Journal of Information Technology Education, 19(3), 123-137.

WANG, Y., & LEE, C. (2018). Enhancing student engagement in teaching IT standards: A case study approach. International Journal of Information Management, 38(2), 45-60.

SURVEY OF ONLINE TEACHING EVALUATION AT SLOVAK UNIVERSITIES DURING THE COVID-19 PANDEMIC FROM THE PERSPECTIVE OF TEACHERS

Pavol Jurík[13], Gregor Bilčík[14], Mária Szivósová[15]

Abstract
From 2020 to 2022, the COVID-19 pandemic affected many areas of social life, including education. Individual states adopted various safety measures to stop or slow down the spread of the disease based on the recommendations of the World Health Organization, including lockdowns. In this article, we will focus exclusively on the field of higher education in Slovakia during the pandemic, which was implemented in a distance way using various e-learning tools. The transition to distance education was perceived differently among teachers, and it was possible to meet both positive and negative reactions. This article will discuss the survey results of teachers teaching at Slovak universities in more detail. Our goal was to determine how the transition from face-to-face education to distance education was perceived by teachers at Slovak universities during the COVID-19 pandemic and which e-learning tools were used to support the teaching process.

Keywords
COVID-19, distance education, e-learning, higher education, teachers, pandemic

1 Introduction

Many challenges marked the year 2020. Perhaps the biggest challenge was managing the COVID-19 pandemic, which unexpectedly affected the lives of billions of people worldwide. The pandemic has affected many areas of human life, including education. Education was faced with ensuring the continuity of education even when everything seemed uncertain. Due to this problem, a diploma thesis was created at the University of Economics in Bratislava titled *Survey of Online Teaching at Slovak universities during the COVID-19 pandemic*. Ing. Gregor Bilčík wrote this diploma thesis under the guidance of Ing. Pavol Jurík, PhD. Our goal was to survey and determine by what means online teaching was implemented at Slovak universities during the forced transition to distance learning to prevent spreading the disease. As part of the survey, we also focused on the overall evaluation of this type of education compared to traditional face-to-face education (i.e. education in classrooms) from the point of view of teachers and students. Because of this, we implemented two online questionnaire surveys – the first was intended for teachers, and the second one was intended for students. The maximum allowed scope of this article does not allow us to present the results of both surveys. Therefore, in this article, we will

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focus only on the survey conducted with teachers. The student's point of view will be presented in a separate article.

2 State of the art

Online and distance education via the Internet using various e-learning tools formed the foundation for ensuring the educational process during the pandemic. The topic of online teaching and learning has been the subject of several research studies. Martin, Sun, and Westine prepared a systematic review of research on online teaching and learning from 2009 to 2018. In the scientific article, the authors summarise and follow up on previous systematic reviews dating back to 1990. The review showed that in the last decade, the focus of research shifted from instructional characteristics and course design in online education to online engagement and learner characteristics (Martin et al., 2020).

As the study above suggests, online education has existed for a while. However, the arrival of the global pandemic led to its massive spread among students and teachers in Higher education. This has led to the emergence of new studies and surveys similar to ours focused on the field of online teaching in universities during the pandemic. For example, a study from Bangladesh found that university teachers consider online teaching an effective way of teaching during the pandemic. During the pandemic, more than 3/4 of the surveyed respondents preferred online teaching. However, when the question is based on the choice of the preferred method of teaching after the end of the pandemic, a plurality of teachers (45.43%) preferred face-to-face, and slightly fewer teachers (44.52%) preferred a combined (hybrid) mode of teaching. Only 10.05% of teachers in the survey preferred purely online teaching after the end of the pandemic. In the case of e-learning tools to provide online teaching, specifically web-conferencing software, most teachers in Bangladeshi universities used the Zoom platform (Saha et al., 2022). We have different results from a similar survey, but from Europe, which focused on university teachers in Romania. In this survey, the respondents chose MS Teams as the most used web-conferencing software (Barbu et al., 2022).

The use of different software tools and hardware requirements may indicate that such a sudden and massive expansion of online learning was associated with technical problems. The results of a survey of several European university teachers by Schütte et al. confirm their occurrence, but the authors in the scientific article conclude that the problems of online teaching were primarily of a social nature rather than a technical one. This survey showed that teachers lacked direct student interactions (Schütte et al., 2021). This identified drawback of online teaching is in line with the results of a survey from the University of L'Aquila in Italy, where the absence of direct "face-to-face" contact was the main drawback of online teaching considered by teachers (Casacchia et al., 2021).

In Slovakia, studies on online education focus more on students‘ points of view. Surveys have been conducted among university teachers on this topic, but these were isolated surveys at individual schools or faculties. However, there have been fewer nationwide surveys. In their research, Hvorecký et al. (2021) conducted an online survey in which teachers from Slovak and Czech universities participated. The survey was focused on the transition from on-site face-to-face teaching to fully online teaching. The survey results were analysed as a whole, not separately according to the country they teach. The study showed that most teachers had no previous experience with online teaching, and the sudden transition from face-to-face to online teaching caught them unprepared. However, based on the data, the authors state that university teachers could adapt very quickly to the new mode of education. In addition, Hvorecký et al. found that since the pandemic hit, more teachers had started synchronous online teaching in real-time compared to the period before the lockdowns, which was characterised more by asynchronous online teaching.

Considering the future of online teaching, teachers saw online teaching as only a temporary substitute for face-to-face teaching (Hvorecký et al., 2021).

3 Methodology and goal

The questionnaire survey intended for teachers was carried out from February 19, 2023, to April 3, 2023, and 313 respondents participated. Teachers from 16 Slovak universities were approached (two universities were selected from each region of the Slovak Republic). The number of teachers included in the study in terms of which university they taught at was as follows (Table 1).

Tab. 1: Number of teachers included in the study from different universities

University	Absolute number	Relative number
University of Economics in Bratislava	59	18.85%
Catholic university in Ruzomberok	25	7.99%
University of Prešov in Prešov	19	6.07%
Slovak University of Agriculture in Nitra	16	5.11%
Technical University of Zvolen	18	5.75%
Alexander Dubček University of Trenčín in Trenčín	8	2.56%
Trnava University in Trnava	13	4.15%
Comenius University in Bratislava	29	9.27%
Constantine the Philosopher University in Nitra	24	7.67%
Matej Bel University in Banská Bystrica	20	6.39%
Pavel Jozef Šafárik University in Košice	9	2.88%
University of St. Cyril and Methodius in Trnava	26	8.31%
University of Veterinary Medicine and Pharmacy in Košice	14	4.47%
DTI University in Dubnice nad Váhom	4	1.28%
University of Žilina in Žilina	29	9.27%
In total	**313**	**100%**

Source: authors

In our survey, we had the largest representation of university teachers from the University of Economics in Bratislava, numbering 59, constituting 18.85% of the entire sample of respondents. The smallest number of respondents were from DTI University in Dubnica nad Váhom, numbering 4, representing 1.28% of all respondents. We also approached teachers from University ISM Slovakia Prešov, but we did not manage to obtain any responses from this school.

Our goal was to find out how the transition from face-to-face education to distance education was perceived by teachers at Slovak universities during the COVID-19 pandemic and which e-learning tools were used to support the teaching process.

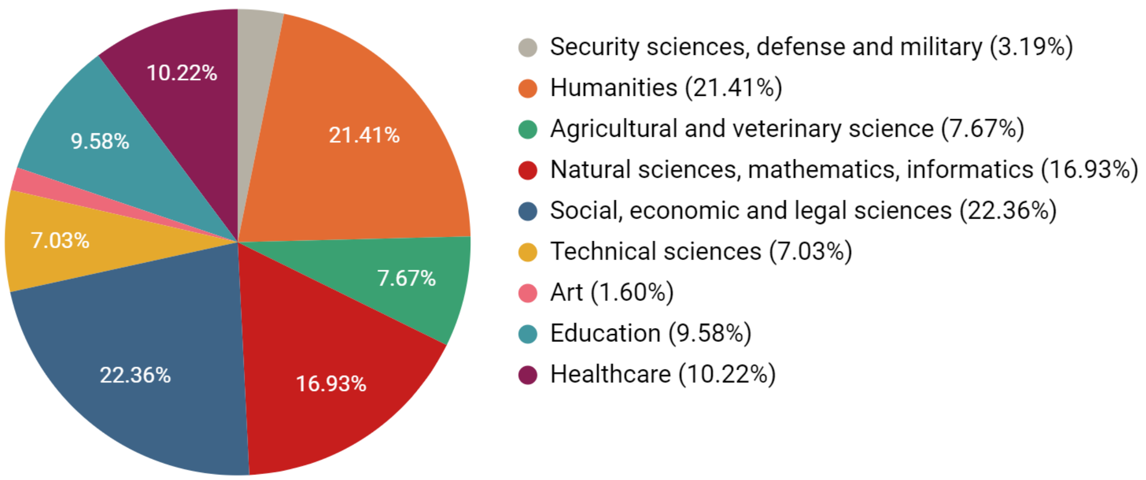
The questionnaire for teachers consisted of 11 items, all of which were in the form of questions. There were 10 closed questions and 1 semi-open question in this questionnaire. There were single-choice and multiple-choice questions (the so-called "tick boxes were used") when the respondent could choose more than one answer.

Universities are usually divided into faculties, which are further divided into smaller workplaces (departments, institutes, clinics, etc.). At each faculty, we selected at least one workplace whose teachers we tried to contact. At individual faculties, we prioritised workplaces with the highest number of teaching staff. We have contacted the heads of the selected workplaces, or their secretariats, by e-mail or in person and asked whether we may contact the teachers of the given workplace with a request to fill out our questionnaire. With the leaders' approval, we sent an e-mail message to each teacher of the chosen workplace with information about the survey and a link to the online questionnaire. The teachers' e-mail addresses were publicly available on the official websites of the selected schools or workplaces. In many cases, however, the heads of the workplaces were willing to forward our questionnaire directly to the workplace teachers, or it was forwarded through the secretariat. (it was *the avalanche sampling method*). However, some workplace managers did not respond to our messages.

The avalanche sampling method is based on the principle that one person is contacted, and that person sends the questionnaire to other persons whom the contacted person knows and who fall within the respondent criteria for the given survey. These persons may be able to forward the questionnaire further. The answers are, therefore, "wrapped up" by further sending, and the effect resembles the formation of a snowball.

We also investigated the structure of the respondents in terms of their fields of study. In doing so, we used the classification of study fields, which is presented by "Portál Vysokých Škôl" (which means *Universities Portal* in Slovak language) on its website (Portál VŠ, 2023). This classification and the representation of teachers from the survey in its categories are shown in Figure 1. Most respondents were from the fields of Social, economic, and legal sciences (22.36%). They were followed by Humanities (21.41%), Natural sciences, mathematics, and informatics (16.93%), Healthcare (10.22%), Education (9.58%), Agricultural and veterinary science (7.67%), Security sciences, defence and military (3.19%). The fewest respondents were from the Arts category (1.60%).

Fig. 1: The structure of respondents' fields of study according to the classification of fields of study used by „Portál Vysokých skôl" (Universities Portal)

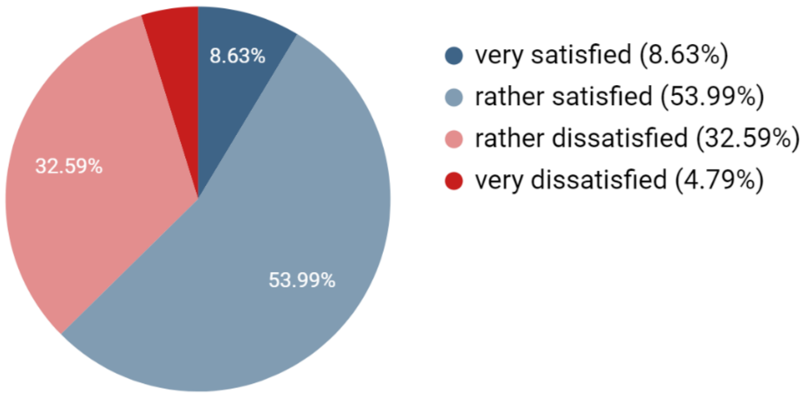


Source: Authors

4 Results

At first, we monitored teachers' overall satisfaction with online teaching. The survey showed that 8.63% of teachers were *very satisfied* with online teaching, and 53.99% were *rather satisfied*. Thus, we can conclude that most teachers were satisfied with online teaching. Regarding the negative answers, we found that 32.59% of teachers were *rather dissatisfied*, and 4.79% were *very dissatisfied*. This data can be seen in Figure 2.

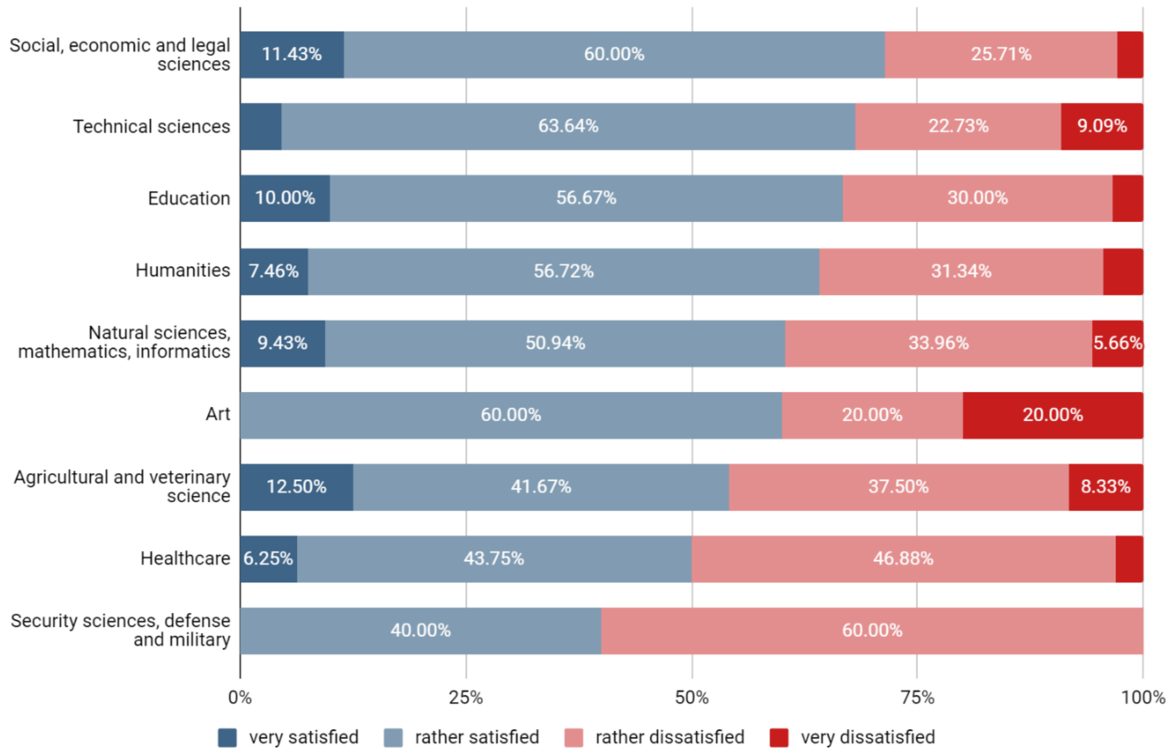
Fig. 2: Overall satisfaction of teachers with online teaching during the pandemic



Source: Authors

We also evaluated teachers' satisfaction with online teaching according to the categories of taught subjects. The most satisfied teachers in our survey were teachers of *Social, economic, and legal sciences* (60% were rather satisfied, and 11.43% were very satisfied. Thus, 71.43% were satisfied). However, seeing the data we can conclude that satisfaction prevailed in all but one category. The only category where dissatisfaction prevailed was Security, defence, *and military*. In this category, 60% of teachers were dissatisfied, and 40% were satisfied. Interesting is also the result we obtained for teachers who classified their subjects in the category of *Healthcare*. In this category, satisfaction came out exactly 50/50, i.e. 50% of teachers were satisfied (very satisfied or rather satisfied), and 50% were dissatisfied (very dissatisfied or rather dissatisfied). The exact data on teachers' satisfaction with online teaching during the COVID-19 pandemic, according to the classification of their subjects into groups of study fields, can be seen in Figure 3.

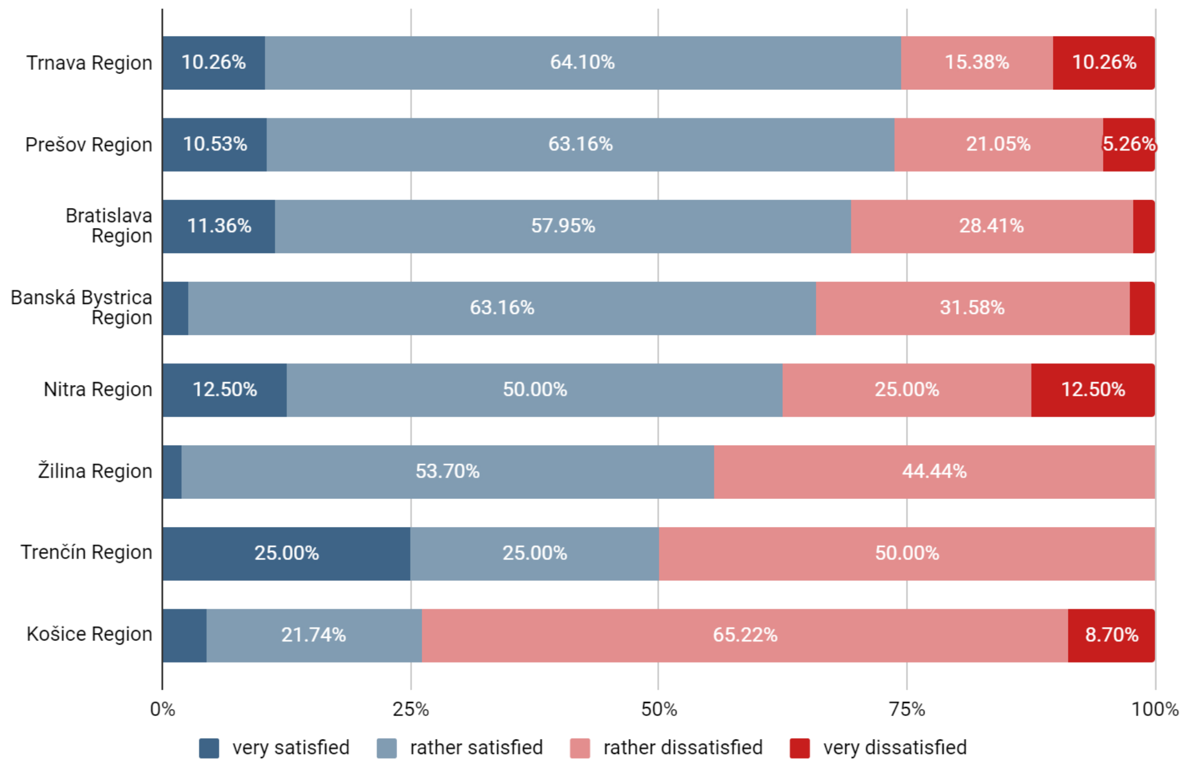
Fig. 3: Teachers' satisfaction with online teaching during the COVID-19 pandemic according to the classification of their subjects into groups of study fields



Source: Authors

The level of satisfaction can also be evaluated based on the regions (Figure 4) in which the schools where the respondents teach are located. We noted significant dissatisfaction among the teachers who work in the Košice region, where up to 73.92% of respondents expressed dissatisfaction (thus, they were very dissatisfied or rather dissatisfied) with online teaching during the pandemic. The most satisfied were teachers working in the Trnava region, in which 64.10% of teachers expressed themselves to be rather satisfied and 10.26% were very satisfied in the questionnaire. Thus, we can conclude that 74.36% of teachers in the Trnava region were satisfied with online teaching during the pandemic. The answers in the Prešov region were very similar to the Trnava region. 63.16% of respondents in the Prešov region were rather satisfied, and 10.53% of respondents were very satisfied. Thus, the total satisfaction rate in this region was 73.69%. In the third place in terms of satisfaction was the Bratislava region (69.31% of respondents in this region were very satisfied or rather satisfied).

Fig. 4: Teachers' satisfaction with online teaching during the COVID-19 pandemic according to the regions in the Slovak Republic in which they operate/work



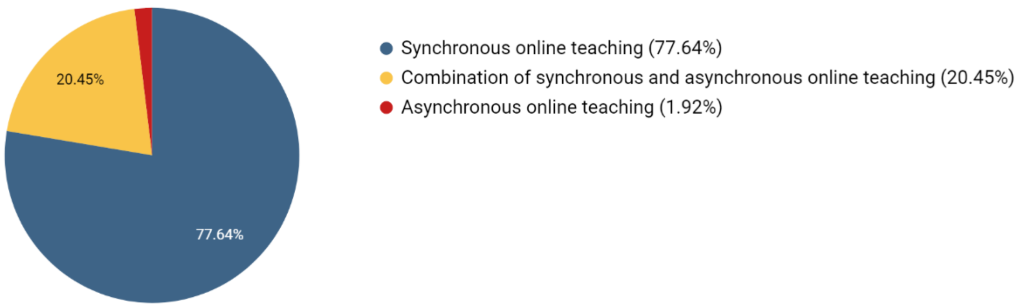
Source: Authors

Online education can be conducted in one of three ways:

1. *synchronously* – in an interactive way in real-time (students and the teacher must be online at the same time),
2. *asynchronously* – with a time delay (students and the teacher don't need to be online at the same time),
3. or *as a combination of these two methods* (some activities are done synchronously, while others are done asynchronously).

Our survey found that Slovak university teachers mainly used *synchronous online teaching* (77.64%). This is mainly because the synchronous type of online teaching is the closest to face-to-face teaching. In addition, 20.45% of teachers stated that they *combined elements of both synchronous and asynchronous teaching*. Only 1.92% of teachers exclusively applied the *asynchronous online teaching method* during the pandemic. The preference for synchronous, asynchronous, or combination teaching among the teachers at Slovak universities during the COVID-19 pandemic can be seen in Figure 5.

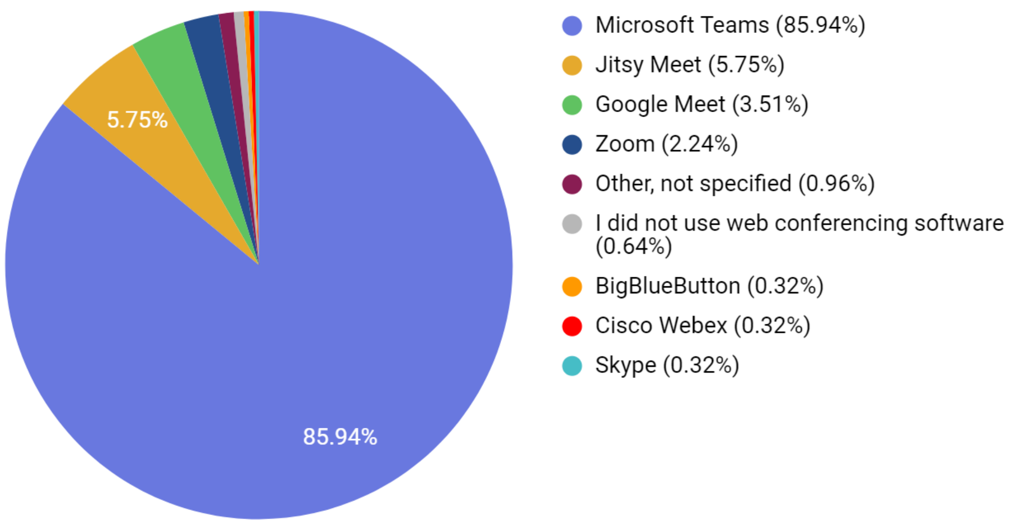
Fig. 5: The preference for synchronous, asynchronous, or combination teaching among teachers during the COVID-19 pandemic



Source: Authors

Our survey respondents were also asked to select their primary web-conferencing software during the COVID-19 pandemic. Up to 85.94% of teachers chose *Microsoft Teams*, followed by the *Jitsi Meet* platform (5.75%) and *Google Meet* platform (3.51%). This points to the clear dominance of MS Teams software, which does not necessarily mean it is the best in its category. It is just the most commonly used one. Other systems such as Jitsy Meet, Zoom, Google Meet, BigBlueButton, or Skype were only used in a negligible number of cases. The share of use of individual web conferencing software among teachers at Slovak universities during the COVID-19 pandemic can be seen in Figure 6.

Fig. 6: Share of use of individual web-conferencing software among teachers



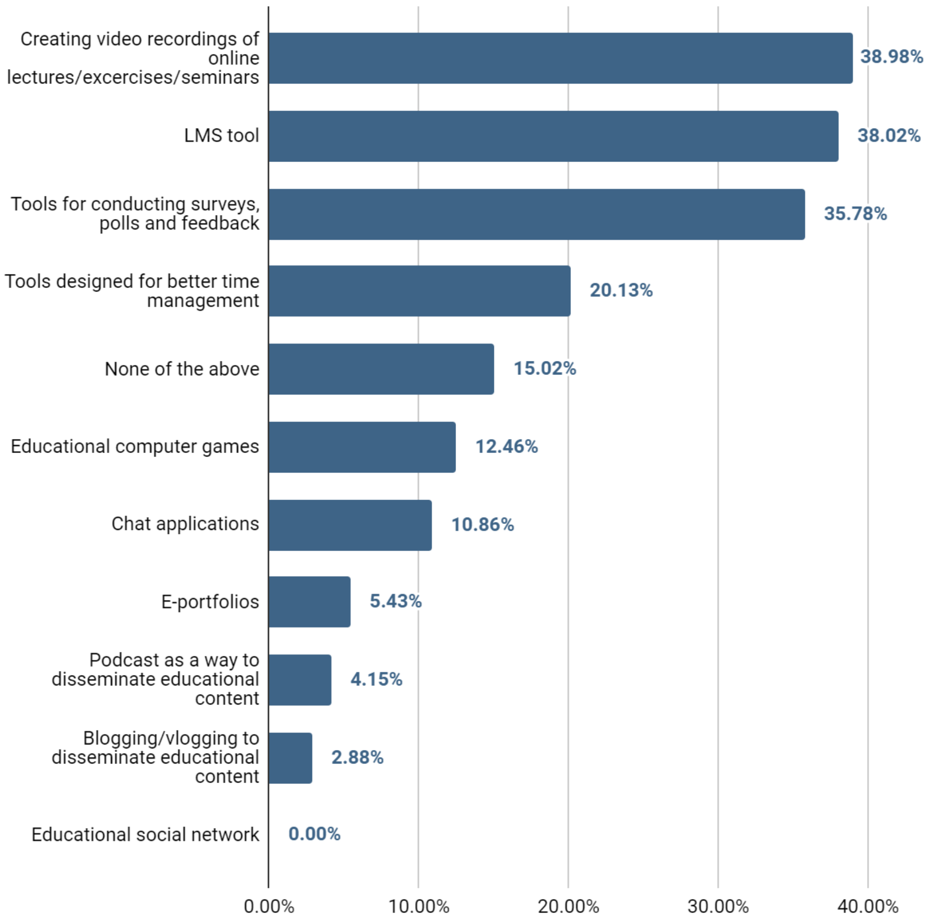
Source: Authors

MS Teams is a complex system supporting teaching, part of the Microsoft 365 package. It allows real-time transmission of both video and audio (i.e. streaming of lectures and exercises), creation of events representing distance learning hours, viewing and sharing of presentations and other documents with other participants, chatting with participants, writing on a virtual whiteboard, reporting for a word by raising the virtual hands, testing students based on live image and sound transmission (streaming) and other useful functionalities.

Microsoft 365 package (known as Office 365 until April 2020) is a set of cloud services provided by Microsoft on a subscription basis. When it was first introduced in 2011, this package was primarily intended for the corporate sector, but two years later, a variant intended for end users was also launched on the market. It includes applications and services such as Word text editor, Excel spreadsheet, PowerPoint presentation editor, Outlook mail client, OneDrive cloud data storage, OneNote note editor, Teams for Education comprehensive educational support system, and others.

In addition to web-conferencing tools, we tried to find other e-learning tools teachers used to support online teaching during the pandemic. The teachers answered our question: "Which other e-learning tools from the ones listed did you use during online teaching?". It was a closed question, and the respondents could choose one or more options offered in advance. The options offered to the respondents are based on Jurík's classification of e-learning tools (Jurík, 2021). The answers to the above-mentioned question are shown in Figure 7.

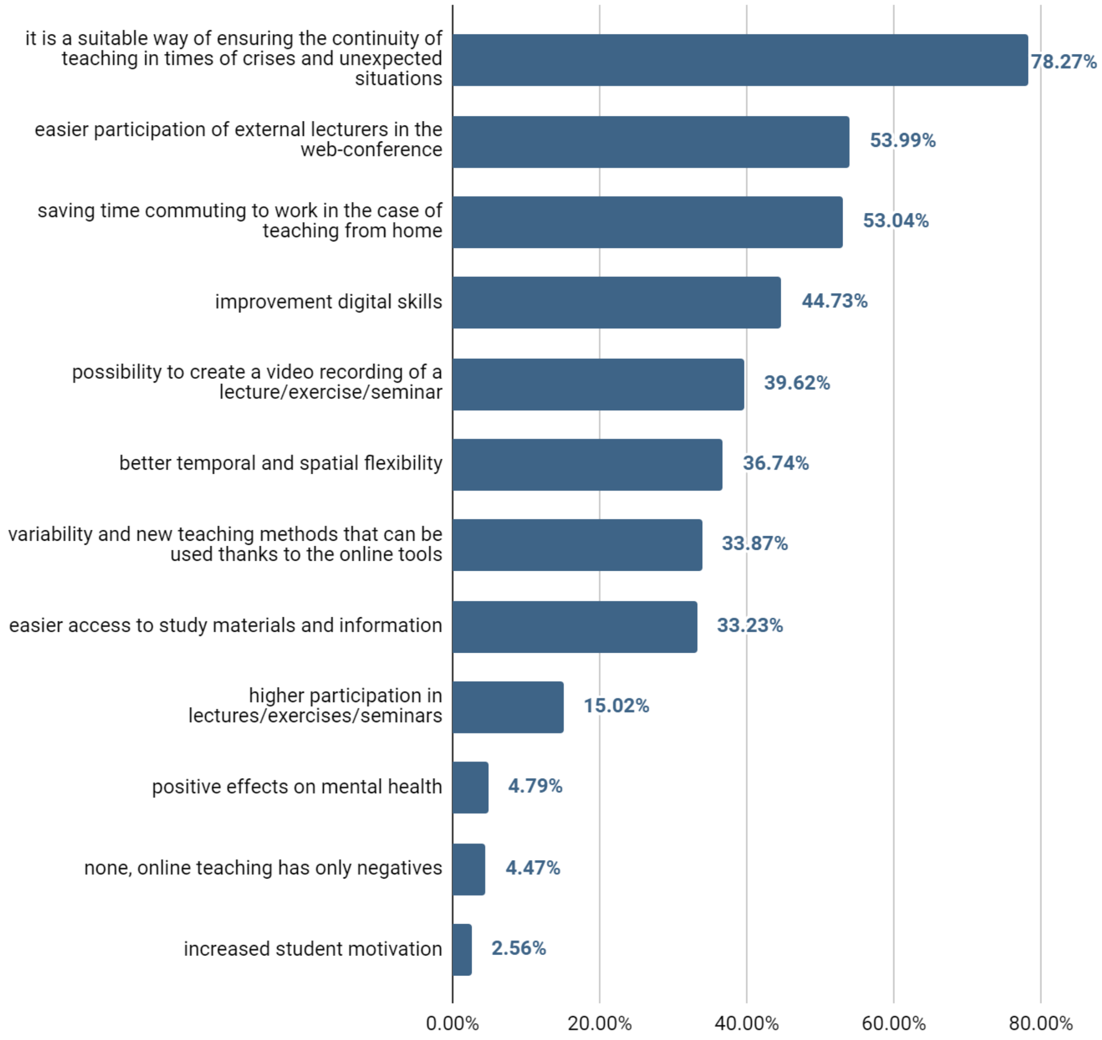
Fig. 7: Various e-learning tools used by teachers during the pandemic



Source: Authors

Among the different options, *the possibility of creating video recordings from online lectures/exercises/seminars* received the most positive answers. 122 teachers created video recordings from teaching units out of a total of 313, which represents 38.98% of teachers from the entire sample. Fewer teachers said they used an *LMS (Learning Management System)* tool (38.02%). According to Simonson, learning management systems are "software systems designed to assist in managing student courses, particularly by assisting instructors and students with course administration. Such systems usually make it possible to track the progress of individual students. They are primarily intended to support distance learning, but are also often used to support face-to-face classroom instruction." (Simonson, 2007).

Fig. 8: The main benefits of online teaching from the perspective of teachers



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The third most numerous answer to this question were *tools for conducting surveys, surveys, and feedback* (35.78%). This is followed by *tools for better time management* (20.13%), *educational computer games* (12.46%), and *chat applications* (10.86%). Some teachers used *e-portfolios* (5.43%), *podcasts* (4.15%) or they were *writing blogs* (2.9%). No respondent used an *educational social network* (for example, Edmodo falls into this category).

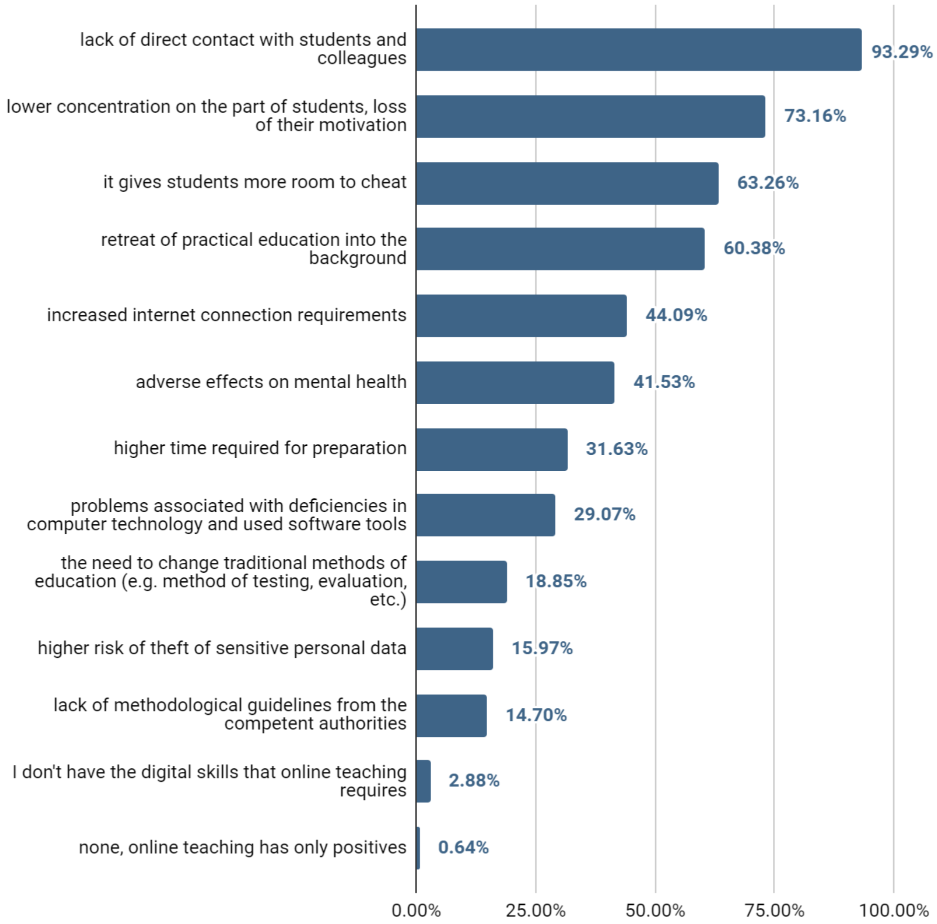
At the same time, it should be noted that 15.02% of teachers told us that they did not use any tool from the possibilities that we offered them.

In the next question, we asked the teachers what they considered the main benefits of online distance teaching. The survey allowed them to choose one or more answers. All benefits arranged in descending order according to their percentage frequency are captured in Figure 8 on the previous page.

We found out that 78.28% of teachers consider online teaching a suitable way to ensure the continuity of teaching in times of crises and unexpected situations. More than half of the teachers also consider the *possibility of easier participation of external lecturers in web conferences* and the *possibility of saving time commuting to work while teaching from home*, among the main benefits of online teaching. On the other hand, *positive effects on mental health* and *increased motivation* were perceived as the main benefits of online teaching only by a low proportion of respondents (less than 5%). 4.47% of teachers think that online teaching has only negatives.

After the question focused on the benefits of online distance teaching, in the next question, we asked the teachers about the main drawbacks of this approach. As in the previous question, in this one, the teachers had pre-prepared options from which they could choose one or more. The results of the answers to the question about the drawbacks of online distance teaching from the teachers' point of view are presented visually in Figure 9.

Fig. 9: The main drawbacks of online teaching from the perspective of teachers



Source: Authors

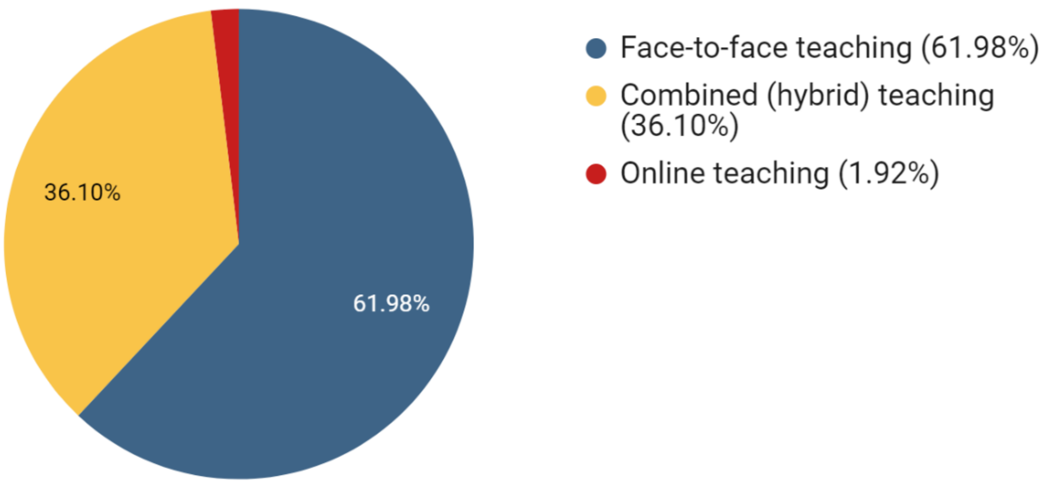
By far, the most significant drawback of online teaching perceived by teachers was *the lack of direct contact with students and colleagues*, according to 93.29% of respondents. Many teachers also considered students' lower concentration and loss of motivation one of the biggest drawbacks of online teaching (73.16%). Up to 63.26% of teachers also think online teaching provides *more room for students to cheat*.

Given the duration of pandemic restrictions in Slovakia and the various stages of their easing, many teachers had the opportunity to teach online for several semesters. Thus, they can compare individual types of teaching. We tried to find out their preferences in our survey. There are 3 basic types of teaching:

- face-to-face teaching (in a classroom)
- online (distant) teaching
- combined (hybrid) teaching, which combines face-to-face and online teaching – an effective way of implementing a combined form of teaching at universities can be, e.g. conducting lectures in a distance online format and exercises in a face-to-face format directly in the classrooms. Lectures usually do not require practical work from students. They are more about the interpretation of theoretical knowledge, which, in most cases, students can also participate remotely without problems, and it will fulfil the same purpose. It is mainly a one-way transfer of information from the teacher to the students. Exercises, or however, seminars, generally require practical work by students and increased communication with the teacher and each other – if they perform teamwork in groups.

In our survey, we have found out that most teachers (61.98%) prefer face-to-face teaching. This form of teaching is followed by combined (hybrid) teaching (36.10%). Online teaching was preferred only by 1.92% of teachers. These numbers can be seen in Figure 10.

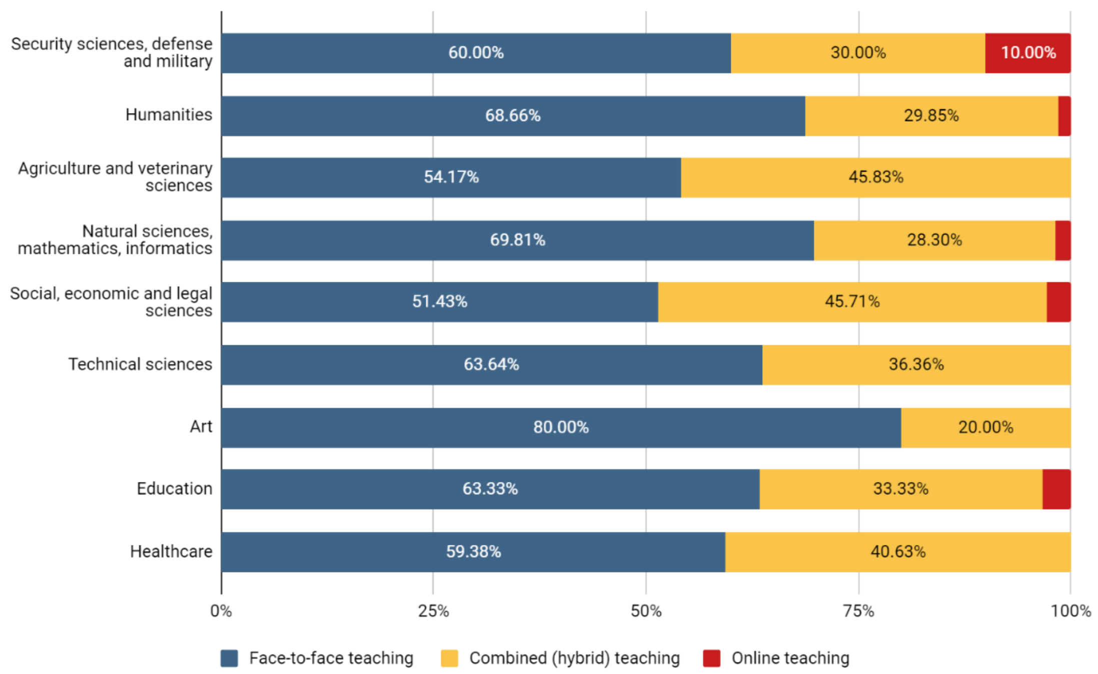
Fig. 10: Teachers' preferred form of teaching



Source: Authors

We also analysed the teachers' preferred form of teaching according to the classification of their subjects into groups of fields of study (Figure 11). Again, we have used the classification of the fields of study which is presented by “Portál Vysokých škôl“ (which means Universities Portal in Slovak language) on its website (Portál VŠ, 2023). We discovered that face-to-face teaching made up more than half of the share in all categories of taught subjects. It was most preferred by teachers from the field of Art (80%). Face-to-face teaching was the least preferred among teachers of Social, economic, and legal sciences (51.43%). We also found that face-to-face teaching was preferred in all Slovak regions. The highest preference was in the Košice region (78.26%), and the lowest in the Bratislava region (50%).

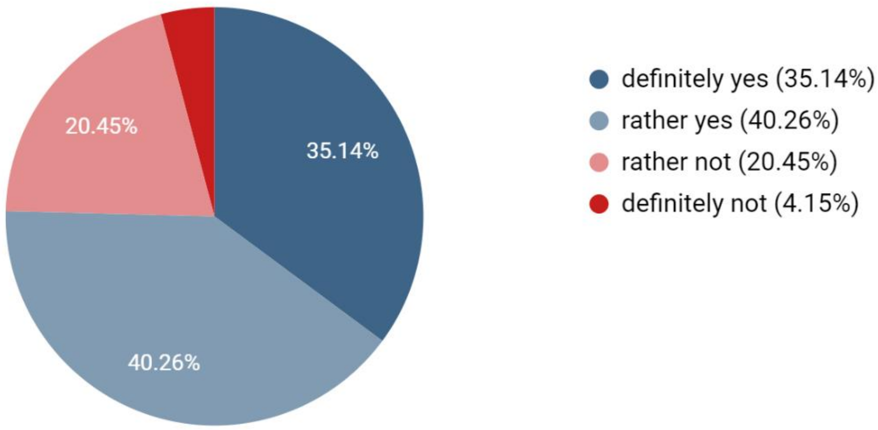
Fig. 11: Teachers' preferred form of teaching according to the classification of their subjects into groups of fields of study



Source: Authors

At the end of the survey, we asked the teachers whether they plan to incorporate some elements of online teaching into face-to-face teaching. 35.14% of respondents stated that they *plan* to incorporate elements of online teaching during in-person classes. About 40.26% of teachers leaned towards the option of *rather yes*. The remaining teachers in the survey chose responses from the negative part of the scale, with 20.45% preferring *rather not* and 4.15% *not*. These results can be seen in Figure 12.

Fig. 12: Teachers' intention to incorporate elements from online teaching also during face-to-face teaching



Source: Authors

5 Conclusion

Among the key findings from the conducted questionnaire survey, we can include the following in particular:

- Most of the teachers who participated in the survey implemented online teaching interactively in real time - they used synchronous online teaching (or also synchronous access). About one-fifth of the teachers combined the synchronous approach with the asynchronous approach.
- The most used web-conferencing tool was Microsoft Teams.
- Teachers often recorded their teaching units in the form of videos and used LMS tools (Learning Management System) and tools for conducting surveys, questionnaires, and obtaining student feedback.
- More than half of the teachers surveyed were either rather satisfied or very satisfied with online teaching. Thus, less than half of the teachers were dissatisfied.
- Online teaching appears to be a suitable way to ensure the continuity of the educational process in times of crises and unexpected situations. This was the most numerous answer regarding the benefits of online teaching (78.27% of respondents said this).
- Most of the teachers in our survey considered the lack of direct contact with students or colleagues as the main drawback of online teaching (93.29%). According to this information, we can conclude that online teaching cannot fully replace real social contact at the moment.
- More than half of teachers prefer face-to-face teaching (61.98%) over distant education.
- 34.14% of teachers plan to apply elements from online teaching also in face-to-face teaching after the experience gained during the pandemic, while 40.26% of teachers said that they rather plan to apply elements from online teaching in face-to-face teaching.

6 Acknowledgement

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Resources

Barbu, A., Popescu, M.-A.-M. & Moiceanu, G. (2022). Perspective of Teachers and Students towards the Education Process during COVID-19 in Romanian Universities. *International Journal of Environmental Research and Public Health, 16(6)*. https://doi.org/10.3390/ijerph19063409

Casachia, M., Cifone, M.-G., Giusti, L. et al (2021). Distance education during COVID-19: an Italian survey on the university teachers‘ perspectives and their emotional conditions. *BMC Medical Education 21*. https://doi.org/10.1186/s12909-021-02780-y

Hvorecký, J., Beňo, M., Ferenčíková, S., Janoščová, R. & Šimúth, J. (2021). Czech and Slovak Educators‘ Online Teaching Experience: A Covid-19 Case Study. *Acta Informatica Pragensia: Journal of Social and Business Informatics, 10(3),* 236-256. https://doi.org/10.18267/j.aip.162

Jurík, P. (2021). Stručný prehľad e-learningových nástrojov a možností ich používania. *PEDAGOGIKA.SK,* (2), pp. 68–84.

Martin, F., Sun, T. & Westine, C.-D. (2020). A systematic review of research on online teaching and learning from 2009 to 2018. *Computers & Education, 159*. https://doi.org/10.1016/j.compedu.2020.104009

Portál VŠ. (2023). *Študijné programy rozdelené podľa odborov*. PortalVS.sk. https://www.portalvs.sk/sk/.

Saha, S.-M., Pranti, S.-A., Rana, J., Islam, J. & Hossain, E. (2022). Teaching during a pandemic: do university teachers prefer online teaching? *Heliyon, 8(1)*. https://doi.org/10.1016/j.heliyon.2021.e08663

Schütte, P.-M., Van der Sypt, G., Gabriel, A. & Kretschmer, S. (2021). Teaching in higher education during COVID-19 pandemic – Empirical findings and assumptions based on results of an online survey in a European context. *7th International Conference on Higher Education Advances (HEAd'21) Universitat Politecnica de Valencia, Valencia, 2021*. http://dx.doi.org/10.4995/HEAd21.2021.12905

Simonson, M. (2007). Course Management Systems. *Quarterly Review of Distance Education, 8*(1), 7–9.

OVERVIEW STUDY OF CURRENTLY USED INNOVATIVE TEACHING METHODS AT SLOVAK TECHNICAL UNIVERSITIES

Janette Kotianová[16], Zuzana Červeňanská [17]

Abstract

Our contribution provides an overview of innovative teaching methods and forms that are used today at Slovak universities, primarily those that are technically oriented. We focus mainly on methods and forms of teaching in areas such as mathematics, statistics, and related data analysis, respectively on technical subjects. Our claims are supported by the results of a survey obtained through a questionnaire addressed to randomly selected teachers at Slovak universities with the above specialisation.

Keywords

Education at technical universities, Innovative teaching methods, Questionnaire, Overview study

1 Introduction

The quality of Slovak education is declining in international comparisons. This is evidenced, for example, by the deteriorating indicators in the PISA and PIAAC tests. In the ranking of world universities in 2023, Slovak University ranked 589th as the best. A significant part of high school graduates continues their university studies abroad, especially to the neighboring Czech Republic. According to the Czech Ministry of Education, 20 900 Slovak students studied at Czech universities last year. Most have no plans to return to Slovakia after completing their studies. Slovakia is, therefore, forced to look for ways to motivate young people not to leave.

2 Overview of the current state of the issue

Lectures are a well-known form of teaching in tertiary education. However, as described by (Sivarajah et al., 2019) there are many newer innovative teaching skills, pedagogical techniques and forms of educational technology that teachers can use. The role of universities as a source of knowledge for regional innovation processes was investigated by (Fritsch & Slavtchev, 2007). Many innovative teaching methods in higher education are constantly being developed to engage students better and improve their learning. Some innovative methods will be mentioned further in the article.

Problem-based learning and Project-based learning are student-centred learning approaches that involve active learning, critical thinking, and application of knowledge in

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practical scenarios. While problem-based learning aims to facilitate student learning by solving complex real-world problems, project-based learning involves the creation of some output, namely a project. (Maros, 2023), (Tsybulsky, 2019)

The Flipped Classroom involves an inversion of the traditional teaching methods. (Sertic at al., 2020) This method involves students engaging with lecture material at home through videos or readings, while class time is devoted to discussions, problem-solving, and interactive activities.

Active learning can be ensured by encouraging students to be actively involved in the learning process through discussions, debates, case studies and practical activities instead of passively listening to lectures.

The Jigsaw method is a pedagogical strategy that promotes collaboration and mutual learning among students. It is based on the principle that a group of students is divided into smaller "expert" groups, where each member studies a specific aspect of the material and then shares this information with others in the main group. The meta-analysis (Solissa at al, 2023) concluded that the jigsaw model of learning based on higher-order thinking skills has a significant impact on the thinking of 21st century students. This cooperative method can support inclusive education for all only through thoughtful preparation of teachers (Drouet et al., 2020), (Cochon Drouet at al., 2023)

Inquiry-based learning fosters critical thinking, problem-solving, research, and communication skills. It promotes a deeper understanding of concepts and encourages lifelong learning by nurturing curiosity and independent thinking in students. Because it relates to inquiry and research, it has its place in technical universities. (Jungman, 2019), (Kori, 2021)

The "use the design thinking process" method is a creative and systematic approach to problem-solving and innovation, often used in developing new products, services, or processes. Although it is used in many areas, it also has its benefits in technical education, from business and innovation to creating user-friendly products or services. The influence of problem-solving ability and creativity of students has been proven (Guaman-Quintanilla et al., 2023).

3D printing applications in education support interactive and experiential learning that helps students better understand the subject matter and develop practical skills that are important for their future. Teaching sustainability using 3D printing in engineering education was presented in an observational study (To et al., 2023)

The ideal solution is personalised learning, where creating individual student learning plans, adaptive software, and mentoring can help students access relevant information while supporting their strengths. Here, we see the possibilities soon of the involvement of artificial intelligence in education (Gillani et al., 2023), (Chiu et al., 2023).

Today, information and communication technologies (ICT) are among the innovations that have revolutionised various areas of the world, including education.

ICT is important in education because such platforms and opportunities have recently been created that have facilitated knowledge acquisition and significantly enabled the improvement of learning in an online environment (Hrablik Chovanová, 2023). Students have an increased awareness regarding the usefulness and advantages of e-learning (Al-Fraihat et al., 2020). The study's conclusion (Alhefnawi, 2021) claims that the Internet as a class presentation method is less effective than teaching through direct, active, face-to-face lectures. However, the observed difference between the two was small and limited.

Many authors of articles dealt with online education in connection with the Covid-19 pandemic. Education was one of the main areas disrupted by this pandemic. The pandemic has been a catalyst for online advancements in educational practices, and it has accelerated the use of the latest ICT. According to UNESCO statistics, the closure of universities worldwide to limit the Covid-19 pandemic has affected 91% of the student population. The coronavirus outbreak forced the university to launch e-learning programs to ensure regular teaching (Mushtaha et al., 2022). Faculty members and students had to use high-tech tools and platforms to guarantee continuous teaching and learning (Sofi-Karim et al., 2023). Individual universities were forced to create new study plans that made it possible to acquire new competencies and consider new teaching methods., which resulted in several challenges (Ingaldi et al., 2023). Many studies have analysed the effects of online learning on teaching during the Covid-19 pandemic, for example, in Italy (Mari et al., 2021), in India (Mishra et al., 2020), in Brunei (Haidi & Hamdan, 2023), in South Korea (Ke & Zhang, 2023), in the United Kingdom universities (Al-Fraihat et al., 2020). Student evaluation of online learning during the COVID-19 pandemic was investigated in Poland (Szopiński & Bachnik, 2022) and other countries.

Cloud computing teaching (learning in the cloud) involves using cloud technologies and platforms to provide educational content and teaching materials to students and teachers. This form of education takes advantage of cloud services, such as access to information and applications via the Internet. (Sabadash, 2023) Online teaching methods based on Artificial Intelligence and edge calculation using edge-cloud computing platforms are described in (Zhong, 2023).

Integrating technologies using digital tools, educational applications, virtual reality, and interactive platforms provides space for creating engaging and dynamic learning experiences. It can be concluded that digital technologies show a range of tools, including formalised learning environments in higher education teaching, and students use these tools to support their learning (Alenezi, 2023). Globally, engineering education is experiencing a shift from teacher-centred to student-centred teaching and learning, from content-based learning to outcome-based learning, from knowledge-providing teachers to teacher-facilitators, from lecture-based learning to learning technology-based (Milićević, 2021).

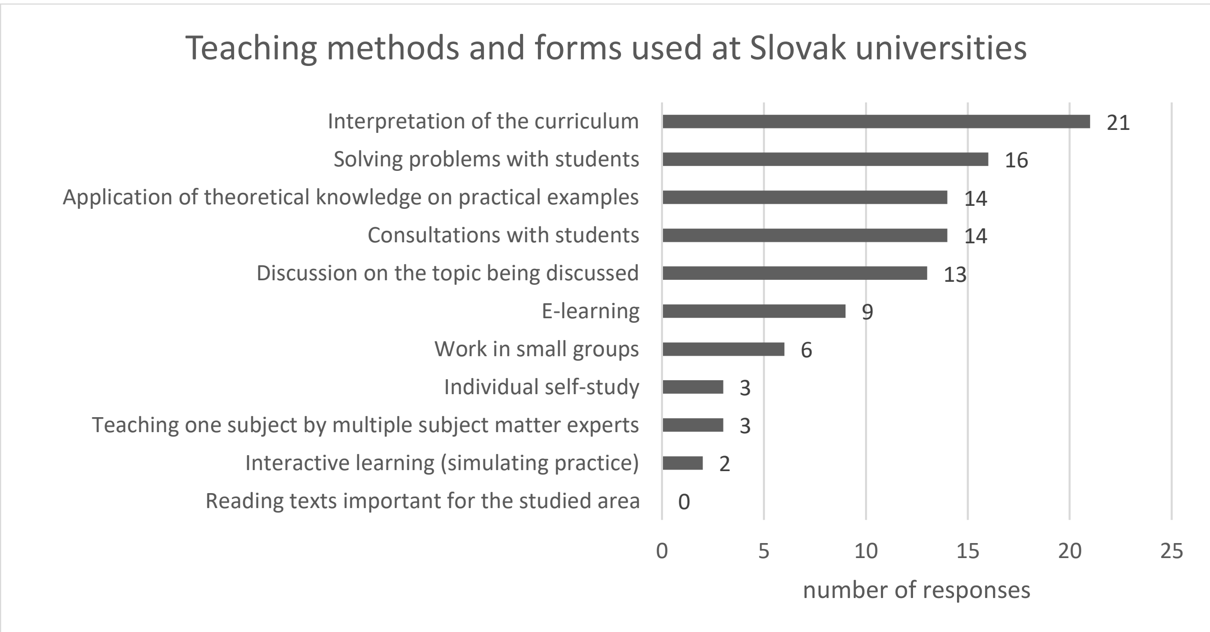
Blended learning is an educational approach combining traditional face-to-face instruction with online learning activities or resources. It is a flexible model that integrates the best aspects of both offline and online learning environments to create a comprehensive and effective learning experience and adapt to different learning styles and student preferences. (Okaz, 2015), (Leininger-Frézal, 2023) After the end of the COVID-19 pandemic, blended learning has become extremely widespread, especially in higher education. (Yang, 2023),

3 Implementation of the survey and obtained results

Our survey focused on using innovative teaching methods at technical universities. It was implemented in the form of a short online questionnaire. 150 randomly selected teachers at Slovak universities were approached and asked to answer questions. Teachers who teach mathematics or technical subjects were preferred. Considering the area of our research, we were interested in what methods and forms of teaching our colleagues prefer in their classes today and whether they have retained some elements of online teaching since the COVID-19 pandemic. Out of 150 distributed questionnaires, 22 were returned, i.e. approximately 14.67 percent.

To the question of which of the teaching methods and forms are used by university teachers in the teaching process, we obtained the following answers shown in Fig. 1. Almost all respondents (21 out of 22 respondents) stated that they use the interpretation of the curriculum in their pedagogical practice (21 answers out of 101 of all answers, i.e. 20.79%). This finding corresponds to the overall statistics of the Learning Makes Sense project regarding the teaching methods and forms used in our universities. (Mesa 10) Considering the difficulty of the curriculum, this fact is understandable. The effort of university teachers to develop students' critical analytical thinking is reflected in the use of the method of solving problems with students (16 answers out of 101, i.e. 15.84%). Applying theoretical knowledge to practical examples is also an effort to connect university education with technical practice (14 answers out of 101, i.e. 13.86%). For students, consultations with their teacher are indispensable during their studies; therefore, teachers also often include them in their pedagogical activities (14 answers out of 101, i.e. 13.86%). Also, the ability to discuss and work in a team is important from the point of view of the future practice of engineers, and therefore, good teachers often include them in classes (13 answers out of 101, i.e. 12.87%). Nowadays, the relatively frequent use of e-learning is also related to the development of ICT (9 answers out of 101, i.e. 8.91%). We assume that the development of e-learning is related to the fact that many e-materials had to be prepared during the previous years of the COVID-19 pandemic. Individual self-study is typical for the education of university students. (3 answers out of 101, i.e. 2.97%). It is used primarily in their home preparation and not in the classroom. It is excellent if the teacher knows how to motivate students to self-study already during the semester, not only during their exam period. To be effective, self-study must be correctly managed. The answers to the questionnaire also mention the option of teaching one subject by multiple subject matter experts (3 answers out of 101, i.e. 2.97%). It would be excellent if the school could provide and ensure this opportunity for its students, especially if they are experts in the practice field. We also recorded two responses where interactive learning was mentioned. (2 answers out of 101, i.e. 1.98%). For example, we see a great benefit for technical fields when students can acquire the necessary skills and habits through the provided simulation applications. Creating such a simulation application is indeed difficult. However, we see its subsequent contribution as enormous. We did not have any answers regarding reading texts important for the studied area in our questionnaire. We see this as logical for technical universities. We can imagine it, for example, for the study of law and the interpretation of studied laws, which, however, was not our area of interest.

Fig. 1: Use of teaching methods and forms at Slovak universities according to our questionnaire



We are aware that the use of teaching methods and forms is conditioned by time availability and the type of school subject. The number of students a university teacher has in his class is also an important factor. That's why, as we mentioned above, we focused our research on the areas of mathematics and statistics close to us. Subsequently, we looked for connections between the size of study groups and preferred teaching methods and forms.

We expected that there would be a relationship between study group size and preferred study methods and forms. However, no connection has been proven. The most frequently mentioned group sizes at universities by teachers were 10-20 students and 20-30 students. But neither here nor with groups of more than 40 students or less than 5 students, certain same or similar teaching methods and forms were not preferred. The implemented teaching method is probably most influenced by the teacher's personality. Respectively, according to the given studied sample, it is impossible to predict the dependence of the method and form of teaching on the student sample size. Innovative methods are also used by teachers with large numbers of students, where we expected their frequency to be lower. The results also do not indicate any relationship between class size and preferred innovative teaching methods.

Teachers were asked to describe what is typical of their teaching briefly. Thanks to their open approach, we got these answers. The responses are presented in random order, although some statements were repetitive; for example, discussion with students was a frequent element. Due to the researched area, solving the tasks was also typical. Selected answers are:

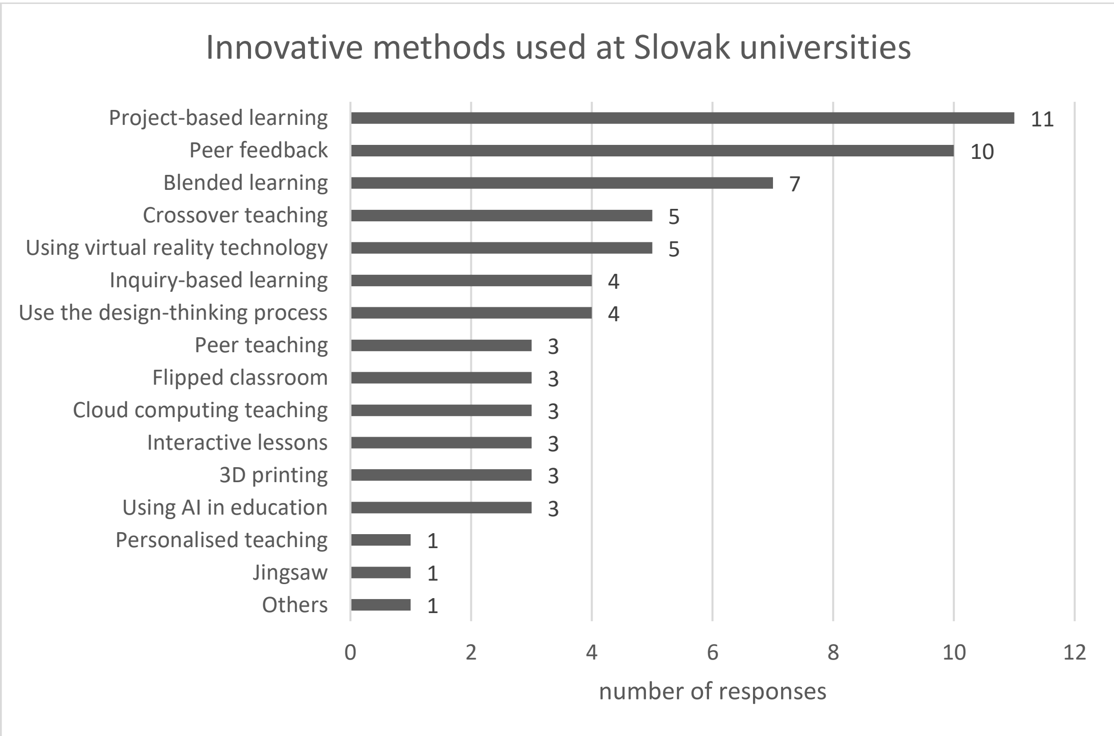
- solving examples from practice,
- logical explanation of the principles of technical drawing based on production requirements,
- use of practical examples in teaching, comparison of theoretical approaches and their real use in practice,
- adapting to the student's pace, from simpler to more complex,
- leading students to independence in their work,
- variety of methods used,
- discussion with students,
- communication with students,
- student activity,
- projects,
- presentations,
- use of available software,
- explanation and motivation of students during lectures, discussion of problems when solving projects,
- brainstorming,
- solving examples from practice using free software,
- consistency,
- communication with students and establishing direct contact at the blackboard,
- emphasis on solving examples from practice and searching for the most common cases and situations where theoretical knowledge can be applied,
- solution of sample tasks.

The chart in Fig. 2 shows the proportion of respondents' answers to the question of their use of innovative teaching methods. The types of innovative methods offered in the questionnaire were selected from Innovative Teaching Methods with Guide and Examples (Best in 2023) according to (Tran, 2023).

The answers to the direct question about using innovative methods were split 19/3 in favour of innovative methods. Nineteen respondents to the questionnaire stated that they actively use innovative methods in their classes. On the contrary, three university teachers say they do not use innovative methods. Eighteen respondents indicated a total of 67 of the offered innovative teaching methods. We also recorded one answer, "others", where the respondent states that they use eduScrum and mini PBL methods.

According to the results of the questionnaire, Slovak university teachers prefer project teaching (11 answers out of 67, i.e. 16.42%) and teaching based on peer feedback (10 answers out of 67, i.e. 14.93%) as part of innovative teaching methods. The third largest share of responses was expressed in blended teaching (7 responses out of 67, i.e. 10.45%). Next in order are the use of virtual reality technology and crossover learning (5 answers out of 67, i.e. 7.46%) and the use of the design-thinking process and inquiry-based learning (4 responses out of 67, i.e. 5.97%). The use of AI in education, 3D printing, interactive lessons, cloud computing teaching, flipped classrooms and peer teaching were also indicated as innovative teaching methods (3 responses out of 67, i.e. 4.48%). In the questionnaire, we also registered the chosen jigsaw method and personalised teaching, but these answers were given with a low frequency (only 1 answer out of 67, i.e. 1.49%). As mentioned above, one answer, "others", contains an unmentioned eduScrum and mini PBL methods. Scrum is a well-developed method used mainly in the Netherlands and Germany, allowing people to work intensively in a team. Scrum was developed in the IT world for complex IT projects, while eduScrum focuses on learning (https://eduscrum.org/). Mini PBL is essentially project-based learning, while this method specialises in learning through short-term projects that we could apply, for example, in mathematics or statistics.

Fig. 2: Use of innovative teaching methods at Slovak universities according to our questionnaire



We also used questionnaires to determine if teachers retained any elements of online teaching from the Covid era. The surprising result was that 6 respondents out of a total of 22 respondents, i.e. 27.27%, said none. Most of the teachers said they kept all the prepared electronic materials for the students or used online consultations (occasionally, but some also regularly). Some teachers give students recorded exercises or videos of online lectures. Subsequently, they can devote more time to consultations, solving problems or other activities. Somewhere, large lectures run online for capacity reasons. The 3D interactive textbook also remained part of the education. Some teachers leave more assignments for homework. Some universities continue to use tried and tested specialised software for teaching. Student voting is also an element that has been successfully retained.

In our personal experience, students evaluated the provision of electronic materials very positively. One of the first questions students still have during face-to-face teaching at the first lecture is whether an electronic version of the presented materials will be provided. It is beneficial to have an electronic version of the presented materials available in sufficient time. Also, trial electronic tests, by which they receive immediate feedback, are positively appreciated by students.

4 Conclusion

If we want the school to effectively prepare young people for their future profession, it must adapt to the rapid changes in today's society. The need to find new, more effective education methods is related to this.

Our paper describes innovative methods of education that are commonly used today, especially at technical universities. Our survey also focused on those elements of education that remained part of tertiary education at universities even after the Covid period, in subjects such as mathematics, statistics and data analysis or in technical subjects.

While bringing innovative teaching strategies into the classroom used to be a narrow academic practice carried out by a few brave educators, our research shows that these strategies are commonplace today.

No, we do not want to say that a teacher who does not use innovative methods is bad or that his teaching is ineffective. In our opinion, it is always important that the teaching process focuses on the student's personality and adapts to his needs. But it is good to use all the opportunities the moment allows.

The testing results and current personal experiences from teaching at our universities indicate an inevitable change in the use of teaching methods and forms. At least we all know that the COVID-19 pandemic has accelerated changes in the use of information and communication technologies in the teaching process. Practice has shown that maintaining online education elements in face-to-face education brings many positives. It would be a big mistake not to take advantage of all the challenges we were forced to overcome during the pandemic because both students and teachers found their positives in the new methods, which they do not want to lose.

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Resources

Alenezi, M. (2023) Digital Learning and Digital Institution in Higher Education. *Education Science, 13*(1), 88. https://doi.org/10.3390/educsci13010088

Alhefnawi M.-A.-M. (2021). Assessing the efficacy of online handouts and active lectures in learning outcomes at the engineering undergraduate level. *Ain Shams Engineering Journal, 12* (3), 3375-3380. https://doi.org/10.1016/j.asej.2021.02.012

Al-Fraihat, D., Joy, M., Masa'deh, R., & Sinclair J., (2020). Evaluating e-learning systems success: an empirical study *Computers in human behavior, 102* , 67-86. https://doi.org/10.1016/j.chb.2019.08.004

Cochon Drouet O, Lentillon-Kaestner V, & Margas N. (2023) Effects of the Jigsaw method on student educational outcomes: systematic review and meta-analyses. *Front Psycholology, 14*. https://doi.org/10.3389/fpsyg.2023.1216437

Drouet O., Millet G., & Lentillon-Kaestner V. (2020). Coopérer en éducation physique: Le Jigsaw, une méthode prometteuse? Cooperate in physical education: the Jigsaw, a promising method?. *eJRIEPS 46*, 21–50. https://doi.org/10.4000/ejrieps.4941

Fritsch, M., & Slavtchev, V. (2007) University and Innovation in Space. *Industry and Innovation, 14*(2), 201-218. https://doi.org/10.1080/13662710701253466

Gillani, N., Eynon, R., Chiabaut, C., & Finkel, K. (2023). Unpacking the "Black Box" of AI in Education. *Educational Technology & Society, 26*(1), 99–111. https://www.jstor.org/stable/48707970

Guaman-Quintanilla, S., Everaert, P., & Chiluiza, K. (2023). Impact of design thinking in higher education: a multi-actor perspective on problem solving and creativity. *International Journal of Technology and Design Education 33*, 217–240. https://doi.org/10.1007/s10798-021-09724-z

Hrablik Chovanová, H., Fidlerová, H., Babčanová, D., & Banáš D. (2023). Operations Research in Online Environment Using ICT in Higher Technical Education. *Acta Polytechnica Hungarica, 20*(7), 117-132. https://doi.org/10.12700/APH.20.7.2023.7.7

Haidi, H., & Hamdan, M. (2023). Analysis of the home-based online teaching and learning policy during the COVID-19 second wave in Brunei: a joint parent/teacher perception. *Asia Pacific Educ. Rev. 24*, 487–502. https://doi.org/10.1007/s12564-022-09798-x

Chiu, T.-K.-F., Xia, Q., Zhou, X., Chai, Ch.-S., & Cheng, M. (2023) Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 4,* https://doi.org/10.1016/j.caeai.2022.100118

Ingaldi, M., Ulewicz, R., & Klimecka-Tatar, D. (2023). Creation of the university curriculum in the field of Industry 4.0 with the use of modern teaching instruments - Polish case study. *Procedia Computer Science*, *217*, 660–669, https://doi.org/10.1016/j.procs.2022.12.262

Jungmann, T. (2019). Inquiry-Based Learning in the Engineering Sciences. In: Mieg, H.A. (eds) Inquiry-Based Learning – Undergraduate Research. Springer, Cham. https://doi.org/10.1007/978-3-030-14223-0_19

Ke, G., & Zhang, Y. (2023). Innovative Teaching and Learning Approaches During the COVID-19 Pandemic: A Case Study of Five Liberal Arts Institutions in East Asia. In: Jung, I., Mok, K.H. (eds) The Reinvention of Liberal Learning Around the Globe. Crossing Cultures: Liberal Learning for a World in Flux. Springer, Singapore. https://doi.org/10.1007/978-981-19-8265-1_13

Kori, K. (2021). Inquiry-Based Learning in Higher Education. In: Vaz de Carvalho, C., Bauters, M. (eds) Technology Supported Active Learning. Lecture Notes in Educational Technology. Springer, Singapore. https://doi.org/10.1007/978-981-16-2082-9_4

Leininger-Frézal, C., Sprenger, S., de Lázaro Torres, M. L., Rodríguez Domenech, M. Ángeles, Heidari, N., Pigaki, M., Naudet, C., Lecomte, A., & Gallardo, M. (2023). Global Change Challenge in the Higher Education Curriculum on the approach of Blended Learning. *European Journal of Geography, 14*(2), 1 – 14. https://doi.org/10.48088/ejg.c.lei.14.2.001.014

Mari, E., Lausi, G., Fraschetti, A., Pizzo, A., Baldi, M., Quaglieri, A., Burrai, J., Barchielli, B., Avallone, F., & Giannini, A.-M. (2021). Teaching during the Pandemic: A Comparison in Psychological Wellbeing among Smart Working Professions. *Sustainability, 13,* 4850. https://doi.org/10.3390/su13094850

Maros, M., Korenkova, M., Fila, M., Levicky, M., & Schoberova, M. (2023). Project-based learning and its effectiveness: evidence from Slovakia. *Interactive Learning Environments*, *31*(7), 4147-4155. https://doi.org/10.1080/10494820.2021.1954036

Mesa 10 (2023). Available online: https://en.todarozum.sk/

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *Int J Educ Res Open, 1*. https://doi.org/10.1016/j.ijedro.2020.100012

Milićević, V., Denić, N., Milićević, Z., Arsić, L., Spasić-Stojković, M., Petković, D., Stojanović, J., Krkic, M., Milovančević, N.-S., & Jovanović A., (2021). E-learning perspectives in higher education institutions. *Technological Forecasting and Social Change,*166. https://doi.org/10.1016/j.techfore.2021.120618

Mushtaha, E., Dabous, S.-A., Alsyouf, I., Ahmed, A., & Abdraboh N.-R. (2022). The challenges and opportunities of online learning and teaching at engineering and theoretical colleges during the pandemic. *Ain Shams Engineering Journal, 13*(6). https://doi.org/10.1016/j.asej.2022.101770

Okaz, A.-A. (2015) Integrating Blended Learning in Higher Education, *Procedia - Social and Behavioral Sciences,186,* 600-603. https://doi.org/10.1016/j.sbspro.2015.04.086

Sabadash, D., Melinyshyn, O., Oliinyk, B., & Petriv, L. (2023). Capabilities of cloud computing teaching in application of interdisciplinary approach in tertiary level. Collection of Scientific Papers «SCIENTIA», (May 19, 2023; Berlin, Germany), 95–98. Retrieved from https://previous.scientia.report/index.php/archive/article/view/979

Sertic, M., Alshafai, L., Guimaraes, L., Probyn, L., & Jaffer, N. (2020) Flipping the Classroom: An Alternative Approach to Radiology Resident Education. *Academic Radiology, 27*(6), 882-884. https://doi.org/10.1016/j.acra.2019.08.013

Sivarajah, R.-T., Curci, N.-E., Johnson, E.-M., Lam, D.-L., Lee, J.-T., & Richardson, M.-L. (2019). A Review of Innovative Teaching Methods. *Academic Radiology,* 26(1),101-113, https://doi.org/10.1016/j.acra.2018.03.025

Sofi-Karim, M., Bali, A.-O., & Rached. K. (2023). Online education via media platforms and applications as an innovative teaching method. *Educ Inf Technol, 28*(1), 507-523. https://doi.10.1007/s10639-022-11188-0

Solissa, E. M., Marzuki, K., Arniati, A., Mufti, D., & Santosa, T. (2023). The Influence of the Jigsaw Model Based on Higher Order Thinking Skills on Students 21st Century Skills : Meta-Analysis. *Edumaspul: Jurnal Pendidikan, 7*(2), 2470-2479. https://doi.org/10.33487/edumaspul.v7i2.6689

Szopiński, T., & Bachnik, K. (2022). Student evaluation of online learning during the COVID-19 pandemic, *Technological Forecasting and Social Change, 174,* https://doi.org/10.1016/j.techfore.2021.121203

To, T.-T., Al Mahmud, A., & Ranscombe, C. (2023).Teaching Sustainability Using 3D Printing in Engineering Education: An Observational Study. *Sustainability*, *15*, 7470. https://doi.org/10.3390/su15097470

Tran, E. (2023). Available online: https://ahaslides.com/blog/15-innovative-teaching-methods/

Tsybulsky, D., & Muchnik-Rozanov, Y. (2019). The development of student-teachers' professional identity while team-teaching science classes using a project-based learning approach: A multi-level analysis. *Teaching and Teacher Education, 79,* 48–59. https://doi.org/10.1016/j.tate.2018.12.006

Yang, H., Cai, J., & Yang, H.-H. (2023). Examining key factors of beginner's continuance intention in blended learning in higher education. *Journal of Computing in Higher Education 35*, 126–143. https://doi.org/10.1007/s12528-022-09322-5

Zhong, L. A (2023). Convolutional neural network based online teaching method using edge-cloud computing platform. *Journal of Cloud Computing 12*, 49. https://doi.org/10.1186/s13677-023-00426-6

THE GLOBAL LANDSCAPE OF HIGH-PERFORMANCE COMPUTING EDUCATION: A COMPREHENSIVE ANALYSIS

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Abstract

This article offers an extensive review and analysis of the current status of High-Performance Computing (HPC) education worldwide. The escalating significance of computational power across diverse scientific, engineering, and data-driven disciplines has elevated the necessity for robust HPC skills in educational settings. This study delves into an extensive exploration of HPC education in various countries, evaluating the breadth and depth of curricular offerings and the accessibility of resources. Drawing upon a wide-ranging survey of educational institutions globally, a spectrum of approaches to HPC education was uncovered, encompassing dedicated programs and interdisciplinary courses. The emphasis was placed on observing the availability and use of supercomputers at universities. In the final analysis, the article presents the results of parallel computations on the ParamBilim supercomputer located at the L. N. Gumilyov Eurasian National University. By consolidating all this information, we aim to provide a comprehensive overview of the state of HPC education worldwide, identify opportunities for enhancement, and offer insights that can aid in fostering a more cohesive and effective landscape for the education of High-Performance Computing.

Keywords

High-Performance Computing, Parallel computing, supercomputers, education

1 Introduction

In today's era, revolutionary findings and innovations rely heavily on technology, data, and advanced computing, which leads to rapidly growing demands for computation requirements. In this connection, High-Performance Computing (HPC) has been widely adopted in various research and practical applications. HPC methods have the potential to aid scientists, engineers, and other experts in tackling exceptionally intricate issues in the fields of linear algebra, physics, chemistry, biology, aerospace, etc. Utilising high-performance computing involves combining modelling, algorithms, software creation, and computational simulation, which has evolved into an essential foundation for advanced research in the field of cutting-edge fundamental science [1].

This matter is directly impacted by education in High-Performance Computing (HPC). Due to its complexity, this domain critically needs good courses in the university program curriculum.

2 Methodology

To find out the current state of high-performance computing education, the curriculums within the scope of "High-performance computing" of the following universities, which are

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among the high-rated universities according to QS's 2023 ranking and Kazakhstani leading universities reviewed [2].

Table 1. University ranking in QS World University Rankings 2023

University	Rank in QS World University Rankings 2023
Massachusetts Institute of Technology	1
Harvard University	4
Stanford University	5
University of California, Berkeley	10
Al-Farabi Kazakh National University	230
L. N. Gumilyov Eurasian National University	355
Satbayev University	481

Source: Authors

Ranked #1 in the world's QS's 2023 ranking, MIT (Massachusetts Institute of Technology) in Cambridge, the USA, covers a wide range of courses in the field of high-performance computing, including parallel programming, algorithm optimisation, supercomputer architecture, and parallel processing technologies [3]. MIT students can choose different programs and courses on HPC, such as "High-Performance Computing Architecture", "Parallel Programming for Multicore Machines with OpenMP and MPI", "Parallel Computing", etc. These courses include theoretical lectures, practical exercises, and project work that allow students to acquire the necessary skills in the field of high-performance computing. [4].

The Parallel Computing course introduces applied parallel computing on modern supercomputers. It has a practical focus on understanding computational problems on the world's fastest machines. Topics include dense and sparse linear algebra, N-body problems, multigrid, fast-multipole, wavelets, and Fourier transforms. Geometrical topics include partitioning and mesh generation. Other topics include applications-oriented architecture, understanding parallel programming paradigms, MPI, data-parallel systems, Star-P for parallel Python and parallel MATLAB®, graphics processors, virtualisation, caches, and vector processors.

A special feature of this course is VHLLs or Very High-Level Languages for parallel computing. This includes the Julia programming language. Julia is a high-level, high-performance dynamic language for technical computing with a syntax familiar to users of other computing environments. It provides a sophisticated compiler, distributed parallel execution, numerical precision, and an extensive library of mathematical functions [5].

At Stanford University, students use Open HPC, Intel Parallel Studio, Environment Modules, and cloud-based architectures as part of the "Introduction to High-Performance Computing" course. In addition, HPC clustering with remote physical hardware installation, high-speed network configuration and optimisation, and familiarisation with parallel programming and high-performance Python programs. To get the most out of the course, you must be familiar with Bash and Python. Group work and projects are allowed and encouraged. All laboratory work and student projects are practised in a specially designed high-performance computing centre called "HPCC" (High-Performance Computing Center) [6].

In addition, Stanford University has supercomputing resources that can be used to teach high-performance computing. These resources allow students and researchers to gain hands-on experience using supercomputers in real-world projects [7].

Harvard University's High-Performance Computing for Science and Engineering curriculum consists of 21 lectures, 6 labs, and individual or group projects, starting with an introduction to parallel computing and ending with CUDA technology. Covered topics: Open MP, UMA/NUMA memory architectures, MPI, CUDA, etc. Programming language – C/C++ or Fortran. The course project aims to create a real program using the techniques learned in class to gain hands-on experience writing parallel code. The final report is written as a proposal to request computing hours to the HPC centre to test the project on a supercomputer. Faculty members evaluate student proposals in the role of the HPC admissions committee. Programs that meet the criteria will be tested on supercomputers [8].

The University of California, Berkeley offers courses such as “GPU Programming for High-Performance Computing”, “High-Performance Computing for Science and Engineering”, and “Applications of Parallel Computers”. The “Applications of Parallel Computers” curriculum includes the basics of parallel computer architecture and programming languages and also emphasises models commonly used in all applications requiring high-performance computing. This course aims to write programs that run fast while minimising programming effort. Topics covered:

- Shared memory (OpenMP on your multicore laptop)
- Distributed memory (MPI and UPC on a supercomputer)
- GPUs (CUDA and OpenCL)
- Cloud computing (MapReduce, Hadoop, and Spark) [9].

Also, in recognition of the increasing importance of research computing across many disciplines, UC Berkeley has developed the BRC High-Performance Computing service as a way to grow and sustain high-performance computing for the university.

All the courses mentioned above include theoretical lectures, practical exercises, and project work that enable students to acquire the necessary skills in high-performance computing.

As for Kazakhstan universities, Al-Farabi Kazakh National University, ranked 1st in the country and 150th in the world QS rating, offers subjects like “Parallel computing system architecture”, “Design and Analysis of Parallel Algorithms”, “High-performance programming with multi-core and GPUs” and “High-Performance Computing Models” to provide students with theoretical and practical training in the field of high-performance computing. The courses cover bases of parallel computing system classification: Flynn's taxonomy, single-threaded instruction, multi-threaded data (SIMD), multi-threaded command, multi-threaded data (MIMD); high-performance processors, VLIW processors; NUMA architecture; working with OpenMP and creating parallel programs using the MPI library [10].

L. N. Gumilyov Eurasian National University provides courses like “Methods of Teaching High-Performance Computing” for bachelor's and “Parallel Computing Cluster” for Master’s degrees. These courses cover parallel computing fundamentals, introducing students to techniques for writing efficient code that can harness the power of parallel processing architectures. High-Performance Computing (HPC) Curriculum focused on HPC delves into the principles, architectures, and tools used in high-performance computing systems. This

includes understanding hardware/software interactions, optimising performance algorithms, and effectively utilising parallel computing paradigms.
OpenMP, MPI, parallel algorithms, GPU architecture, CUDA threads, introduction to quantum computing, and many other topics are covered.
The university also has a supercomputer, "Param-Bilim," which allows students to apply theoretical knowledge to real-world scenarios to gain practical skills [11].

The course "Parallel Programming" of Satbayev University, the purpose of which is to study the basics of parallel programming, the development of thinking associated with high-performance computing, focuses on fundamental knowledge of the subject area - methods of parallel programming on systems with distributed memory and systems with shared memory and methods for constructing parallel programs for solving SLAE (system of linear algebraic equations) problems and problems solved by grid methods. The course provides an opportunity to get acquainted with parallel programming methods with shared variables, synchronisation of processes through access to shared resources, MPI and OpenMP parallel programming systems, create parallel programs for solving systems of linear equations using the Gauss method, etc. [12].

Table 2. Information on disciplines and used technologies at universities

№	University	Discipline name	Used technologies	Programming language
1	Massachusetts Institute of Technology	"High-Performance Computing Architecture", "Parallel Programming for Multicore Machines with OpenMP and MPI", "Parallel Computing",	— OpenMP — MPI — Matlab — MapReduce	— Python — Julia
2	Stanford University	"Introduction to High-Performance Computing"	— Open HPC — Intel Parallel Studio — Environment Modules — OpenMP — MPI	— Bash — Python
3	Harvard University	"High-Performance Computing for Science and Engineering"	— CUDA — OpenMP — UMA/NUMA memory architectures — MPI	— C/C++ — Fortran
4	University of California, Berkeley	"GPU Programming for High-Performance Computing", "High-Performance Computing for Science and Engineering", "Applications of Parallel Computers"	— OpenMP — MPI — UPC and UPC++ — CUDA/OpenCL	— C++
5	Al-Farabi Kazakh National University	"Parallel computing system architecture", "Design and Analysis of Parallel Algorithms", "High-performance programming	— OpenMP — MPI	— C++

		with multi-core and GPUs” and “High-Performance Computing Models”		
6	L.N.Gumilyov Eurasian National University	“Parallel programming”, “Methods of teaching High-Performance Computing”	— OpenMP — MPI — Matlab	— C++
7	Satbayev University	“Parallel programming”	— OpenMP — MPI	•

Source: Authors

We also carried out calculations on the Param-Bilim supercomputer of the Eurasian University to test the effectiveness of high-performance computing.

Below is one example: parallel multiplication of two two-dimensional arrays using OpenMP technology.

Figure 1. The parallel program code in C++

root@parambilim:/

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <omp.h>
#include <sys/time.h>

#define N 10000

int A[N][N];
int B[N][N];
int C[N][N];

int main()
{
        int i,j,k;
        struct timeval tv1, tv2;
        struct timezone tz;
                double elapsed;
        printf("Matrix size = ", N);
        int omp_set_num_threads(4);
        for (i=0; i<N; i++)
                for (j=0; j<N; j++){
                        A[i][j] = 2;
                        B[i][j] = 2;
                }
        gettimeofday(&tv1, &tz);
        #pragma omp parallel for private(i,j,k) shared(A,B,C)
        for (i=0; i<N; ++i){
                for (j=0; j<N; ++j){
                        for (k=0; k<N; ++k){
                                C[i][j] += A[i][j]*B[k][j];
                        }
                }
        }

        gettimeofday(&tv2, &tz);
        elapsed = (double) (tv2.tv_sec-tv1.tv_sec) + (double)(tv2.tv_usec-tv1.tv_usec)* 1.e-6;
        printf("elapsed time = %f seconds.n", elapsed);

        return 0;

}
~
```

Source: Authors

Figure 2. Sequential program code in C++

sequential – Блокнот

Файл Правка Формат Вид Справка

```
#include <iostream>
#include <chrono>

#define N 10000

using namespace std;

int A[N][N];
int B[N][N];
int C[N][N];

int main() {
    int i, j, k;
    std::chrono::time_point<std::chrono::system_clock> start, end;
    double elapsed;

    std::cout<<"Matrix size = "<<N<<std::endl;
    for (i = 0; i < N; i++)
        for (j = 0; j < N; j++) {
            A[i][j] = 2;
            B[i][j] = 2;
        }

    start = std::chrono::system_clock::now();

    for (i = 0; i < N; ++i) {
        for (j = 0; j < N; ++j) {
            for (k = 0; k < N; ++k) {
                C[i][j] += A[i][k] * B[k][j];
            }
        }
    }

    end = std::chrono::system_clock::now();
    elapsed = std::chrono::duration_cast<std::chrono::duration<double>>(end - start).count();
    std::cout << "elapsed time = " << elapsed << " seconds." << std::endl;

    /* for (i = 0; i < N; i++) {
        for (j = 0; j < N; j++) {
            std::cout << C[i][j] << "\t";
        }
        std::cout << std::endl;
    } */
}
```

Table 3. Results of computing

Computer	Matrix size	Threads	Execution time
16 core Param-Bilim	1000	4	0.647 sec
	5000	4	62.234 sec
	10000	4	490.593 sec
Quad-core(4) Lenovo Ideapad 81y3	1000	4	1.674 sec
	5000	4	335.068 sec
	10000	4	8378.485 sec
	1000	Sequential	3.236 sec
	5000	Sequential	557.934 sec
	10000	Sequential	4910.5 sec

Source: Authors

3 Conclusion

Teaching high-performance computing in universities is an important aspect of modern education. Due to the rapid development of information technologies, high-performance computing is becoming an integral part of scientific and engineering research and industrial processes.

Teaching high-performance computing enables students to learn modern methods and technologies for working with large amounts of data, efficient algorithms, and clustered computing. These graduates work in science, industry, finance, medicine, etc., ensuring they become competitive, qualified specialists in the labour market, ready to solve complex problems in various fields.

As a result of the analysis of the situation of teaching high-performance computing, it was determined that universities use various software equipment and technologies in education. OpenMP and MPI technologies for algorithm calculations, and C++ programming language are often used among them. All analysed foreign and Kazakhstani universities are equipped with supercomputers used for research and teaching of practising high-performance computing. However, it can be seen that in the educational programs of the Republican higher education institutions, more attention is not paid to the experience and projects that allow students to acquire knowledge and skills more effectively and in-depth than in foreign higher education institutions. It is hoped that within the coming years, we can address this issue and enhance educational programs, equipping learners with the skills needed to solve the complex challenges of the digital era.

References

E.J. Nielsen, B. Diskin. (2017). High-performance aerodynamic computations for aerospace applications. *Parallel Compute, 64*, 20–32.

Sh. Ren, Y. Li. (2023). A review of High-Performance computing applications in high-speed rail systems. *High-speed Railway, 1*(2), 92-96.

QS World University Rankings 2023: Top global universities. (2023, June 27). QS Top Universities. Retrieved from *https://www.topuniversities.com/university-rankings/world-university-rankings/2023*

Parallel Programming for Multicore Machines Using OpenMP And MPI. (2010). MIT Open Courseware. Retrieved from *https://ocw.mit.edu/courses/12-950-parallel-programming-for-multicore-machines-using-openmp-and-mpi-january-iap-2010/pages/syllabus/*

Parallel Computing. (2011). MIT Open Courseware. Retrieved from *https://ocw.mit.edu/courses/18-337j-parallel-computing-fall-2011/pages/syllabus/*

Introduction to High-Performance Computing. Standford High-Performance Computing Center. Retrieved from *https://hpcc.stanford.edu/teaching*

Student Immersion Project. (2019). Stanford University High-Performance Computing Center. Retrieved from *https://hpcc.stanford.edu/*

F. Wermelinger. High-performance computing for science and engineering. (2021, December 17). Harvard IACS. Retrieved from *https://harvard-iacs.github.io/2022-CS205/pages/cs205_syllabus.pdf*

Applications of Parallel Computers. Berkeley EECS. Retrieved from *https://www2.eecs.berkeley.edu/Courses/ CSW267/*

Informatika mamandygy boiynsha tiptyk oqu bagdarlamalary. (2017). Al-Farabi Kazakh National University. Retrieved from *https://www.kaznu.kz/content/files/pages/folder17397/5%D0%92060200%D0%98%D0%BD%D1%84%D0%BE%D1%80%D0%BC%D0%B0%D1%82%D0%B8%D0%BA%D0%B0.pdf*

Param Bilim. India Kazakhstan Centre of Excellence in Information and Communication Technology. Retrieved from *http://ikceict.enu.kz/index.php?view=about0*

Curriculum program «computer science». (2020). Satbayev University. Retrieved from *https://official.satbayev.university/download/document/18523/Computer%20Sience%20B%202020%20%D1%80%D1%83.pdf*

APPLIED COMPUTER SCIENCE IN BUSINESS

Azamat Khidirnazarov Mamarajabovich[19]

Abstract

Applied Computer Science (ACS) in Business Informatics is a transformative field combining the technical prowess of computer science with the strategic execution of business processes. As an integral component of modern economic frameworks, ACS leverages information and communication technologies to streamline and enhance decision-making and strategic planning in both business and public administration sectors. By systematically designing, implementing, and maintaining bespoke information systems, ACS supports integrating technological solutions into daily business operations, thereby enhancing operational efficiency and security. This discipline addresses the technological needs of organisations and anticipates the complexities of market dynamics and legal frameworks, ensuring adaptability and sustainability in a rapidly evolving digital landscape. Through the development of virtual enterprises and optimising business processes, ACS plays a pivotal role in aligning technology with business goals, facilitating a more robust, efficient, and competitive economic environment. The ongoing evolution of ACS highlights its indispensable role in merging technological innovation with business acumen to meet the challenges of the 21st century's digital economy.

Keywords:

applied informatics, business, method, network, problem.

1 Introduction

Applied computer science is one of the most modern and promising areas of the 21st century, which includes the science of design, development and application of information and communication systems in business. Applied management informatics covers the planning, design, implementation, operation and development of information and communication technologies that are used to support, strategic planning and decision-making in business and public administration. Applied computer science combines computer science itself and those areas in which computer knowledge can be applied [1]. Applied computer science allows you to create software and complex information systems to meet the needs of large, medium and small businesses. Process automation eliminates many problems in communication and interaction between business entities. However, the use of products requires a specialist who combines technical and business knowledge to organise the processes. Business processes are a complex hierarchical system that ensures the implementation of strategy and tactics. Creating a system that meets business needs and achieves its goals is the task of business IT professionals.

Applied computer science is used in the formation of complex solutions for business and government agencies. His areas of interest include the development of innovative projects, the design and development of virtual enterprises, the organisation of process management and business in general.

The structure of applied computer science consists of the following components: performing system analyses to study business processes in order to identify strengths and

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weaknesses; making forecasts based on analysis data; business process modeling, integration process management; monitoring, support and management of technologies.

The modern economy interacts with high technologies that require integration with existing economic processes. Applied computer science specialists need to understand how relationships between business entities are formed and understand the laws of the market. It is also important to know the regulatory framework, which provides guarantees for all aspects of economic activity [2].

Economics covers the stages of the product, which include the creation, distribution, marketing and final consumption of products. There are relationships between business entities that require legal regulation, as well as the presence of certain government institutions that reduce transaction costs and time for various operations. Interaction processes are provided, among other things, by applied computer science.

Information technologies today penetrate into all spheres of human activity. They must take into account the specifics of the relationships that develop between subjects. If we talk about business, the following aspects are important here:

- economic entities are dependent on their actions; they pursue their own goals and objectives;
- regulation of relationships between subjects is carried out with the help of regulatory documents and ethical standards;
- the influence of the state is indirect;
- due to the characteristics of virtual enterprises, data protection is paramount [3].

Simultaneously with the discussion on key capabilities of IS graduates, there is an ongoing debate regarding the nature and identity of information systems as a discipline. Most of the debate is focused on whether information systems is informed by the business discipline or if it can be rootedin other domains, like healthcare or public administration. Indeed the current model curriculum for IS undergraduate students has clearly identified business as the domain in which IS is located (Gorgone et al., 2002). Although ongoing curricula revision extends this view and recognizes that information systems is a discipline that integrates technology and organizational processes with domain expertise, domain knowledge and business knowledge is still seen as fundamental to the information systems discipline.

Within the business informatics community, broad agreement exists that business informatics shows numerous similarities to the discipline of information systems; however, there are some particular characteristics that makes business informatics a discipline in its own right. First emerging in the 1970s as a technology course in, business, over the last decade, it became an accepted field of research and study. As a stream of information systems, business informaticsfocuses on business information systems as socio-technical systems comprising both machines and humans (Ferstl & Sinz, 2001; Heinrich, 2001; Retzer et al., 2003; Wissen-schaftliche Kommission der Wirtschaftsinformatik, 1994).

However, business informatics combines and complements explicitly the domains of informatics and business studies. Informatics is primarily concerned with the technology of information and communication systems, while business studies focuses on management functions. Business in- formatics aims to support business functions by applying informatics principles and technologies.Business informatics is concerned with the concept, development, implementation, maintenance and utilization of business information systems (Disterer et al., 2003; Scheer, 1998). Business informatics also includes the management of information systems while it emphasizes the relationship between humans, business functions, information and communication systems, and technology (Heinrich, 2002). Defined as a science discipline, business informatics is generally cate- gorized as

- applied science that studies real-world phenomena,
- formal science that creates and applies formal description methods and models,

- engineering *discipline* that systematically designs and constructs information and communication systems (Wissenschaftliche Kommission der Wirtschaftsinformatik, 1994).

Therefore, business informatics is an interdisciplinary subject (Gesellschaft für Informatik, 2003).It can be summarized as a socio-technological and business oriented subject with *engineering* penetration (Disterer et al., 2003). In the following section, by comparing selected study programmes, we aim to indicate differences between typical information systems and business in- formatics programmes.

For our study, we combined a list of different subjects taught by the selected degree programmes. However, due to many subjects, a further classification was necessary to identify differences between the degrees. Applying the framework above, we assigned particularcourses to our categories in the framework. The qualitative results are presented along with characteristics of the terminology used, content, structure and legal framework as well as credit system.

Table 1: Framework for information systems study programmes

Category	Contents
Fundamentals in Informatics	Information Systems, Information and Communication Technology (Hardware, Software, Networks and Communication Technology), Programming and Algorithms, Data and Object Structures, Mathematics and Logic (Analysis, Linear Algebra, Numeric, and Logic), Structural Science (Decision theory and methods for strategic decision making (e.g. risk analysis), statistics and quantitative models and methods, operations research, computational modelling and simulation)
Business and Economics	Accounting and Financing, Marketing, Production, Procurement, Logistics, Supply Chain Management, Organization, human resources and corporate management, Legislation and Economics, Fundamentals of Information Systems (Types of IS, IS Industry, IS relevant legal frameworks, Management and IS)
Domain-specific career electives (representative)	Principles of Business Information Systems (Principles of functional and process orientation and industry solutions), Data Engineering (Data modelling and management, knowledge engineering and business intelligence), System and Software Engineering (analysis, modelling and design), Managing Data Communication and Networking, Information Management (Information, Knowledge and People, Project and Change Management, IS/IT Policy and Strategy, Ethics and Privacy)
Academia and Research	Business Engineering and Information System Architecture, Integrating Information System Functions, Processes and Data, Integrating Information System Technologies and Systems, Academia and Research Biochemistry and Molecular Biology Consulting, Consumer Health Information, Customer Relationship Management,

Category	Contents
	Data Warehousing, Decision Making, E-Government, Electronic Commerce, Electronic Publishing, Environmental management, Financing and Banking, Healthcare Information, Human Factors, Insurance Management, Knowledge Management, Library Services, Multimedia Technologies, Research Libraries, Techniques of IT-consulting, Technology Management

Source: Authors

2 Terminology

The term 'business informatics' (in German: 'Wirtschaftsinformatik') is widely accepted in busi-ness and academia in the German-speaking countries (nearly all degree programmes are labelled as 'business informatics'). In the UK/Ireland, the term information systems or information management is often used. Table 2 illustrates some further examples of masters level degree programmes and the terminology used in the UK/Ireland.

Table 2: Overview of Terminologies used for study programmes in the

MSc Analysis, Design and Management of Information SystemsMSc Business Administration (IT)
MSc in Advanced Computer Science with ICT ManagementMSc in Information Management
MSc in Multidisciplinary Informatics
MSc Information and Knowledge ManagementMSc Information Systems MSc in Electronic Commerce (Technical and Business)

Source: Authors

In order to provide an indication of key subjects, we identified some indicators by summarizing typical study profiles (Although the number of study programmes involved does not allow a de- tailed quantitative analysis). In contrast to information systems, business informatics appears to have a stronger focus on mathematics, logic, and structural science, which includes statistics and operations research. One reason for these could be the focus on the systematic construction and the application of methodological principles, which are often stated as typical for business informat- ics (Disterer et al., 2003; Gesellschaft für Informatik, 2003; Heinrich, 2002; Retzer et al., 2003). In this regard business informaticians are often described as information system architects (in thesense of engineers) who are actively and systematically analyzing and designing business infor- mation systems. Indeed, in general, mathematical principles are perceived as essential in order to systematically construct, formalize, and analyse models and architectures of information systems(Henderson, 2003).

It is also interesting to note that universities in both the UK/Ireland and the German-speaking countries regard systems and software engineering courses as important. This might be an inter-esting differentiator to programmes in North America. Another indication of the importance of programming in the study programme might be indicated by the proportion of information and communication technology, programming and algorithms, data and object structures courses in both UK/Ireland and the German-speaking regions. In addition, most UK/Ireland based degreesinclude a substantial course in data engineering.

Study programmes in the UK/Ireland generally have a more open structure. They are often designed as conversion programmes, which require no particular knowledge in management or informatics or accept students from various backgrounds. Within conversion programmes, fundamentals of information systems are given more weight in contrast to the more specific courses on business information systems in the German-speaking area. This specialization in business subjects might be justified by considering the comparatively long study duration of nine semesters and the design as integrated curriculum (even over two levels of Bachelor and Master). De- grees in the UK/Ireland are mostly designed as one-year programmes.

Another interesting observation is the stronger focus on information management in UK/Ireland. The courses focus more on the alignment of business strategies and information technology (e.g. courses in information systems strategy) as well as the management of information technology and technology-orientated teams. In addition, the UK/Ireland based courses tend to have a high proportion of career electives, which might indicate the character of masters level degrees as a means of specialization beyond the undergraduate level. In contrast, courses in the German-speaking countries appear to have more detailed courses in business. The majority of business informatics degrees in German-speaking countries offer particular and substantial courses in accounting, finance, and logistics (or supply chain management) and include a course in econom-ics.

2.1 Structure and legal framework

Despite the Bologna Declaration, with an agreement among European countries for a common educational area with a three-level study structure, the degree structure in different countries is still very different (General reports regarding the current status of the higher education area of each European Union member state can be found at Ministry of Education and Research, 2005). Some of the differences in study programmes might be attributed to the lack of a comprehensive framework of qualifications and requirements. This is notable, as since the identification of a three cycle structure within the Bologna Declaration, a need for developing an over-arching quali-fications framework for the European Higher Education Area (EHEA) was identified (Bologna Working Group on Qualifications Frameworks, 2005). At present, only a few European countries have developed comprehensive qualification frameworks; an accepted common European Framework is still some way off.

2.2 Programme Layout

The central focus of the curriculum for business informatics is to educate individuals to plan and lead IS-related projects, both technological and organisational. The core aim is enables students to apply technological solutions and develop information systems architectures to solve business problems of organizations. With this goal in mind the curriculum focuses on an engineering and methodology perspective. Intended intakes for the programme are students who have achieved a primary degree in computing, computer science, software engineering, or a comparable disci- pline. Furthermore, the objective was to integrate cultural work experiences into the programme. The programme is designed to be completed in one calendar year of full-time study, with 90 ECTS workload. It consists of two taught semesters followed by a practical project in the third semester over the summer months.

3 Conclusion

The interaction processes described above necessitate a systematic approach to creating, implementing, and maintaining information systems specifically tailored to the needs of the fields they serve. In other words, the design and support of software products are driven by their intended uses. Applied computer science in economics allows for integrating two distinct areas, forming a cohesive and effective system.

Economics has long been an independent field of study. However, a more recent development is that applied computer science encompasses a broader scope than just economic processes. It significantly aids every business entity engaged in daily economic transactions, enhancing the efficiency and security of these processes.

In conclusion, Applied Computer Science in Business Informatics is a crucial nexus of technology and management strategies, vital for modern businesses and public administration. This discipline utilises technological innovations to refine business processes through systematic design, implementation, and management of information systems aligned with organisational goals. As businesses navigate an increasingly digital world, the role of Applied Computer Science is becoming ever more central. It streamlines business operations via automation and improved communications and significantly influences strategic planning and decision-making. The increasing importance of this field is marked by its fundamental contributions to shaping business strategies and boosting operational efficiencies across various sectors. Looking ahead, the fusion of Applied Computer Science with business operations will remain indispensable, requiring a deep understanding of both technological capabilities and business imperatives to drive innovation, optimise performance, and sustain competitiveness in a rapidly evolving economic environment.

References

Baldin, K.V. (2017). *Information technologies in management*. Moscow: Academia.

Ivasenko, A. G., Gridasov, A. Yu., & Pavlenko, V. A. (2019). *Information technologies in economics and management: Textbook allowance*. Moscow: KnoRus.

Meshcheryakov, P. S. (2018). *Applied informatics: Textbook allowance*. Tomsk: El Content.

Helfert, M. (2007). Teaching information quality skills in a business informatics programme. In *Proceedings of the MIT Information Quality Industry Symposium* (pp. 908-912). Cambridge, Massachusetts, USA.

Laundry, J. P., Pardue, J. H., Longenecker, H. E., & Feinstein, D. F. (2003). A common theme for IT degree programs. *Communications of the ACM, 46*(11), 117-120.

Straub, D. (2003). IS research perspectives: A mandate for scholarly debate. *Journal of the Association for Information Systems, 4*(5), 233-236.

SUPPORTING THE RESEARCH WORK OF AN H2020 CYBERSECURITY PROJECT WITH INNOVATION MANAGEMENT TOOLS AND METHODOLOGY - A CASE STUDY OF THE ECHO PROJECT

Márton[20] Kis, Antal[21] Bódi, Gábor[22] Kiss

Abstract

The European Union provides structured funding to solve priority problems affecting the Union as a whole and the individual Member States, including open calls for tenders. Problems are regularly evaluated, reviewed, and supplemented. The projects submitted to the calls are carefully selected based on a transparent, strict criteria system. Project ideas usually come from a small initiating team, and the consortium undertaking the implementation is built around this. During the implementation of individual projects, the work takes place according to a well-defined work plan, the progress of which is constantly monitored by the Commission. With all of this, even in the case of completed projects, it is difficult to verify whether the original intention of novelty and innovation content was realised and whether the project produced a useful result reflecting the original problem. This article presents the process and methodology of good practice for a specific cybersecurity project. With the involvement of project members, the problem statement, solution, and response can be validated on a much wider scale than usual, making it much more likely to deliver a useful, relevant solution for the community during and after the project's life cycle. It is presented how the Innovation Management work package of the ECHO (European Network of Cybersecurity Centers and Competence Hub for Innovation and Operations) H2020 research and development project mobilised the members of the other professional work packages, and along which activities it was possible to achieve that the problem definition became more precise, and thus in the development process it was possible to rely on this definition continuously and to check the expected results and effects.

It can be determined based on the good practice described in the article that the practical application of the innovation methodology, and thus the joint thinking of experts, developers, and cyber defence specialists working in different fields and putting it into a structured form, resulted in timely and exact response to a shock (Covid) and the project could publish a relevant white paper about the new cyber threats arising from the pandemic. Those results were then built into the development process, and the products were adjusted accordingly, which supported the high quality and future usefulness of the project's deliverables and products.

Keywords

Cybersecurity, Innovation management, Exploitation, Research and development, Good practice

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1 Introduction

The European Union provides structured funding to solve priority problems affecting the Union as a whole and the individual Member States, including open calls for grants and tenders. Problems are regularly evaluated, reviewed, and supplemented. The projects submitted to the calls are carefully selected based on a transparent, strict criteria system. Project ideas usually come from a small initiating team, and the consortium undertaking the implementation is built around this. During the implementation of individual projects, the work takes place according to a well-defined work plan, the progress of which is constantly monitored by the Commission. Even in the case of completed projects, verifying whether the original intention of novelty and innovation content was realised and whether the project produced a useful result reflecting the original problem is difficult. Within this rigid structure, it is also almost impossible to reflect on the changing of the original societal/market need during the project's lifetime.

The article presents the process and methodology of good practice of a specific project, where the problem statement and the solution can be validated with the involvement of project members, enabling the delivery of relevant solutions for the EU after finishing the project.

It presented how the Innovation Management work package of the ECHO (European Network of Cybersecurity Centres and Competence Hub for Innovation and Operations) H2020 R&D project mobilised the members of the other professional work packages.

The innovation management (Walder, 2021) activities presented in the article made it possible to achieve a more precise problem definition, which allowed the development process to rely on it continuously and check the expected results and effects against it.

It can be established that the practical application of the innovation methodology, resulting in the joint thinking of experts, developers, and cyber defence specialists, supported the high quality and future usefulness of the project's deliverables and products.

2 Cybersecurity projects in the EU

One of the major challenges of the EU is to strengthen its cybersecurity capacity and capabilities. The purpose of a European Cybersecurity Network and Competence Centre - delivered through 4 key pilot projects (CONCORDIA, ECHO, SPARTA, and CyberSec4Europe (Figure 1) aimed to retain and develop cybersecurity technological and industrial capacities and strengthen and sustain Europe’s cybersecurity competence. Each of the four projects took a different approach to these goals. The four projects coordinated their activities and worked together with other European cybersecurity actors to advance cybersecurity research in Europe. The range of cybersecurity-related activities included demonstration use cases in eHealth, finance, telecommunications, smart cities, and transportation.

Figure 1 - H2020 pilot projects

Source: EC infographics

These pilot projects had over 160 partners, including major companies, SMEs, universities, and cybersecurity research institutes from 26 EU Member States. The overall EU investment in these projects was over 63.5 million Euros. The four pilots were selected among 12 eligible proposals that the European Commission has received for the Horizon 2020 call SU-ICT-032018. This call was part of the Horizon 2020 focus area 'Boosting the effectiveness of the Security Union (SU)'.

3 Research problem

Based on their previous experience in the field of European research projects, the authors state that the research and development work during the projects' lifetimes is not optimal. Innovation-based methodologies embedded into the project workflow can improve the cooperation and information sharing of the project partners and the validation and outcome of project results.

This statement applies to all the project cases where the environment and market needs and circumstances change during the project's lifetime, requiring adjustments to be made to the deliverables. But the problem is even bigger when unexpected, sudden events dramatically change the landscape (pandemics, financial crisis, war, political turmoil) (Zupancic, 2023), and the project must make a swift evaluation of the situation and implement the necessary adjustments and increase organisational resilience (Liu, 2021).

The following use case depicts this process, how the new cyber threats caused by the Covid pandemic could be detected and summarised rapidly using the innovation management methodologies (Jobbágy, 2021), how it supported the development work of the project internally, and how it supported all the EU community by publishing the findings in a White Paper.

4 The ECHO use case

ECHO (the European network of Cybersecurity centers and competence Hub for innovation and Operations) was one of the four projects to connect and share knowledge across multiple domains to develop a common cybersecurity strategy for Europe.

Figure 2 - ECHO main products

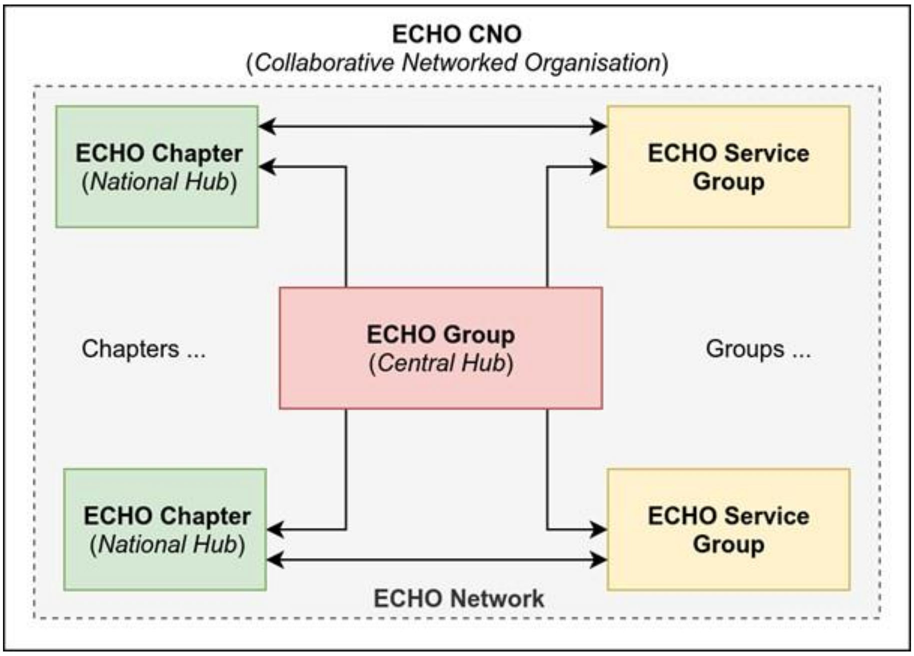
Source: ECHO project presentation, Matteo Merialdo et al.

The work was divided into six different but connected main activities, as shown in Figure 2. Federated Cyber Ranges (FCR)and Early Warning Systems (EWS) aimed to prepare for cyber threats and share knowledge timely and effectively between EU cyber actors (Carvalho, 2019). The three frameworks – Cyberskills, Certification, and Multi Sector Assessment – produced frameworks and benchmarks for future cooperation. Ultimately the Governance Model provided an operational structure where the coordinated knowledge sharing of partners on cybersecurity development can be continuously conducted even after the project's finish.

The final governance structure has been established after a long negotiation process, as shown in Figure 3. The transition from the ECHO project life to future independent operations was only possible by introducing a central hub, where all the project results would be deposited, and the public and private utilisation could be monitored and separated.

Figure 4 shows the planned working structure of the ECHO project, submitted during the time of application. It is a clear and logical breakdown of the working plan. The main development work packages (WP2-3-4-5-6) are followed by prototyping and demonstration work (WP7-8) and it is framed by the usual coordination and project management (WP1) and Dissemination (WP9) activities. It is interesting to realise that already at the project planning, WP9 aimed to deliver much more than the usual communication and dissemination work, covering exploitation, innovation management, and societal aspects. As will be elaborated later in this article, this forward-looking planning was vital for the project's success.

Figure 3 - ECHO governance model



Source: ECHO project presentation, Todor Tagarev et al.

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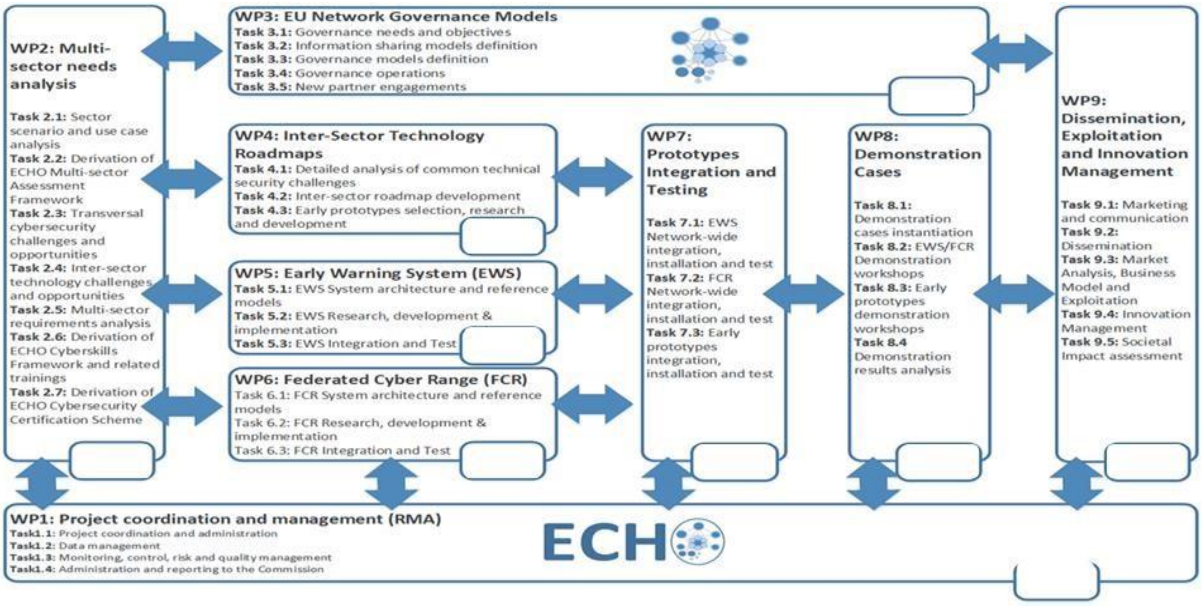
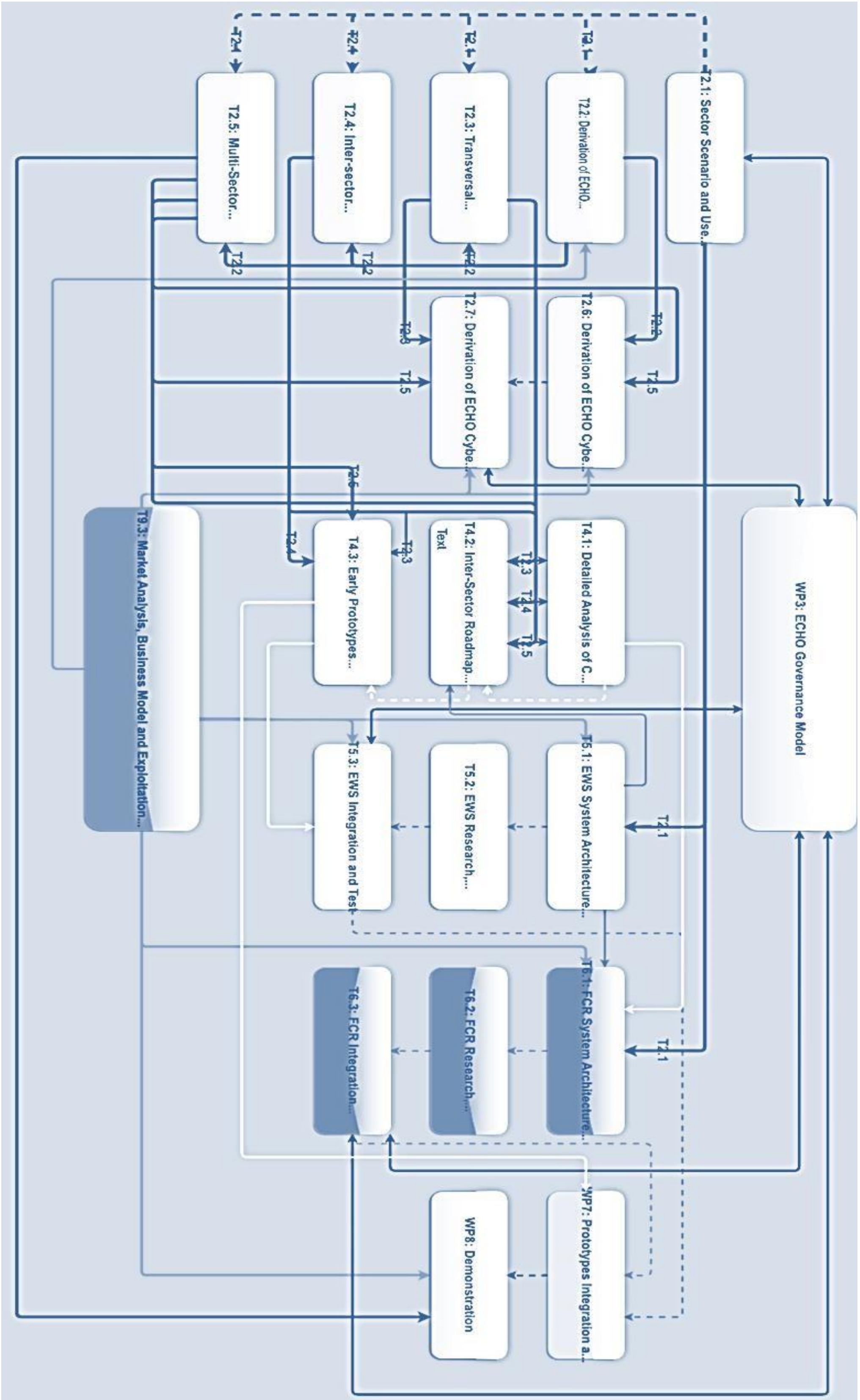
Figure 4 - planned working structure



Source: ECHO project presentation, Matteo Merialdo et al.

Figure 5 shows the actual representation of project work and especially the interdependencies and knowledge transfer relations between the work packages on the task level. It is worth noticing how knowledge flows between different development stages and how the information from development tasks was fed into prototyping and demonstration cases. The importance of governance (the work defining the future operational model) and exploitation (market needs, business modelling) is much more visible from the multiple direct connections to the development work.

Figure 5 - actual working structure

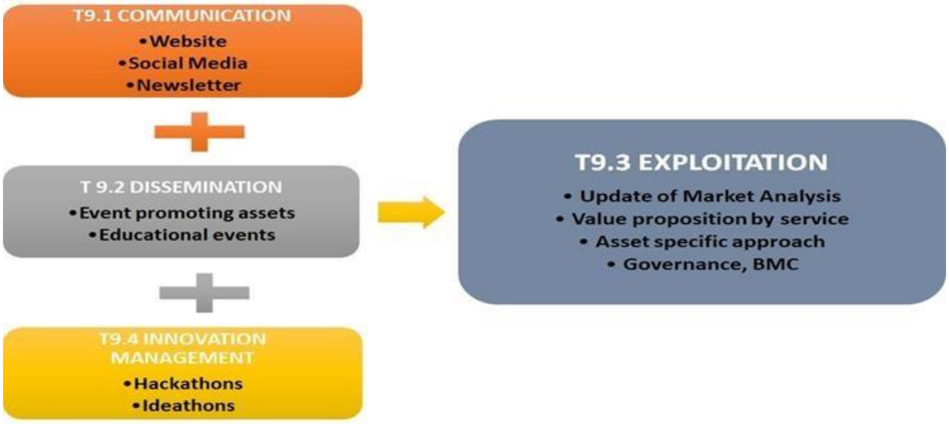


Source: ECHO project presentation, Matteo Merialdo et al.

4.1 Role of WP9

Usually, EU project partners consider the communication and dissemination work as a must and nuisance (it is compulsory) as it is viewed by many as taking away resources from the development and professional work. As exploitation is already a mandatory activity, too, it brought in further complications for the development work packages – as the project must continuously investigate the need and added value of the products/services created during the lifetime of the project and their commercial or societal value and impact.

Figure 6 - WP9 task structure



Source: ECHO project presentation, Marton Kis et al.

As Figure 6 depicts, ECHO took this important approach even one step further. WP9 did not just deliver the regular dissemination work by publishing the project results on different online channels and international conferences or publications. The work was carefully planned, and with exploitation as the main focus, one additional winning element was added. Innovation management work became part of WP9 activities. While TRL levels and evolution were monitored carefully, the biggest advantage lay in introducing the structured co-creation activities (Ideathons and Hackathons), where the consortium contributed to predefined problems and their solutions. As detailed in later chapters, these innovation management tools enabled the teams to better express the actual underlying problems (by codefining problem statements), and it was also part of the co-creation process to search for solutions for those problems and carry out a joint validation process.

4.2 Challenges during the project

Figure 7 includes the 5 main challenges of the project that could be identified. As the work started in 2019, the planned routine started to function – a usual and effective combination of in-person and virtual meetings. This has been abruptly changed with the introduction of travel bans in the entire EU. Project partners had to reorganise work to only virtual. During the process, a lot of problems were identified. Thus, the partners decided to focus the innovation management activities on clarifying the exact problems, cyber threats, and potential solutions- which led to organising an all-project hackathon and resulted in the published unique white paper discussed in detail in a later chapter.

Figure 7 - ECHO challenges

Source: own figure

The complicated work structure posed a threat in itself, but combined with COVID-19, it became obvious that the WP1 coordination team must put in extra effort to streamline the information flow within and between work packages to avoid major delays and quality decreases in project deliverables and results. Extra management focus paid off, the project partners adjusted to the new normal, and the full virtual work could deliver the required quality.

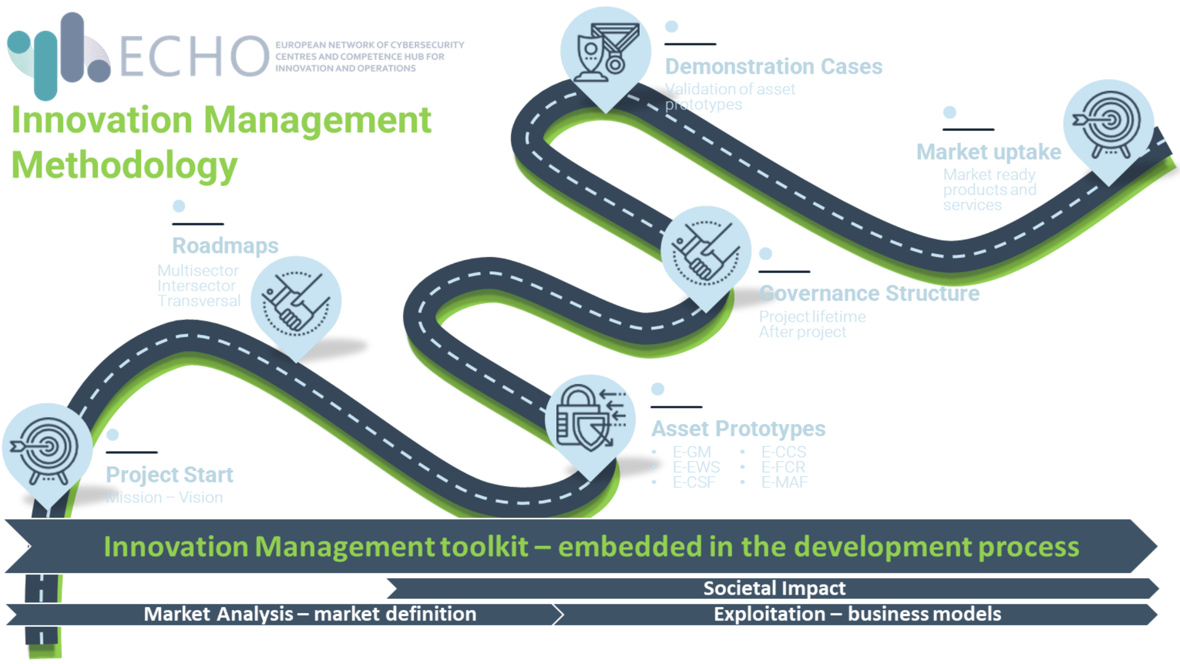
The size of the project meant, that the 30+ partners' and 200+ individual contributors' work had to be coordinated. The EU projects usually carry some cultural differences between the different member states, which is expected. The cooperation problems from different academic and private companies' approaches are also known. Further complications derived from the different mindsets of developers, hackers, engineers, academics, and politicians.

The last two challenges are interconnected – it is difficult to define the current cybersecurity challenges of Europe, let alone describe in detail what those problems will be in 5 or 25 years. The project work has been conducted following a preset path and work plan. The developers had no time neither focus on following the long-term or rapid short-term changes and shocks affecting their work, ultimately resulting in the need to make major adjustments to the planned products and services as cybersecurity threats and challenges might have changed drastically or the future need might be different from what the project anticipated at the proposal phase. These open questions were articulated into problem statements and fed into the co-creation events to stimulate discussion, exchange of views, and ultimately arrive at new ideas, results, and change of plans.

4.3 Innovation Management in Action

The innovation management approach was an organic part of the project's development process from the very start, as visualised in Figure 8 below. As the project's development work moved forward from the initial goal setting through setting roadmaps, launching prototypes, defining the targeted governance structure, and piloting asset demonstration cases, ultimately reaching market-ready results, innovation management activities were embedded in the process.

Figure 8 - Innovation management methodology



Source: ECHO project presentation, Marton Kis et al.

Regular Ideaathon events were organised, and development WPs were directly involved. The Ideaathon results were used in research and development work to support sustainability and exploitation planning. The events always started with a high-level problem definition. This was then further refined to exact problem statements and subject to group validation during the events.

Once there was an agreement on the exact challenge, problem, or obstacle, the co-creation could commence, aiming to find the best solution. The events always concluded with a list of proposed solutions and actionable items to be directly used in the development process, and some of the public interest was published as blog items or white papers for wider uptake.

5 Identified cyber threats during Covid

Using the above methodology, the ECHO project partners could identify the changing environment during COVID-19 and capture the new or increased cyber threats arising from the abruptly changing digital working environment of major populations worldwide.

This unique approach also enabled ECHO to synthesise the project findings and publish a white paper very quickly after the onset of the pandemic, helping not only the project work but the whole EU community to raise awareness and take precautions against the new cyber threats. ECHO efforts became a major part of the coordinated EC efforts to step up against adverse COVID-related cybersecurity issues.

The following is the summary of the findings published in the white paper (ECHO, 2020).

5.1 General considerations

The white paper established that the general conclusion is that during Covid, the approaches and the technology being used by hackers were the same as it was before. However, there were two major differences. Firstly, the transition to online working and schooling.

Secondly, the human factor is an even bigger weakness than before because of the instability arising from limited information and increased fears of the pandemic, thus becoming more vulnerable and less suspicious to cyber attacks.

5.2 Profile of the Attacker

Three profiles of potential threat actors are identified: the criminal hacker, the hacktivist, and the nation-state-supported hacker's group.

5.3 Modus operandi of attack

During the event, several attack vectors were discussed in combination with the different profiles of the attackers, as summarised in Table 1.

Table 1 - Modus operandi of attack

Platforms	Attack method/threat	Scenarios
Emails	open the attachment, download the file, click the link	WHO, donation, conspiracy, home delivery
SMS	cloned websites of authorities	government announcement
Messaging apps	cloned websites	fake news
BYOD	use of home PC vulnerability, office apps installations	
Critical infra providers	rapid change from stand-alone to remote access	
Medical devices	malware threat	
Covid applications	steal of personal information	
Online conf apps	cloned websites calling for online meetings	

Source: own table

6 Conclusion

Cybersecurity is one of the major challenges for several reasons (pandemics, wars, digitalisation) for the European Union. EU R&D projects are useful and efficient in delivering results to tackle this issue and bring fresh, innovative, and coordinated solutions. However, these projects are not ideal for delivering timely results; actual needs and goals have to be updated, and they will change during the lifetime of a project. Problems arise from the difficulties of working in diverse, multi-national, and multi-disciplinary teams, offline and online. The EC valuation of preset milestones and deliverables does not leave enough space to adjust results to tackle new needs and challenges.

Coordinated innovation management (IM) activities can be vital in facing these challenges. From identifying and validating the key demand/market need to validating results, IM can support several important steps of a project's development process. Continuous cooperation and co-creation among project members will lead to useful results.

ECHO partners and individual project members pioneered this approach, embedding the IM methodologies into the daily routine of the project work across the whole project timeline. This resulted in better information flow, common definitions, and an understanding of the previously listed challenges. The common ground then helped the developers and professional members within the project make the necessary adjustments to the products so that they could be applied to the changing needs of the cybersecurity landscape.

The research should continue to analyse the methodology used in the ECHO project to evaluate how to standardise it and how it can be used as good practice in future Horizon projects.

Resources

Carvalho, T. (2019, February 27). *H2020 echo cybersecurity*. VisionSpace Blog. https://www.blog.visionspace.com/blog/2019/2/27/h2020-echo-cybersecurity

ECHO. (2020, April 8). The COVID-19 Hackers Mind-set. Funded by the European Union's Horizon 2020; www.echonetwork.eu.

Jobbágy, Z. (2021). Innovation Methodologies for Defence Challenges: On Design Thinking and Organic Approaches. *Honvédségi Szemle – Hungarian Defence Review, 148(2)*, 50–64.

Liu, Y. &. (2021). Analysis of the Influencing Factors of Organizational Resilience in the ISM Framework: An Exploratory Study Based on Multiple Cases. *Sustainability.*, 13492.

Walder, D. H. (2021). Transformation and Design Thinking: perspectives on sustainable change, company resilience and democratic leadership in SMEs. *Leadership, Education, Personality: An Interdisciplinary Journal*, 145–156.

Zupancic, N. (2023). Systematic Literature Review: Inter-Reletedness of Innovation, Resilience and Sustainability - Major, Emerging Themes and Future Research Directions. *Circular Economy and Sustainability*, 1157– 1185.

ARCHITECTURE AND ATTRIBUTES OF INTELLIGENT ONLINE EDUCATION SYSTEM

Martin Mišút[23], Maria Mišútová [24]

Abstract
Technological advancements are transforming educational practices by integrating digital tools and promoting online learning, a trend accelerated by the COVID-19 pandemic. Innovations in AI, big data, and analytics are revolutionising education, enabling personalised learning experiences. This discussion underscores the importance of intelligent e-learning approaches that analyse student data to customise education. Intelligent learning systems offer tailored, engaging experiences, crucial for enhancing education quality. These systems incorporate customisation, flexibility, and analytics, essential for their success. They combine educational content, algorithms, and infrastructure to support varied learning styles while ensuring security and ethical standards. By embracing these advanced e-learning strategies, educational outcomes improve, and access to quality education expands, benefiting many learners.

Keywords
Intelligent educational systems, Personalization of learning, Adaptive learning, Artificial intelligence in e-learning, Intelligent educational system architecture

1 Introduction

Technology integration in education across all levels has recently enhanced and diversified traditional teaching methods. The rise of online and distance learning, catalysed by the pandemic and subsequent lockdowns, underscores the urgency of adopting digital learning platforms and tools. (Liu & Yu, 2023) This shift necessitates teachers and students to adapt to an environment where physical distance demands more effective educational approaches. Consequently, research is increasingly transitioning from merely establishing online infrastructure and content delivery to fostering interdisciplinary efforts to enhance the online learning experience, as Shute and Towle (2003) have noted.

Technological advancements like artificial intelligence, big data, and learning analytics are revolutionising education by analysing students' digital interactions with educational technologies, as Daniel (2015) highlighted. Educators must deliver scalable, personalised, and adaptive learning programs that respond to individual student needs and support online learning.

The use of advanced techniques in e-learning is crucial in providing content tailored to students' needs and motivations while also considering their emotional states. The need to incorporate new intelligent technologies into the educational process is significant so that e-learning systems can offer personalised educational content and adaptive learning trajectories (Mote et al., 2016). This approach requires recognising students' individual characteristics, such as their knowledge, cognitive abilities, and preferences for learning strategies, as Van Seters et al. (2012) emphasised.

Drawing from research such as Becker et al. (2018), Mangaroska and Giannakos (2017), and Canales et al. (2007), which underscore the significance of intelligent methods in e-learning for educational enhancement, this paper seeks to examine and assess AI techniques in specific

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e-learning components. It aims to measure their impact on the educational process and outline the framework of an intelligent educational system.

2 Intelligent educational system

An intelligent learning system leverages advanced technologies like AI, machine learning, and analytics (Badaracco & Martínez, 2011) to enhance education by offering personalised, adaptive learning experiences. These systems analyse data to tailor content and support to each student's needs, incorporating adaptive content, interactive tools, and intelligent agents for support (Shute & Towle, 2018). They aim to enhance learning effectiveness and efficiency, catering to individual preferences and promoting better educational outcomes and innovation.

An intelligent learning system differs from traditional e-learning in several key aspects:

- Personalisation: Intelligent learning systems can personalise content and learning processes according to students' individual needs and preferences. Unlike traditional e-learning, where static content is often provided, intelligent systems can customise learning for each learner.
- Adaptability: Intelligent systems can adapt to changes in student performance or needs and provide relevant learning materials and exercises based on their current state. Traditional e-learning may not have this capability of dynamic adaptation.
- Evaluation and feedback: Intelligent learning systems use advanced algorithms to evaluate student performance and provide them with more accurate and relevant feedback. Traditional e-learning often relies on standard assessment methods such as tests and quizzes.
- Interaction and engagement: Intelligent systems can have interactive elements that increase student engagement with the content. These may include games, simulations, or adaptive exercises. Traditional e-learning may have limited opportunities for interaction and engagement.
- Predictive analytics: Intelligent learning systems can use predictive analytics to predict future student performance and identify improvement areas. Traditional e-learning usually does not deal with such predictive analytics.

3 Intelligent techniques

Intelligent techniques are pivotal in enhancing e-learning, offering efficient, personalised educational services through technologies like AI, which simulates human reasoning to make data-driven decisions and adapt to student needs. Integrating machine learning and deep learning, AI analyses data to discern patterns, enhancing system responsiveness and performance. Machine learning allows systems to learn from data, optimising behaviour. Big Data processes vast data volumes, revealing insights into student performance and needs and facilitating tailored learning experiences (Zhang et al., 2021). Natural Language Processing (NLP) enhances system-student interaction by processing and generating human language (Jiang & Li, 2020). Predictive analytics forecasts students' future needs and achievements, aiding in personalised educational planning (Mangaroska & Giannakos, 2017).

The mentioned techniques and methods contribute to educational systems' intelligence by enabling them to analyse data, learn from experience and adapt based on the acquired knowledge. This, in turn, enables these systems to provide personalised, adaptive, and effective learning experiences for students.

Intelligent techniques affecting e-learning can be implemented in different ways so that the intelligent educational system acquires the ability to:

- Adaptive behaviour: - includes adapting to student needs and learning styles through personalised learning contents, exercises, and feedback.
- Machine learning: - allows the educational system to learn from data and adapt its behaviour based on the analysis of student results, thus improving the effectiveness and accuracy of the content provided.
- Natural Language Communications (NLP): NLP enables systems to understand, interpret, and generate human language, which can be used to automate answers to questions, information retrieval, and content generation.
- Recommendations of suitable content for study: Recommender systems analyse user behaviour and recommend relevant content or courses based on this, improving the learning experience.
- Experience analytics: This technique includes data analysis of student activities and performance. Analysing allows for improving learning processes, identifying problems, and providing personalised recommendations.
- Interactive communication: Chatbots are intelligent agents that can answer students' questions and provide help in real-time, improving accessibility and support for students.
- Interaction with students through virtual and augmented reality: These technologies allow students to interact with virtual environments and simulations, providing realistic and meaningful learning experiences.

4 Key features of intelligent learning environments

Designing educational systems should prioritise student needs, focusing on their requirements, abilities, and goals (Sakarkar et al., 2012). Intelligent learning systems need to develop student models (Ilić et al., 2023) that track progress and needs through data mining, allowing students to access and analyse their information. The adaptability and personalisation of these systems hinge on their capacity to manage and interpret educational data and context (Shute & Towle, 2018), using insights to enhance learning experiences and outcomes. Personalised education in such systems adjusts the educational pace and content to fit individual preferences and learning styles, integrating various content forms and interactive features to support diverse learning preferences (Liu & Yu, 2023).

Intelligent learning systems are characterized by their adaptability. Based on assessments and progress analytics, they adjust to students' evolving needs and abilities. Such systems respond to students' changing requirements and adapt to new developments within a knowledge domain (Gunda & Dongeni, 2017). They automate content management, ensure materials remain updated and pertinent, and tailor recommendations to meet students' interests and needs.

To increase the engagement and participation of students in education, it is appropriate if intelligent educational systems include interactive elements, such as games, simulations, online discussion forums or other interactive tools. (Wang & Zhao, 2021)

Providing immediate and accurate feedback is an essential feature of intelligent learning systems. This feedback can be generated automatically based on the results of tests or assignments, or teachers and tutorials can provide it. Some intelligent learning systems can provide real-time learning and support, allowing students to get immediate help or clarification when solving problems. The prerequisite is the integration of chatbots and intelligent explanatory modules.

Data security and protection are also self-evident requirements. Ensuring data confidentiality, integrity, and availability is a crucial priority for intelligent education systems, especially regarding students' personal data and sensitive information.

From the above, intelligent learning systems should have several properties that distinguish them from traditional ones and allow them to provide improved learning experiences. They mainly include:

1. Personalisation:
    - o the ability to adapt to each student's needs, preferences and learning style.
    - o Providing personalised content, exercises and assessments.
2. Adaptability:
    - o ability to adapt to changing needs and abilities of students in real time.
    - o Automatic adjustment of teaching content and procedures according to the assessment results and analysis of student progress.
3. Interactivity:
    - o the presence of interactive elements such as games, simulations, or online exercises to increase students' engagement and active participation.
4. Feedback:
    - o Providing immediate and accurate feedback to students regarding their performance and progress.
    - o Analytical tools for tracking and evaluating student results.
5. Education analytics:
    - o ability to collect and analyse student data to identify patterns, trends and areas for improvement. Using predictive analytics to predict future student performance.
6. Real Time Learning:
    - o Providing immediate support and explanations to students during their learning process.
    - o Dynamic adaptation of teaching based on students' current abilities and knowledge.
7. Automated content management:
    - o Automatic management and updating of educational material content according to new information and student needs.
    - o Recommending new topics or materials based on the results of the analysis.
8. Integration with artificial intelligence technologies:
    - o Using artificial intelligence technologies, machine learning and other advanced algorithms to improve the system's behaviour and ability to learn from experience.

If an intelligent education system is to approach teacher-led education in its characteristics, it must be able to flexibly adapt to individual students' different needs, learning styles and progress. So, it must be adaptable. Here are some ways to achieve this:

- Analysing and tracking student progress: The system should be able to track student progress through interactions with content and various activities. This progress should be systematically analysed to identify strengths, weaknesses, and potential areas for improvement.
- Personalised Feedback: The system should have mechanisms to provide personalised feedback to students based on their individual needs and performance. This feedback should be immediate, relevant and tailored to specific student challenges.
- Adaptive learning environment: The system should be able to dynamically adapt the

content and learning methods according to individual students' needs and preferences. This includes offering alternative materials, assignments, and activities based on student performance and interests.

- Personalised recommendations: Based on the analysis of students' results and progress, the system should be able to offer personalised recommendations for the next steps in the educational process. These recommendations should support students in their learning and development.
- Flexibility in content and format: The system should provide various content and formats to allow students to use different learning and interaction methods. This includes text, audiovisual, interactive, and other types of content that can suit different student preferences and learning styles.
- Continuous updating and improvement: The system should be able to regularly update and improve its functions and capabilities based on new knowledge, technological innovations and user feedback. In this way, it will be ensured that the system will be able to constantly adapt to the changing needs and requirements in the field of education.

5 Architecture of an intelligent educational system

The architecture of an intelligent educational system outlines its structure, components, and operational relationships, crucial for visualising the system's organisation and achieving educational objectives (Cheung et al., 2003; Dutt et al., 2022). Understanding this architecture is key to optimising system performance, enhancing transparency, and fostering stakeholder confidence. It allows for identifying and rectifying issues, generating innovative improvements, and better grasping user needs. Additionally, architectural knowledge facilitates security risk analysis and ethical evaluations, underpinning the system's reliable deployment, functionality, and evolution (Yilmaz et al., 2022).

The system's architecture can be represented from several points of view, while each of these approaches the system from a different aspect. (X. Zhang & Cao, 2021) Critical aspects of an intelligent learning system architecture include:

1 Architectural elements – elements define the structure of the system. In the case of software architecture, it can be components, modules, or packages. Architectural elements form a system, and architecture describes how these parts are organised. These can be modules for content management, adaptive learning, data analysis, interaction with students, etc.

2 Description of system behaviour. System behaviour is determined through relationships and interactions. Architecture describes how the individual components of the system communicate and cooperate to achieve common goals. This may include data transfer, information exchange, synchronisation of activities and other forms of interaction.

3 Technological and software solutions: Identifies what technologies and software tools are needed to implement individual system components and modules. These can include database systems, development tools, algorithmic libraries, etc.

4 Data structure describes how data is organised and managed within the system. It includes database structure, data formats, backup and recovery processes, data protection, and more.

5 Security aspects: How data and information in the system are protected against unauthorised access, manipulation, or loss is identified. This includes access policies, encryption, audibility, and other security measures.

When designing the architecture of an intelligent learning system about the technical solution and available technologies, it is essential to consider several key factors that affect its effectiveness, flexibility and usability. These are mainly the following factors:

- Flexibility and Modularity: The architecture should be flexible and modular, allowing system components to be easily added, removed, and updated depending on needs and requirements.
- Scalability: It is vital to ensure the architecture is scalable and can handle the growing number of users, data volume and performance requirements.
- Integration with existing systems: If learning systems or technology platforms already exist in the organisation, it is crucial to ensure that the new intelligent learning system can integrate with and work effectively with them.
- Security: Data security and student privacy are key factors in the architecture design. It is important to ensure that the system is resistant to attacks, has data protection mechanisms in place and complies with the relevant legal requirements for privacy protection.
- Personalisation and adaptability: Architecture should support the personalisation and adaptation of education according to students' individual needs and preferences. This includes monitoring student progress and adapting content and teaching methods based on their performance and learning style.
- Analysis and use of data: It is important to have a mechanism included in the architecture for collecting, processing, and analysing data about students and their educational process. This data can be used to identify trends, improve learning processes, and provide personalised feedback.
- Sustainability and governance: Architecture should be designed with sustainability and governance in mind. This includes ensuring easy system maintenance, updates, and management and effective resource and cost management.

In accordance with the content of the previous chapter, in which we listed the critical properties of an intelligent educational system, it is clear that it must be made up of elements that ensure the mentioned critical properties. From this point of view, an intelligent educational system must contain the following elements:

- Learning contents: Creating and making educational materials and content available is key. These contents may include texts, images, videos, interactive exercises, and other forms of educational material.
- Learning Algorithms: Learning algorithms are the cornerstones of an intelligent learning system. These algorithms analyse and process data, generate recommendations, and personalise learning for individual users.
- Personalisation and adaptability: The ability to personalise learning content and procedures according to student's needs and preferences is crucial for effective education. Intelligent systems often use personalised approaches to improve learning outcomes.
- Feedback mechanisms: Providing feedback and evaluating student performance is important for monitoring their progress and identifying areas for improvement.
- Interactive elements: Interactive elements such as simulations, games and discussion forums can improve student engagement and involvement in the learning process.
- Learning Management: Learning management involves planning, organising, and monitoring the learning process, including planning lessons, assigning tasks and

monitoring student progress.

- Technical infrastructure: Technical infrastructure includes the hardware and software required to operate the system, including servers, databases, web interfaces and applications.
- Ethical and Security Aspects: Because student data is sensitive and sensitive, an intelligent learning system must adhere to strict security and ethical standards.

An intelligent education system incorporates various modules to deliver tailored and effective learning. The content management module updates and customises materials like lessons and videos based on student needs. The adaptive learning module personalises the educational environment by tracking progress and adjusting content or methods accordingly. Interactive tools facilitate student engagement through forums, group activities, and virtual labs. The analytical module analyses educational data to enhance learning outcomes, while the feedback module offers real-time performance evaluations and improvement suggestions. Assistive technologies, such as chatbots, aid student learning, and security modules protect data and ensure privacy. Collectively, these interconnected components form a holistic system that adapts to and engages students, offering personalised, dynamic learning experiences.

Fig. 1. Architecture of Intelligent e-Learning System.

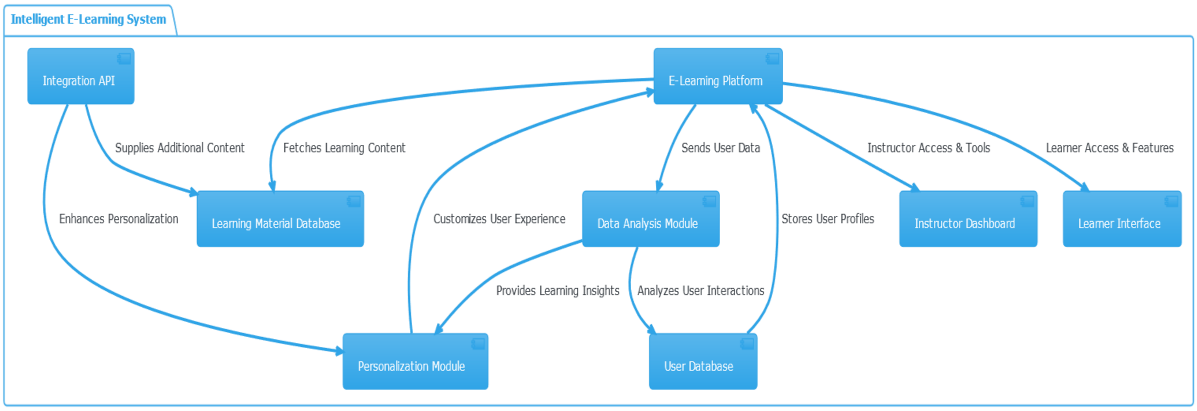

Figure 1 shows a simplified representation of the essential components of an intelligent e-learning system. The mapping of individual functional areas is hidden in other layers of the architecture. The component diagram for the intelligent e-learning system visualizes the structure and interactions among its various components, outlined as follows:

E-Learning Platform (ELP): Serves as the central hub for the system, providing interfaces for learners and instructors while managing the delivery and interaction with learning content.

- Fetches Learning Content from Learning Material Database (LMD): The ELP retrieves educational materials and resources from the LMD to present to the users.
- Sends User Data to Data Analysis Module (DAM)**:** User interactions and engagement data are sent from the ELP to the DAM for processing and analysis.
- Receives Customized User Experience from Personalization Module (PM): Based on insights generated by the DAM, the PM tailors the learning experience, which the ELP then delivers to the users.

Learning Material Database (LMD): Stores the educational content, including multimedia resources, course materials, and other learning aids.

- Supplied with Additional Content by Integration API (IA): External content sources can augment the LMD through the IA, ensuring a broad and up-to-date repository.

Data Analysis Module (DAM): Analyzes user data to extract patterns, preferences, and performance metrics.

- Analyzes User Interactions via User Database (UD): The DAM processes data from the UD to understand user behaviour and learning progress.
- Provides Learning Insights to the Personalization Module (PM): The PM receives insights about learning efficacy and user preferences to inform content customization.

Personalization Module (PM): This module adapts the learning experience based on analytics, ensuring that content delivery is responsive to individual learner needs.

- Enhances Personalization through Integration API (IA): The PM can leverage external tools and data via the IA to refine its adaptive strategies.

User Database (UD): Contains detailed profiles, activity logs, and progress tracking for each user, supporting personalised learning and analytics.

- Stores User Profiles for E-Learning Platform (ELP): The UD provides essential user information to the ELP, enabling tailored interactions and progress tracking.

Instructor Dashboard (ID) and Learner Interface (LI): Provide role-specific functionalities and access points within the E-Learning Platform.

- Instructor Access & Tools via E-Learning Platform (ELP): The ID offers instructors tools for course management, analytics, and learner interaction.
- Learner Access & Features via E-Learning Platform (ELP): The LI presents the students with the learning interface, resources, and personalised content.

6 Conclusion

Artificial intelligence (AI) and emerging technologies are significantly reshaping the landscape of modern education, offering a more dynamic and interactive learning environment. Integrating AI into e-learning solutions marks a revolutionary step forward, enabling the creation of tailored learning pathways that adapt to individual learners' preferences and performance levels. This personalisation extends to the customisation of online courses, ensuring that learners receive content that is most relevant and beneficial to their educational journey.

The transformative potential of AI in the e-learning sector is profound. It has the capacity to revolutionise traditional learning paradigms and make education more accessible, engaging, and effective. The advent of AI-powered educational platforms promises a future where learning is more adaptable, interactive, and aligned with individual needs and goals.

To harness the full capabilities of intelligent educational systems, it is crucial to delineate the features that set them apart from conventional e-learning frameworks. These distinctive characteristics include adaptive learning algorithms, data-driven content personalisation, real-time feedback mechanisms, and advanced analytics for performance tracking.

The development process for intelligent educational systems involves meticulous planning and design centred around the requirements and preferences of end-users, particularly students. This entails a comprehensive analysis of user needs, available technologies, and the extent to which intelligent functionalities can be integrated. The architecture of these systems must be conceived with a keen understanding of technological capabilities and limitations, ensuring that the final product is both technologically advanced and economically viable. Developers can create effective, impactful educational tools that leverage AI to enhance learning outcomes and user experiences by aligning the system's technical specifications and cost with available resources and user expectations.

In conclusion, the evolution of AI and related technologies sets a new benchmark for educational systems, emphasising customisation, efficiency, and user-centric design. As these intelligent systems continue to evolve and mature, they promise to redefine the educational landscape, making it more inclusive, engaging, and attuned to the diverse needs of learners worldwide.

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Resources

Badaracco, M., & Martínez, L. (2011). An intelligent tutoring system architecture for competency-based learning. Paper presented at the Knowlege-Based and Intelligent Information and Engineering Systems: 15th International Conference, KES 2011, Kaiserslautern, Germany, September 12-14, 2011, Proceedings, Part II 15.

Becker, S. A., Brown, M., Dahlstrom, E., Davis, A., DePaul, K., Diaz, V., & Pomerantz, J.

(2018). NMC horizon report: 2018 higher education edition. Louisville, CO: Educause.

Canales, A., Pena, A., Peredo, R., Sossa, H., & Gutierrez, A. (2007). Adaptive and intelligent web-based education system: Towards an integral architecture and framework. Expert Systems with Applications, 33(4), 1076-1089.

Daniel, B. (2015). Big Data and analytics in higher education: Opportunities and challenges. British Journal of Educational Technology, 46(5), 904-920.

Dutt, S., Ahuja, N. J., & Kumar, M. (2022). An intelligent tutoring system architecture based on fuzzy neural network (FNN) for special education of learning-disabled learners. Education and Information Technologies, 27(2), 2613-2633.

Gunda, L., & Dongeni, M. (2017). Intelligent interactive system for E-learning. Paper presented at the EAI International Conference for Research, Innovation and Development for Africa.

Cheung, B., Hui, L., Zhang, J., & Yiu, S.-M. (2003). SmartTutor: An intelligent tutoring system in web-based adult education. Journal of Systems and Software, 68(1), 11-25.

Ilić, M., Mikić, V., Kopanja, L., & Vesin, B. (2023). Intelligent techniques in e-learning: a literature review. Artificial Intelligence Review, 1-47.

Jiang, Y., & Li, X. (2020). Intelligent online education system based on speech recognition with specialized analysis on quality of service. International Journal of Speech Technology, 23, 489-497.

Liu, M., & Yu, D. (2023). Towards intelligent E-learning systems. Education and Information Technologies, 28(7), 7845-7876.

Mangaroska, K., & Giannakos, M. (2017). Learning analytics for learning design: Towards evidence-driven decisions to enhance learning. Paper presented at the Data Driven

Approaches in Digital Education: 12th European Conference on Technology Enhanced Learning, EC-TEL 2017, Tallinn, Estonia, September 12–15, 2017, Proceedings 12.

Mote, C., Dowling, D. A., & Zhou, J. (2016). The power of an idea: the international impacts of the grand challenges for engineering. Engineering, 2(1), 4-7.

Sakarkar, G., Deshpande, S., & Thakare, V. (2012). Intelligent online e-learning systems: a comparative study. International Journal of Computer Applications, 56(4).

Shute, V., & Towle, B. (2018). Adaptive e-learning. In Aptitude (pp. 105-114): Routledge.

Van Seters, J., Ossevoort, M., Tramper, J., & Goedhart, M. J. (2012). The influence of student characteristics on the use of adaptive e-learning material. Computers & Education, 58(3), 942-952.

Wang, J., & Zhao, B. (2021). Intelligent system for interactive online education based on cloud big data analytics. Journal of Intelligent & Fuzzy Systems, 40(2), 2839-2849.

Yilmaz, R., Yurdugül, H., Yilmaz, F. G. K., Şahin, M., Sulak, S., Aydin, F., . . . Ömer, O. (2022). Smart MOOC integrated with intelligent tutoring: A system architecture and framework model proposal. Computers and Education: Artificial Intelligence, 3, 100092.

Zhang, R., Zhao, W., & Wang, Y. (2021). Big data analytics for intelligent online education. Journal of Intelligent & Fuzzy Systems, 40(2), 2815-2825.

Zhang, X., & Cao, Z. (2021). A framework of an intelligent education system for higher education based on deep learning. International Journal of Emerging Technologies in Learning (Online), 16(7), 233.

Math Software in Online Engineering Education

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Abstract

The article describes a teaching model with the support of mathematical software, which can be effectively used in online education and face-to-face teaching. The model was developed as part of the project solution with the support of the KEGA agency entitled Online Teaching Model with an emphasis on increasing the quality of engineering education during a possible pandemic and a project of the KEGA agency entitled Interactive Teaching Materials from Statistics and Design of Experiments. Based on the analysis results, we identified interactive Internet applications suitable for use in individual content parts of mathematics. Pedagogical experiments must be evaluated to verify didactic effectiveness, but interim results suggest that math software has its merits in teaching mathematics.

Keywords

engineering education, math software, mathematics, online education

1 Introduction

Teaching mathematics is often tricky because many are afraid of it. Fear of mathematics is already formed in primary school (Lazaros, 2013) and can significantly affect academic results. (Leppävirta, 2011) Therefore, it is essential to determine the causes of this fear and look for a way to minimise it. As one of the ways to overcome the fear of mathematics, Leppävirta (2011) suggests increasing the emphasis on conceptual understanding of mathematics, increasing the diversity of student assessment and supporting the individualisation of learning styles and strategies. We consider ICT to be a suitable tool for individualising studies. Mathematics teachers complement the traditional teaching model with strategies that emphasise conceptual understanding, active learning, and relevant applications (e.g. (Orszaghova, 2018; Phuong et al., 2022; Rahman et al., 2012)) The quality of mathematics teaching largely determines the competence of future engineers. (Firouzian et al., 2012; Noskov & Shershneva, 2005; Schaathun, 2022) The goal of teaching mathematics at a technical university should, therefore, be the teaching of mathematical foundations following the requirements of the curriculum, cultivating a mathematical "feeling" and developing skills in mathematical modelling of the problems of the studied profession. (Orszaghova & Greganova, 2017) An essential feature of engineers when creating mathematical models is their ability to solve non-standard problems. Thus, the inability to solve them is the reason for the difficulties of university students in studying mathematics for engineers. This fact is also supported by the findings of Firouzian et al. (2012), who state in their study that engineering students in anonymous questionnaires recommended more extensive use of software for solving

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mathematical problems to improve mathematics teaching, increasing practical exercises and solving practical problems on tasks from application disciplines for an easier understanding of mathematical concepts. These findings only further confirm, by our experience, the importance of a holistic approach to creating a mathematics curriculum in an engineering study with full use of the potential of mutual enrichment of teaching both professional subjects and mathematics. Moreover, this approach is facilitated by the use of ICT. The article describes a teaching model with the support of mathematical software, which can be effectively used in online and face-to-face education.

2 Methodology

The teaching model, with the support of mathematical software, was developed as part of the project solution. The goal was that mathematics should not only serve as a “sieve” but that students should not perceive it as a necessary evil to overcome if they want to study programs that interest them. On the contrary, by applying the teaching model, we want to make teaching the introductory mathematics course more attractive for students. We want to make the teaching more illustrative and, therefore, more effective. So that even students who do not have mathematical talent can continue their preparation for the engineering profession.

Tab. 1: Analysis results of open-source mathematical software

The name of the software	Atribút	Control complexity	Reliability of calculations or display	Availability of support
WinPlot	graphic	3	5	3
Desmos	graphic	5	4	5
Geogebra 3D	graphic	5	5	5
WolframAlpha	computational and graphic	4	4	4
wxMaxima	computational	3	4	3
Matrix calculator	computational	5	5	4

Source: authors

Using software in teaching mathematics can also help achieve the stated goal. Based on the analysis results, we identified interactive Internet applications suitable for use in individual content parts of mathematics. We established four analysis criteria: content, difficulty of control, consistency of calculations, and availability of user support. We analysed the selected mathematical software in terms of content and determined the type of software. If the software only allows us to perform calculations, we assign it a type - computational. If it only allows display, the assigned type is - graphic. If the software allows us to perform calculations and is also suitable for effective representation, we have assigned its type - computational and graphic. We evaluated the control complexity on a scale from one to five. We assigned a value of five if the control is simple, intuitive and user-friendly, and we set a value of one if the control of the software is more complex and not very user-friendly. For example, it is necessary to remember the syntax. For use in teaching mathematics, we have selected software with a value of at least three.

The other analysis criterion was software reliability, i.e., consistency of calculations or the accuracy of graphic displays. We assigned a value of five to reliable software. When we find *n* inconsistencies in calculations or display inaccuracies, we reduce the value by *n* points. We also used the five-level scale in the evaluation from the point of view of the availability of user support. On a five-point scale, we assigned a value of five if user support is readily available, i.e. the user can easily find help with problems, e.g. syntax. Otherwise, we assigned a value of one. I.e., if user support is not readily available, the user must search longer. Table 1 shows the results of the analysis of open-source mathematical software.

Subsequently, after choosing suitable mathematical software, we proposed the use of the software in the content parts of the introductory mathematics course for students of the technical university. (Table 2) We assigned values to the software:

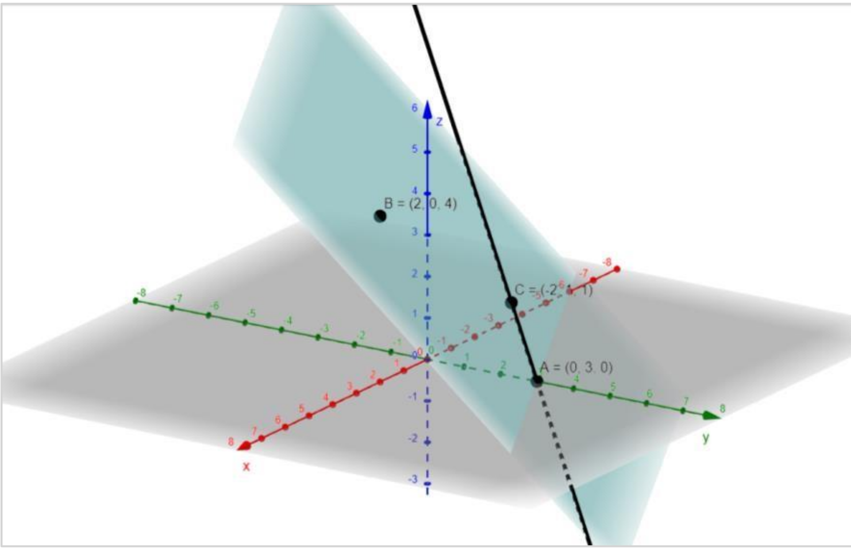
- “Yes” if it is suitable for use in the given content section,
- “Possibly” if use is possible in some part of the solution,
- “No” if using the software in the given content section is inappropriate.
- Three stages were necessary to implement the model.
- 1st stage. Creation of methodical materials. They were designed to make it easier for students to work with the software and to inspire them to use it effectively. The materials contain inspiring examples of using mathematical applications to solve problems.
- 2nd stage. Alerting students to pitfalls in calculations, as well as inaccuracies when displaying graphs of functions. Critical acceptance of the outputs is essential when using open-source mathematical software. The results obtained do not always agree with the mathematical theory; that is, they are not correct from a professional point of view. For example, WolframAlpha will list the multiple roots of an algebraic equation only once. The student must know that an algebraic equation of the nth degree has n roots, and some are multiple. For the above reasons, the student should not passively receive what is presented. Through critical thinking, a constructivist approach, and gaining experience, the student should gradually build an estimate of the given mathematical situation.
- 3rd stage. Use of software in the phase of solving tasks and in the phase of checking the correctness of the solution. In the task-solving phase, it is recommended that students use the software for routine mathematical operations necessary to solve a mathematical problem. For example, if it is necessary to create an analytical expression of a particular plane given by three points, an efficient solution is to calculate the coordinates of the normal vector of the plane. The fastest way is to determine the vector product of two vectors lying in the plane. That is, it is necessary to calculate the determinant of the 3rd-degree matrix. In this part, it is advisable to use mathematical software. (wxMaxima, Matrix calculator)

Tab. 2: Proposal for the use of software in the content parts of the introductory mathematics course

	WinPlot	wxMaxima	Desmos	Geogebra 3D	Wolfram Alpha	Matrix calculator
Algebraic equations	no	yes	possibly	possibly	yes	no
Matrices, Systems Determinants	no	yes	possibly	possibly	yes	yes
Vectors in E3	no	no	no	yes	yes	yes
Coordinate systems	yes	no	yes	yes	yes	no
Linear shapes in E3	yes	no	no	yes	yes	no
Properties of functions	yes	no	yes	yes	yes	no
Sequences and limits	no	yes	no	no	yes	no
Functions and limits	no	yes	no	possibly	yes	no
Rules for differentiation	no	yes	possibly	no	yes	no
Applications of differentiation	possibly	no	yes	possibly	yes	no
Indefinite integrals	no	yes	possibly	no	yes	no
Definite integrals	no	yes	possibly	possibly	yes	no
Applications of DI	possibly	possibly	yes	yes	yes	no

Source: authors

Fig. 1: An example of using the software Geogebra 3D in the solution control phase



Source: authors

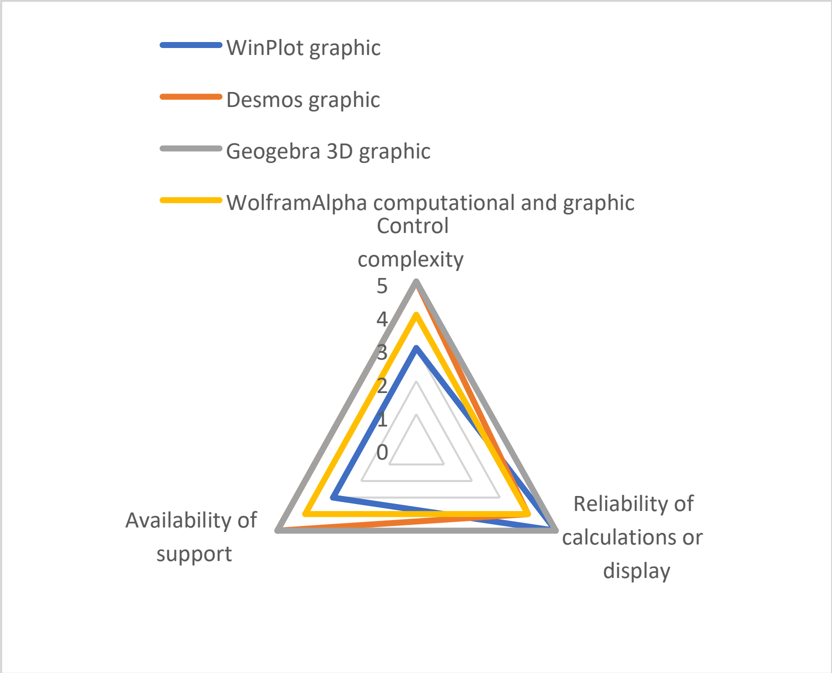
The advantage is also the elimination of numerical errors. An example of the use of mathematical software in a second way is shown in Fig. 1. The Geogebra 3D software was used in the phase of checking the correctness of the analytical geometry task solution. The task was to analytically determine the relative position of the straight line and the planes. By displaying the given straight line and planes, the student can check the correctness of his calculation. From the visualisation through the mathematical software Geogebra 3D, it is clear that the line AC lies in the plane ABC and intersects the plane expressed by the equation z=0.

3 Results

Based on the results of the above analysis, it can be concluded that in terms of the selected criteria, the Geogebra 3D software achieves the highest values from the group of selected graphic software. (Fig. 2) Software control is intuitive and user-friendly. The software is reliable. We found no faults, so we gave it a five on a five-point scale. We assigned the same value to the availability of user support. In addition, Geogebra has a wide range of uses. This software is possible for technicians in almost all content parts of the introductory mathematics course (Fig. 4).

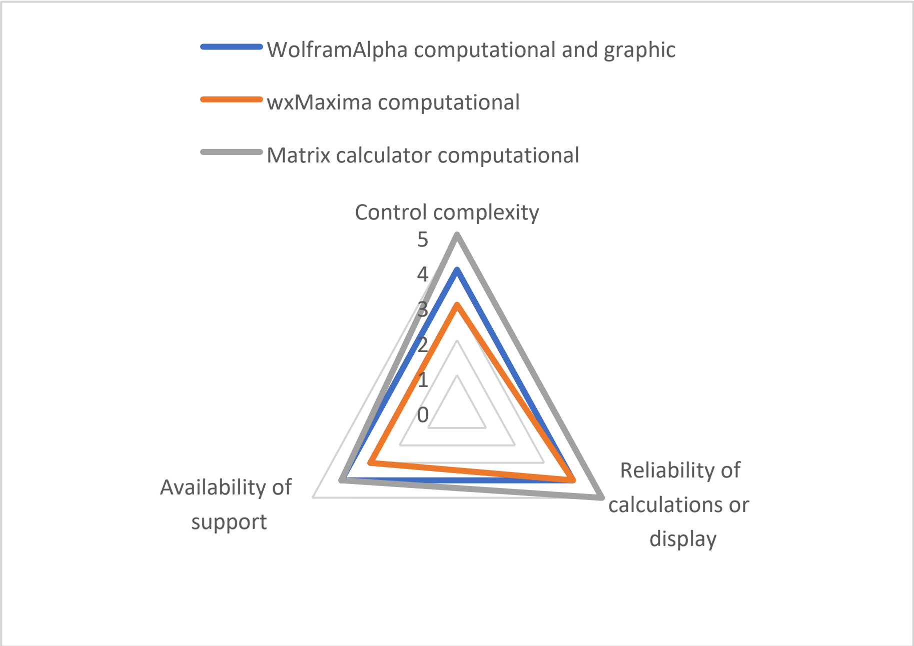
The graph in Fig. 3 shows that the Matrix calculator software achieved the highest values in the computational software group. We rated the difficulty of control with the number five since the control is very simple. It does not need to remember any syntax when working with the software. We consider the software reliable; we have not found any inconsistencies or inaccuracies in the calculations. Therefore, we also assigned the highest value in the calculation reliability criterion. User support is not freely available, but it is not necessary when applying the software in teaching. We assigned a value of four. However, the disadvantage of Matrix calculator software is its narrowly specialised use in the minimum number of content parts of mathematics for technicians, as can be seen from the graph in Fig. 4. Effectively, this software can only be used in the content section Matrices, systems of linear equations, determinants and vectors in E3.

Fig. 2: Comparison of graphic software



Source: authors

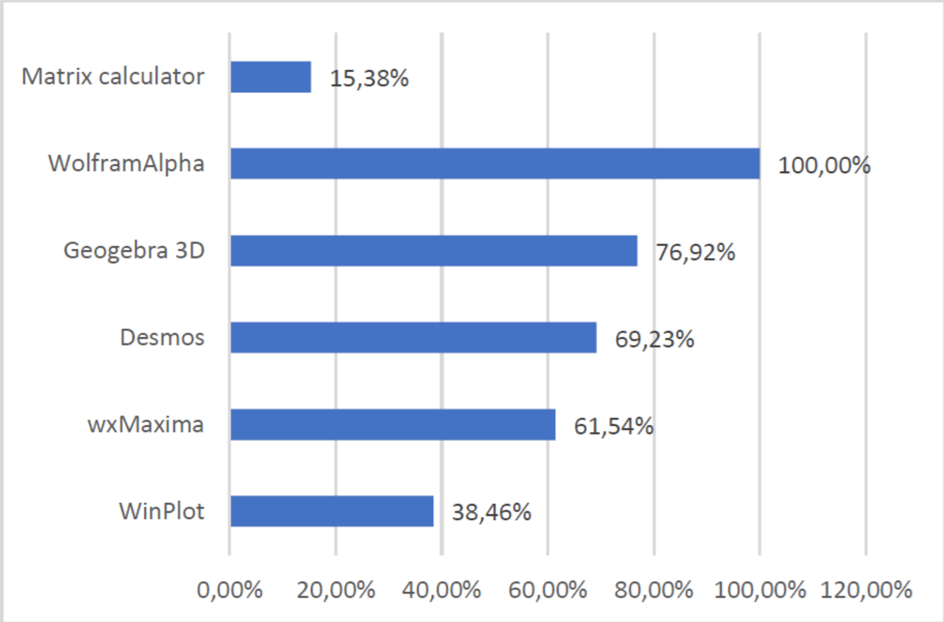
Fig. 3: Comparison of computational software



Source: authors

The designation of possible use in linear shapes in the E3 content area is debatable. In this content part, the software can only calculate determinants. This option is taken into account in the mathematics area above.

Fig. 4: Relative applicability in the content parts of the introductory mathematics course

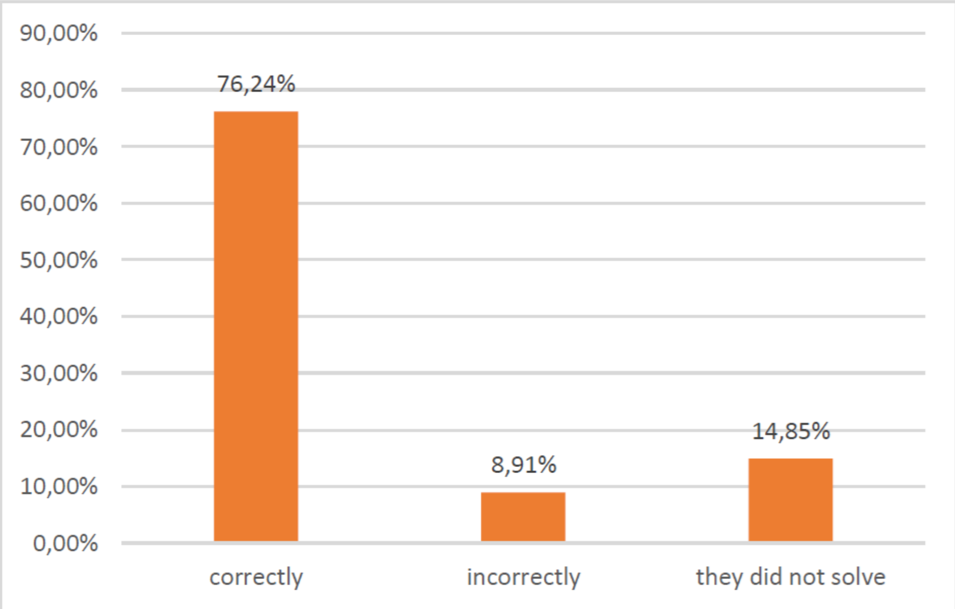


Source: authors

The graph in Fig. 4 also shows that WolframAlpha software has the broadest applicability in mathematics content areas. It can teach all content parts of an introductory mathematics course in technical studies. Although this software in the evaluation achieved only the second highest values in all the examined criteria, it can be used effectively in teaching. In addition to the Geogebra 3D software mentioned above, the Desmos software is also helpful in the introductory mathematics course for technicians. It can be used in almost 70% of content parts of mathematics. Of the calculation software, the wxMaxima software has a relatively wide range of possible uses, but in most criteria, it reached values at the lower limit. It is used only sporadically in teaching, mainly due to low user-friendliness. It is the same with the use of Winplot software. It is being replaced by newer graphic programs such as Desmos and Geogebra.

The teaching model with the support of mathematical software was implemented in the online teaching of the subject Mathematics I at the Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava. In the previous and current academic year, 2023/2024, we used it, and we also used it in face-to-face teaching. We note students' positive attitudes towards the subject taught this way and positive results. Fig. 5 shows a graph of the relative success rate of solving the characteristic algebraic equation. Students had to solve the equation as part of a linear differential equation of the second order on the mathematics exam at the end of the 2022/2023 academic year. Out of the 101 evaluated written works, almost 80 per cent of the students solved the equation correctly. Just under 9 per cent solved the equation incorrectly. Some of the students did not solve the task. (Fig. 5) The results indicated that teaching with mathematics software can increase the effectiveness of mathematics teaching. The results of other research with similar issues also confirm this. (For example (Wijaya et al., 2021), (Juandi et al., 2021)).

Fig. 5: The relative number of students who solved the characteristic algebraic equation



Source: authors

4 Conclusion

It will be necessary to evaluate the pedagogical experiments conducted to verify the teaching model's didactic effectiveness with the support of mathematical software. However, preliminary results indicate that mathematical software has its justification in teaching an introductory mathematics course at a technical university. Mathematics at engineering-oriented universities often has the character of a sieve that serves to separate the successful from the unsuccessful applicants. Students often perceive mathematics as unnecessarily demanding or isolating due to the emphasis on self-importance. Those with mathematical talent can continue to prepare for the engineering profession; those who do not have this talent are viewed with distrust. Their abilities to design creative engineering solutions are not much considered. Teaching mathematics with the support of mathematical software has the ambition to change this situation. The described research aimed to analyse the selected mathematical software and propose a teaching model for the introductory mathematics course at a technical university with the support of suitable mathematical software. Part of the solution is a proposal to effectively use various open-source mathematical software in individual content parts of mathematics. In this way, we wanted to contribute to the development of mathematics teaching theory in the field of effective mathematics teaching methods with the support of mathematical software. The mentioned study was created as part of the project solution, the goal of which is the design, verification and implementation of innovative online teaching models of mathematics and informatics subjects with an emphasis on increasing the quality of educational results, focusing on a student who should be flexible, creative, with critical thinking, able to solve problems, constantly learning and working in a team.

5 Acknowledgements

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Resources

Firouzian, S., Ismail, Z., Rahman, R. A., & Yusof, Y. M. (2012). Mathematical Learning of Engineering Undergraduates. Procedia - Social and Behavioral Sciences, 56, 537–545. doi:10.1016/j.sbspro.2012.09.686

Juandi, D., Kusumah, Y., Tamur, M., Perbowo, K., Siagian, M., Sulastri, R., & Negara, H. (2021). The effectiveness of dynamic geometry software applications in learning mathematics: A meta-analysis study.

Lazaros, E. J. (2013). Promoting the study of mathematics by using Internet resources in the technology and engineering classroom. children’s technology and engineering (March), 10-12.

Leppävirta, J. (2011). The Impact of Mathematics Anxiety on the Performance of Students of Electromagnetics. Journal of Engineering Education, 100(3), 424-443.

Noskov, M. V., & Shershneva, V. A. (2005). Toward a Theory of the Teaching of Mathematics in Higher Technical Educational institutions [K teorii obucheniia matematike v tekhnicheskikh vuzakh]. PEDAGOGIKA (10).

Orszaghova, D. (2018, 2018). E-LEARNING APPROACH IN MATHEMATICAL TRAINING OF FUTURE ECONOMISTS. Paper presented at the Conference on Elearning and Smart Learning Environment for the Preparation of New Generation Specialists, Katowice, POLAND.

Orszaghova, D., & Greganova, R. H. (2017, May 31-Jun 02). BLENDED LEARNING IN MATHEMATICS: TEACHERS’ EXPERIENCE AND STUDENTS’ OPINIONS.

Paper presented at the International Conference DISTANCE LEARNING, SIMULATION AND COMMUNICATION (DLSC), Univ Defence, Brno, CZECH REPUBLIC.

Phuong, T. T. T., Danh, N. N., Le, T. T. T., Phuong, T. N., Thanh, T. N. T., & Minh, C. L. (2022). Research on the application of ICT in Mathematics Education: Bibliometric analysis of scientific bibliography from the Scopus database. Cogent Education, 9(1). doi:10.1080/2331186x.2022.2084956

Rahman, R. A., Yusof, Y. M., & Baharun, S. (2012). Improving the Teaching of Engineering

Mathematics using Action Research. Procedia - Social and Behavioral Sciences, 56, 483-493. doi:10.1016/j.sbspro.2012.09.680

Schaathun, H. G. (2022). On Understanding in Mathematics. Teaching Mathematics and Its Applications. doi:10.1093/teamat/hrac016

Wijaya, T., Zhou, Y., Ware, A., & Hermita, N. (2021). Improving the creative thinking skills of the next generation of mathematics teachers using dynamic mathematics software.

International Journal of Emerging Technologies in Learning (iJET), 16(13), 212-226.

THE EMERGENCE OF INFORMATION SECURITY IN SLOVAKIAN AND HUNGARIAN CURRICULA

Bence Pásztor[28]

Abstract

Teaching information security in elementary and high school education is becoming increasingly important in today's digital society. Young people take advantage of the Internet almost daily and participate in online activities, so data handling, protection, and security have become extremely important issues. Teaching information security at the related school levels is key in informing students of basic methods and principles to protect their personal data in digital space. To understand how information security education is currently widespread in the two Central European countries Slovakia and Hungary, it's important to know how many lessons per week the Information Technology (IT) is taught in these countries and what emphasis is placed on information security in the National Core Curriculum (NCC). My research compares information security education in these two countries based on the education curriculum.

Keywords

Curriculum, Slovakia, Hungary, education, information security

1 Introduction

Information security education is very important in the digital world so that children can know the basics of privacy and online safety. Information security education in schools helps students learn how to protect their personal and sensitive data online. It's important to prepare students for the challenges and dangers of the digital world and provide knowledge that helps them operate safely in online space.

The aim of the work is to explore what emphasis is placed in the National Core Curriculum (NCC) for information security in Slovakia and Hungary. Furthermore, it is needed to explore which country places a bigger emphasis on information security education.

2 IT lessons in Slovakia and Hungary

Slovakia has two Information Technology (IT) lessons during the four years of lower primary education. This is also the case in Hungary.

In Slovakia, upper primary education has four Information Technology (IT) lessons for five years. The same is true in Hungary; however, there are only four classes in Hungarian upper primary education.

Figure 1. illustrates that grammar school classes have three Information Technology (IT) lessons in Slovakia during the whole education; however, in Hungary it is five.

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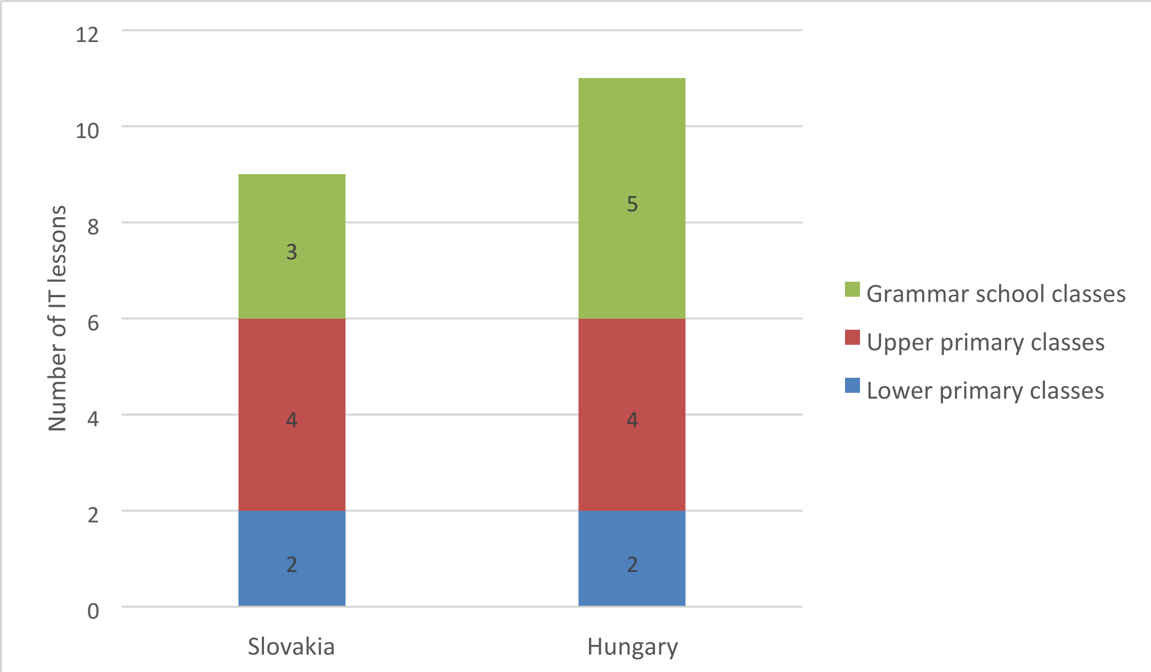
Fig. 1: IT lessons in Slovakia (Domov, 2023) and Hungary (Magyar, 2023)



Source: Author

3 Education system in Slovakia

In Slovakia, the National Core Curriculum is a directive that defines the general goals of education and the key skills that education should focus on. The national curriculum determines what should be acquired by the students in each year. This is the basis for developing the school curriculum. The state education program is issued and published by the Ministry of Education, Science, Research and Sports of the Slovak Republic for all educational levels (Štátny, 2023).

3.1 School Curriculum in Slovakia

Considering the regulations, the school can decide when the individual teaching materials will be included in the given level. At each level (lower elementary school, upper elementary school, grammar school), the number of mandatory hours is defined. However, schools are given a certain level of freedom regarding which subjects and classes they want to teach in an increased number of hours (Rámcové, 2023).

3.2 The emergence of information security in the IT core curriculum in Slovakia

In Slovakia, performance and content standards are linked with each topic's IT core curriculum.

In lower primary classes, the following items are written in performance standards:

- to have a dialogue with students about the dangers of the Internet,
- students can apply rules to protect e-mail accounts against unauthorised use.

In the content standard, the following item is written:

- safe attitude in online space (INFORMATIKA, 2023).

The topic of security and risk in the Information Technology core curriculum defines that by the end of the 6th grade, students should be able to:

- discuss the dangers of the Internet,

- apply the rules for the protection of data, including e-mail, against unauthorised use,
- talk about cybercrime,
- discuss the authenticity of information found on the web.

The content standard includes the following:

- virus as malicious software,
- the authenticity of the information obtained, risks on the Internet and social network risks,
- distribution of computer viruses and spam,
- safe and ethical behaviour on the Internet, activities of hackers.

At the end of the upper primary classes, the student's performance standard according to the IT core curriculum:

- how to talk about the risks of the Internet,
- ability to evaluate which information must be protected from abuse,
- apply the rules about email access and rules against unauthorised use of the community and computer,
- be able to assess the dangers of using malicious software,
- be able to talk about computer crime,
- be able to discuss the reliability of information found on the World Wide Web
- be able to talk about the risks of criminal and illegal content.

Content standard:

- the virus as malware,
- spam as junk mail,
- antivirus as a means of protection against viruses,
- the quality of passwords as a security mechanism,
- the reliability of the information obtained,
- risks on the Internet and social networks.
- distribution of computer viruses and spam,
- safe and ethical behaviour on the Internet,
- and activity of hackers (Nižšie, 2023).

Security and risk also appear in the Information Technology lessons in the curriculum of grammar school education. In the performance standard, the student can:

- assess the risks of working on a computer containing malicious software,
- apply the rules to ensure email access, rules against unauthorised use of the community and computer,
- ensure data and communication against abuse,
- evaluate the reliability of information on the World Wide Web,
- recognise computer crime,
- distinguish illegal content.

Content standard:

- spread of computer viruses and spam,
- safe and ethical behaviour on the Internet,
- hacker activity,
- protection of personal data on the Internet (Inovovaný, 2023)

4 Education system in Hungary

The national curriculum defines what students should be taught. The main target group of this document are teachers and school principals, for whom it provides guidance and a framework for their educational activities (1. melléklet, 2023).

In Hungary, the informatics lesson is called digital culture (Magyar, 2023).

4.1 School Curriculum in Hungary

According to the legislation, schools must prepare their own local curricula, which they must develop based on the national core curriculum. The local curriculum must clearly define which is the underlying core curriculum (Tájékoztató, 2023).

4.2 The emergence of information security in digital culture in the national core curriculum in Hungary

In the topic "Protection against the dangers of the digital world," children are faced with the problem that there is a lot of false and misleading information in the digital space and the dangers of the Internet. It is important for students to learn about defence strategies so that, with their teachers' help and their parents' support, they will be able to identify, block, and report negative influences towards them.

The national core curriculum includes the following four sections for each topic:

- learning results,
- development assignments and knowledge,
- concepts,
- recommended activities.

In Hungary, according to the core curriculum of digital culture, it's discussed in 3rd and 4th grades in elementary schools how to protect our privacy and data against the dangers of the digital world. It's recommended that 6 lessons should be spent on this topic in the mentioned grades. There is a topic, "Protection against the dangers of the digital world", which helps children face the fact that there is a lot of false and misleading information in the digital space, as well as the dangers of the Internet. It's important to form such protective methods and strategies, which prepare children to identify, block and report the negative effects towards them. It could be realised together with their teachers and parents.

Learning results:

- While students are learning, they can use simple procedures to determine the authenticity of information found on the Internet.
- Students will be aware of the concept of personal data and understand its importance.
- They know and use different forms of contact and communication channels in the digital environment.
- Students learn about the advantages and limitations of mobile devices and their ethical aspects.
- They have real experience of using mobile devices for educational purposes.

Development assignments and knowledge**:**

- personal data and its protection,
- methods of recognising online harassment and providing assistance,
- gaining experience with fake news and manipulated content,
- the ethics and safety of online communication,

- online addiction and its knowledge,
- the importance of protecting personal data,
- benefits and risks of using mobile devices.

Concepts: password, blocking, personal data, internet addiction, fake news, gaming addiction, confidential information, exclusion, report, cyberbullying Recommended activities:

- argumentation about the authenticity of the information,
- giving an example of internet bullying,
- playing a situational game about internet attacks/harassment,
- giving advice on reducing the use of digital devices,
- defining sensitive personal data (Oktatási, 2023).

5 Conclusion

A comparison of IT education between Slovakia and Hungary shows some interesting differences. First, the two countries have different amounts of IT lessons in primary and grammar schools. In Slovakia, a total of 9 IT lessons are available for students during the primary and grammar school years, while in Hungary, this number is 11.

In addition, it is important to mention the curriculum differences between the two countries, especially regarding safety and risk. In Slovakia, more emphasis is placed on teaching this, as this topic is mentioned four times in the core curriculum, while in Hungary, it is mentioned only once. So, the conclusion is that more attention is paid to information security education in Slovakia.

Resources

Štátny vzdelávací program, Národný inštitút vzdelávania a mládeže. Avaliable: https://www.statpedu.sk/sk/svp/statny-vzdelavaci-program/. [Access date: 2023-08. 20.].

Rámcové učebné plány, Národný inštitút vzdelávania a mládeže. Avaliable: https://www.statpedu.sk/sk/svp/statny-vzdelavaci-program/svp-druhy-stupenzs/ramcove-ucebne-plany/. [Access date: 2023-08-22.].

Domov | Ministerstvo školstva, vedy, výskumu a športu Slovenskej republiky. Avaliable: https://www.minedu.sk/data/files/6948_priloha_2_rup.pdf. [Access date: 2023-08-21.].

INFORMATIKA - statpedu.sk. Avaliable: https://www.statpedu.sk/files/articles/dokumenty/inovovany-statny-vzdelavaciprogram/informatika_pv_2014.pdf. [Access date: 2023-08-24.].

Nižšie stredné vzdelávanie. Avaliable: https://www.statpedu.sk/files/articles/dokumenty/inovovany-statny-vzdelavaciprogram/informatika_nsv_2014.pdf. [Access date: 2023-08-24.].

Inovovaný Štátny vzdelávací program - ŠPÚ - statpedu.sk, Informatika – gymnázium so štvorročným a päťročným vzdelávacím programom. Avaliable:

https://www.statpedu.sk/files/articles/dokumenty/inovovany-statny-vzdelavaciprogram/informatika_g_4_5_r.pdf. [Access date: 2023-08-24.].

1. melléklet az 5/2020. (I. 31.) Korm. Rendelethez, Magyar Közlöny. Avaliable: https://magyarkozlony.hu/dokumentumok/3288b6548a740b9c8daf918a399a0bed1985db0f/megtekintes. [Access date: 2023-08-25.].

Tájékoztató a kerettantervek alkalmazásáról, Oktatási Hivatal. Avaliable: https://www.oktatas.hu/kozneveles/kerettantervek/2020_nat/bevezeto. [Access date: 2023-08-25.].

Magyar Közlöny, II.2.1.3. táblázat. Avaliable: https://magyarkozlony.hu/dokumentumok/3288b6548a740b9c8daf918a399a0bed1985db0f/megtekintes. [Access date: 2023-08-25.].

Oktatási Hivatal, Digitális kultúra kerettanterv 3-4. évfolyam. Avaliable: https://www.oktatas.hu/pub_bin/dload/kozoktatas/kerettanterv/Digitalis_kultura_A.docx. [Access date: 2023-09-03.].

BRIDGING THE GAP: UNDERSTANDING AND MANAGING NOT SMALL-NOT BIG DATA (NOS-NOB DATA) IN DIVERSE SECTORS

Peter Schmidt [29], Zsolt Simonka [30], Zhanar Moldabaeva[31]

Abstract

The evolution of data management has led to the need to name a frequently used category of data that includes volumes of data larger than traditional datasets but does not meet the extensive requirements of big data as "Not Small - Not Big Data" (NoS-NoB Data). This article introduces the concept of NoS-NoB Data, which is widely used even though most users are unaware of it. Small and big data categories require different approaches for efficient processing. NoS-NoB Data, in our opinion, typically ranges from 10 to 100 GB and contains files too large for standard office tools but not large enough to justify the infrastructure requirements of big data technologies. We discuss the challenges of NoS-NoB data management, such as the need for more sophisticated processing tools that go beyond conventional data management software but do not require the complex distributed systems used for big data. This paper further explores the various sectors where NoS-NoB data is prevalent, including SMEs, healthcare, insurance, and government, highlighting the specific data processing and analytics needs within these domains. By identifying the unique attributes and processing requirements of NoS-NoB data, the study aims to bridge the semantic gap in current data categorisation and improve understanding of data dynamics in today's technological environments.

Keywords: Big Data, Small Data, Not Small – Not Big Data, NoS-NoB Data

1 Introduction

It is often proclaimed that data governs the contemporary world—a statement that closely aligns with reality. The pace at which data volumes expand is vertiginous, and their magnitudes are virtually incomprehensible (Davenport & Harris, 2017). Traditionally, there was no imperative to categorise data based on volume; however, such differentiation has become essential in recent times (Duarte, 2023). Big Data has transitioned from a trendy term to a fundamental component of modern technological infrastructures. Despite this shift, Small Data remains crucial for daily life and computer-assisted work activities (Banafa, 2018). Yet, the growth of Small Data has reached a point where it often exceeds the processing capabilities of existing hardware and software infrastructures. This emerging category of data, neither fitting the traditional definitions of Big nor Small Data, necessitates a new terminology to describe it accurately (Serrant, 2023).

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Due to its size and processing requirements, this intermediate data type falls outside the scope of Big Data but cannot be managed effectively with standard computing technologies. It is commonly referred to by various terms such as 'medium data,' 'middle-range data,' or 'transitional data,' none of which adequately captures its essence. To address this semantic gap, we propose the term 'Not-Small-Not-Big Data' (NoS-NoB Data), indicating data that is neither minuscule nor vast in scope. Such data, typically not as voluminous as Big Data, still presents challenges for processing on conventional personal computers. For instance, opening a 3 GB text file or a 10 GB CSV file on standard software proves problematic due to the limitations of these applications in handling large files. Overcoming these challenges often requires alternative software solutions or custom scripting, for instance, in Python, designed specifically for managing larger data volumes more efficiently.

Recent surveys by Gartner Group and IDC highlight an 85-90% failure rate in Big Data technology implementations, suggesting that many enterprises might not deal with Big Data as often as presumed (Walker, 2017). This indicates a prevalent need for handling data volumes that lie between Small Data, which is readily manageable, and Big Data, which necessitates significant technological investments. Other terms like 'limit data' or 'intermediate data' have been proposed to describe these datasets, but these generally refer to data generated as interim outputs in computational processes, thus not suitable for describing data that is categorically between Small and Big Data. Bill Inmon, renowned for his contributions to data warehousing, suggests that data that is too large for traditional tools yet not as extensive as Big Data should be referred to as 'medium data' (Inmon et al., 2019). Nevertheless, the lack of clear demarcations between Small and Big Data scopes complicates the accurate definition of 'medium data', especially without specifying whether the size concerns individual files or an entire dataset related to a specific project.

2 Characterizing Not Small-Not Big Data

'Not Small-Not Big Data' (NoS-NoB Data) represents a distinct category of data that surpasses the processing capabilities of conventional office tools for structured data and the capacity of traditional database systems hosted on low-end servers. However, it does not reach the magnitude that necessitates using specialised tools and techniques required for Big Data processing, such as cloud-based or distributed systems like Hadoop. Typically, NoS-NoB Data ranges between 10-100 GB, though this scale can vary significantly depending on the specific application domain. While such data volumes can be managed with advanced database systems, they do not generally require large-scale distributed processing or intricate machine learning algorithms. NoS-NoB Data may also include relatively small files, measured in megabytes, whose structure renders them unprocessable by standard tools on a personal computer, such as a spreadsheet containing 15 million rows which exceeds the capabilities of Excel, necessitating alternative tools like the Python programming language and its libraries.

2.1 Basic Indicators of NoS-NoB Data:

- **Size**: The data is larger than what is typically considered traditional data but smaller than what is classified as Big Data.
- **Generation Speed**: NoS-NoB Data is generated faster than traditional data, reflecting its more dynamic nature.
- **Complexity**: It encompasses structured, semi-structured, and unstructured data, though

generally with less variety and lower complexity than Big Data.

- **Processing**: NoS-NoB Data can be processed by relational database systems (RDBMS), NoSQL systems, or through advanced data analytics techniques, but it does not necessitate extensive parallel processing.
- **Analytics**: While advanced analytics are necessary, they are not as intensive as those required for Big Data.

2.2 Detailed Discussion on Size:

- Lower Limit: NoS-NoB Data might not surpass the capabilities that traditional computing systems can handle, often situated in the megabyte range. Its structure may hinder efficient processing by common office applications like Excel or Power BI, where software compatibility or performance becomes a limiting factor.
- Upper Bound: NoS-NoB Data is smaller than typical Big Data, which can extend into terabytes and beyond. However, NoS-NoB Data typically ranges in the tens of gigabytes.
- File Size: The size of individual files is crucial as it directly influences the choice of data processing and storage technology. Large files may necessitate systems like NoSQL databases or distributed file systems capable of simultaneously managing substantial data volumes.
- Project Size: Coordination of access to these files is challenging for projects involving numerous small files that need to be processed collectively. Technologies such as Hadoop or Spark, which enable distributed processing and are optimised for large datasets, are essential for efficiently managing many smaller files.
- Efficiency in traditional relational database systems (RDBMS) may be impacted by increasing data volumes for several reasons. The threshold at which efficiency declines depends on various factors, including hardware configuration, database structure, type of queries, and database optimisation. For instance, a server configured with 4-8 CPU cores, a Linux or Windows Server operating system, database software such as Oracle Database or MS SQL Server, 1-2 TB SSD, and 32 GB RAM could be adequate for processing NoS-NoB Data. Such a setup should effectively manage data volumes from 10 to 100 gigabytes, provided database structures and queries are meticulously optimised. Critical factors for proficient NoS-NoB Data processing include database optimisation, effective indexing, well-designed queries, and appropriate resource management, significantly influencing the speed and efficiency of data processing systems.

2.3 NoS-NoB Data Generation Rate

NoS-NoB Data is characterised by a generation rate that can exceed the generation rate of traditional data but remains well below the generation rates associated with big data. This data category typically comes from various sources, including online financial transactions, telemetry from medical sensors, and detailed records of customer behaviour. These sources contribute to the dynamic and multifaceted nature of NoS-NoB data. Although NoS-NoB Data does not require the massively distributed processing architectures necessary to process big data, it does require more sophisticated database systems or faster-responsive data warehouses. These systems are key to effectively managing the increased speed, volume, and diversity inherent in NoS-NoB Data. The imperative here is about capacity and the agility and efficiency of data processing and search processes. For efficient processing of NoS-NoB data, smaller distributed systems are often deployed. These systems typically consist of a few nodes, which, while smaller in number than large-scale big data operations, focus heavily on maximising throughput and latency. The architecture of such systems is designed to effectively balance the load and ensure that data processing remains fast and efficient, even under the stress of increased data flows. This customised approach allows organisations to enjoy the benefits of fast data processing without the overhead associated with larger and more complex Big Data systems. It supports an efficient yet powerful infrastructure capable of adapting to the unique challenges presented by the speed and complexity of NoS-NoB data, enabling a more responsive data-driven decision environment.

2.4 Managing Data Complexity across Structured, Semi-Structured, and Unstructured Categories in NoS-NoB Data Environments

Unstructured Data: Unstructured data, encompassing diverse formats such as text, images, and videos, exhibits a propensity for significant volume expansion. Within the framework of NoS-NoB Data, the accumulation of unstructured data mustn't necessitate the extensive processing capabilities characteristic of conventional Big Data frameworks. Despite this, unstructured data can be adeptly processed using Big Data technologies tailored to NoS-NoB Data dimensions. These technologies enable efficient unstructured data management without reliance on extensive Big Data infrastructures, thus conforming to the operational limits suitable for NoS-NoB Data contexts.

Semi-Structured Data: This category encompasses formats like XML and JSON, which, despite their potential for rapid volumetric growth, remain manageable on less robust systems. Semi-structured data includes various elements such as emails, website logs, and data derived from Application Programming Interfaces (APIs). While these data types incorporate certain structured aspects, they lack the comprehensive organisation found in traditional database records. The complex nature of semi-structured data demands applying sophisticated techniques for effective data extraction and analysis.

Structured Data: In the realm of NoS-NoB Data, structured data primarily consists of conventional database formats, such as tables and records, which maintain a uniform structure and are relatively straightforward to process. Examples include extensive datasets from Customer Relationship Management (CRM) systems, financial transactions, or inventory records. Although managing this data type requires more advanced tools and methodologies than those typically used for standard office data, it does not necessitate the expansive infrastructure typical of Big Data environments. Effective governance of this structured data enhances organisational data comprehension, thereby facilitating improved business decision-making processes.

2.4.1 Efficient processing of NoS-NoB data: balancing technology and strategy

Handling NoS-NoB Data requires attention to several key aspects essential for its effective use without the extensive infrastructure associated with Big Data. Data collection, storage, management, and analysis are the main components involved. Considering its unique size and complexity, it's vital to adopt a balanced method in dealing with NoS-NoB Data. Although the full-scale infrastructure of Big Data is unnecessary, it is crucial to employ more sophisticated technologies and methods than those typically used for smaller data sets. This tactical approach enables organisations to manage and leverage their data more efficiently, improving their competitive edge and decision-making processes.

a. Nature and challenges of NoS-NoB data:

The processing of NoS-NoB data involves several critical aspects that are necessary for its effective use. This data category differs from big data because it does not require extensive infrastructure, which usually involves complex and expensive setups.

b. Key aspects of data processing:

- Collection: One of the first steps is to collect NoS-NoB data. This involves acquiring data from various sources, which must be done efficiently to ensure the quality and relevance of the data.
- Storage: The text emphasises the need for storage solutions that are capable but less extensive than those used for big data. These solutions should be scalable and flexible to manage different sizes and complexities of NoS-NoB data.
- Management: Effective data management strategies are critical. This includes organising, securing and ensuring the availability of data to facilitate its processing and analysis.
- Analysis: The analysis of NoS-NoB data requires tools and techniques that can handle its unique characteristics but are more advanced than those used for smaller datasets. It is necessary to gain meaningful knowledge.

c. Strategic approach:

- A balanced approach to NoS-NoB data processing is important. This means using strategies that accept its characteristic size and complexity without the extensive infrastructure used for big data.
- Emphasis is placed on using advanced technologies and methodologies that go beyond common data processing tools. This strategic choice is critical because it allows organisations to manage their resources effectively while reaping the analytical benefits of big data environments.

d. Impact on organisations:

- By adopting this approach, organisations can process and use their data more efficiently.
- The final benefit of effective processing of NoS-NoB data is increased competitiveness, reduced costs, and better decision-making possibilities. Organisations that streamline their data processing capabilities can respond more quickly and accurately to market changes and internal demands, leading to better overall performance.

2.5 Analytics: Tools and Techniques for Processing NoS-NoB Data

These tools and platforms are integral to data processing and analysis, providing extensive capabilities for managing data within the NoS-NoB Data spectrum. Their selection should be tailored to the organization's specific requirements and objectives. The tools and platforms selected play a crucial role in data processing and analysis, offering broad possibilities for working with data in the NoS-NoB Data range.

2.5.1 Data Preprocessing and Cleaning:

Pandas: A Python library utilised for data manipulation and cleaning, enabling transformations and normalisation to prepare data for further analysis.

Apache NiFi: An advanced, open-source system for managing data flows, facilitating the automation and control of data transfer between systems. NiFi offers a graphical interface for designing, developing, monitoring, and controlling real-time data streams.

Talend: This tool supports the extraction, transformation, and loading (ETL) processes, allowing efficient transformation and integration of data from various sources.

2.5.2 Database Analysis:

- MySQL/Microsoft SQL Server: These are popular relational database systems known for their effectiveness in managing structured data within the NoS-NoB range (Taylor, 2023).
- MongoDB/Cassandra: These NoSQL databases are well-suited for handling semi-structured and unstructured data, offering flexibility in data organisation and scalability.

2.5.3 Business Intelligence (BI) and Visualization:

- Tableau: Renowned for enabling advanced data visualisation, Tableau is particularly effective for creating interactive BI reports.
- Microsoft Power BI: Provides comprehensive data analysis and visualisation tools, supporting a wide range of BI applications.
- Qlik: Known for its self-service BI capabilities, Qlik facilitates data analysis and visualisation, enabling users to generate insights independently.

2.5.4 Machine Learning and AI:

- Scikit-learn: A Python library for machine learning, suitable for various analytical models.
- TensorFlow/Keras: These deep learning frameworks are utilised for complex analyses, such as image and text analysis (Chollet, 2021).
- RapidMiner: This tool offers a visual programming environment for machine learning and advanced analytics, enhancing the accessibility of complex analytical techniques.

2.5.5 Predictive and Prescriptive Analysis:

- SAS/SPSS: Traditional statistical tools renowned for their efficacy in predictive analysis (Mishra, 2019).
- R: A programming language and environment designed specifically for statistical computations and graphics.
- Python with libraries like NumPy and SciPy: These tools provide robust support for scientific computing and are frequently used in predictive analytics.

2.5.6 Challenges and Solutions in Analysis:

Although NoS-NoB Data does not reach the scale of Big Data, its volume still demands substantial analytical capabilities. The diversity of data formats and the need to analyse structured, semi-structured, and unstructured data necessitate various approaches and techniques. Data quality is a pivotal factor in ensuring the reliability of data sets and is crucial for the accuracy of analytical outcomes. Incorrect or incomplete data can lead to erroneous conclusions.

2.5.7 Tools for Addressing Predictive Analytics Challenges:

- DataRobot: An automated machine learning platform that facilitates predictive analytics, helping to address complex data challenges.
- Alteryx: Provides tools for data integration, analysis, and visualisation, simplifying the processing of NoS-NoB Data.

2.5.8 Key Steps in Managing and Analyzing NoS-NoB Data:

1 Identify Goals: Establish clear objectives, such as improving customer satisfaction or optimising internal processes, which will guide the analytics approach.
2 Data Collection and Storage: Utilize appropriate mechanisms for data collection and storage, such as RDBMS (MySQL, MS SQL Server), NoSQL databases (MongoDB, Cassandra), or cloud solutions (AWS S3, Google Cloud Storage). Distributed systems like Apache Hadoop are valuable for managing large datasets.
3 Data Cleaning and Transformation: Employ tools like Pandas or Apache NiFi to cleanse data, correct errors, and transform data into an analysable format.
4 Data Analysis: Apply various analytical tools and techniques, including machine learning (using Scikit-learn, TensorFlow, Keras) and traditional statistical methods (SAS, SPSS, R), to uncover patterns, detect anomalies, or predict future trends.
5 Visualization and Communication: Utilize tools like Tableau, Microsoft Power BI, or Qlik to present findings, facilitating easier interpretation and communication with stakeholders.
6 Data Security: Implement security protocols to protect data from unauthorised access and data loss, including encryption, regular backups, and access controls.

Choosing the right tools and technologies that align with a project's specific needs and goals is crucial for effectively managing and analysing NoS-NoB Data. This flexibility offers a strategic advantage in addressing various analytical challenges.

2.6 Application area of NoS-NoB Data

The application domains of Not Small-Not Big Data (NoS-NoB Data) cover a range of sectors that utilise this data category. These domains include multiple industries where the data, although more relevant than traditional datasets, does not require the deployment of sophisticated big data technologies. Each domain needs to understand the specific data processing and analysis requirements to derive actionable insights and valuable information.

2.7 Illustrative areas Include:

1 Small and Medium Enterprises (SMEs): SMEs often collect NoS-NoB Data through customer transactions, customer relationship management (CRM) systems, and online interactions. Analysing this data helps gain a deeper understanding of consumer behaviour and enhances the effectiveness of marketing strategies.
2 Healthcare: Smaller healthcare facilities, such as clinics and hospitals, generate significant medical records and operational data volumes. Strategic analysis of this data can greatly improve patient care and operational efficiencies within these institutions.
3 Insurance and Reinsurance Companies: These entities accumulate extensive data covering policy administration, claims processing, and client interactions, ranging from structured data like policy details to semi-structured and unstructured data such as claims descriptions and client communications. Analysing NoS-NoB Data enables more precise risk assessment, customisation of insurance products, improved efficiency in claims processing,

and better customer service. Additionally, this data is crucial in fraud detection, actuarial studies, and setting premiums that accurately reflect the risk profiles of policyholders.

4 Education: Educational institutions, including colleges and universities, use NoS-NoB Data to monitor student performance, manage academic courses, and oversee research projects. Data analysis in this sector supports the development of educational strategies and the improvement of pedagogical methods.
5 Retail and E-commerce: Retailers and e-commerce platforms generate data about purchases, preferences, and consumer behaviour online, which is vital for optimising inventory, personalising marketing offers, and enhancing the overall shopping experience.
6 Financial Services: Small to medium-sized banks and financial institutions use NoS-NoB Data to analyse transaction data, assess risks, and detect fraud.
7 Logistics and Transport: Transport companies utilise this data to optimise routing, vehicle monitoring, and shipment management.
8 Local Government and Public Administration: Local government bodies analyse NoS-NoB Data to study traffic patterns, monitor public services, and plan urban development.

The effective utilisation of NoS-NoB Data in these domains hinges on selecting appropriate tools and technologies that align with each sector's specific data characteristics and analysis requirements.

3 What are the differences between the individual categories of data

Big Data is distinguished by its substantial volume, which far exceeds the more manageable quantities typical of Small Data. Positioned between these extremes, NoS-NoB Data assumes a size that is neither minimal nor vast, embodying a median volume that balances manageability with substantive insight. While Big Data encompasses a variety of unstructured, semi-structured, and structured data, Small Data tends to be more uniform and organised. NoS-NoB Data, however, can exhibit diverse structures, echoing the variety seen in Big Data but on a less extensive scale.

Due to its continuous data flow, Big Data requires rapid and ongoing analysis, contrasting sharply with the less demanding nature of Small Data. The speed required to process NoS-NoB Data depends greatly on the nature of the tasks it supports and the technologies employed. These tasks can range from simple computations to complex applications in machine learning, demonstrating the data's versatile applicability.

Regarding storage, Small Data is typically maintained locally due to its limited size, whereas Big Data is often distributed across multiple servers or stored in the cloud to manage its volume and facilitate access. NoS-NoB Data storage strategies may vary: smaller datasets tend to be local, but as the data grows, it may be distributed akin to Big Data practices.

Data preparation also differs across these categories. End users generally manage Small Data preparation, while Big Data often involves a broader team and may not include direct user interaction. For NoS-NoB Data, preparation might involve tools from the Hadoop ecosystem or utilise programming in R or Python, providing flexibility in handling data of intermediate size and complexity.

Archiving strategies reflect the needs specific to each data size. Small Data is typically retained for short periods, whereas Big Data may require indefinite storage if it is not continuously processed. NoS-NoB Data offers a more adaptable approach, with archiving durations tailored to the particular needs of the task or problem being addressed.

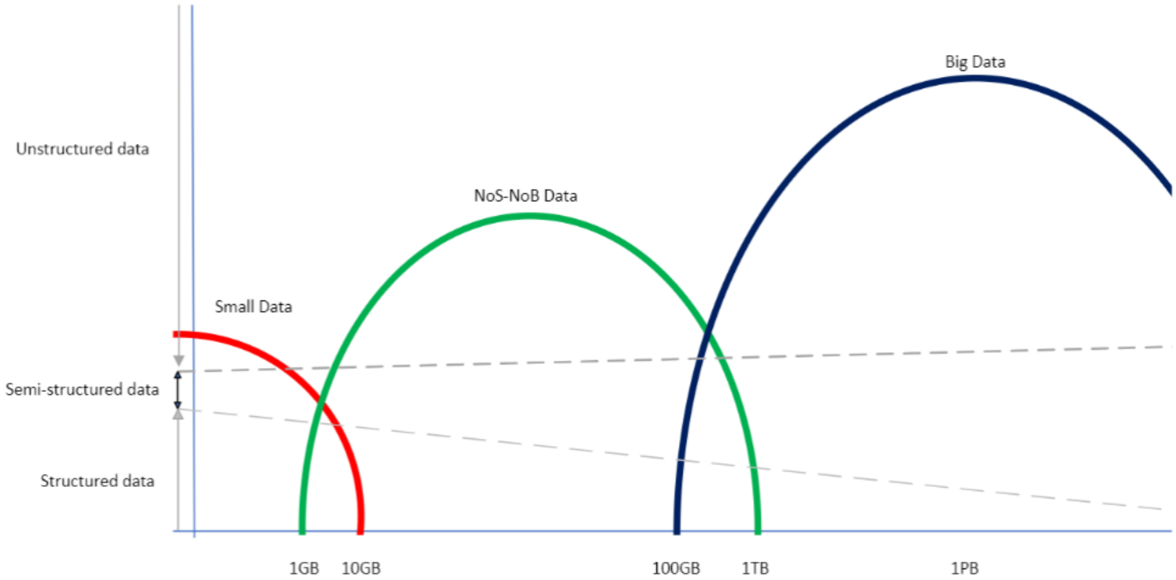
Reproducibility and error management also vary by data scale. Small datasets allow for easier error correction and data recovery, whereas Big Data, due to its volume, often only secures processed results to mitigate storage demands. NoS-NoB Data, benefiting from its moderate size, enables more frequent backups, enhancing data safety and the reliability of subsequent analyses and experiments.

Regarding risk, the smaller scale of NoS-NoB Data reduces the likelihood of costly errors associated with Big Data, aligning more closely with the lower-risk profile of Small Data. Moreover, while interpreting Big Data can be challenging without adequate documentation, NoS-NoB Data typically yields clearer outputs, compatible with analytic tools like Tableau, facilitating easier and more effective data introspection.

Finally, the analysis of NoS-NoB Data, though more complex than that of Small Data, does not require the extensive and distributed computing resources necessary for Big Data. It can be effectively processed on advanced personal computers, although handling tens of gigabytes may increase processing times, as noted by EDUCBA in 2023. This balance makes NoS-NoB Data a practical choice for entities that need more than Small Data capabilities but do not have the infrastructure to support Big Data operations.

"Figure 1 presents a graphical depiction of data distribution by size and structural type. The graph uses a red curve to illustrate Small Data, a green curve for NoS-NoB Data, and a blue curve for Big Data.

Figure 1 Relationship of data types to the data structure.



Source: (Schmidt, 2024)

On the x-axis, the data sizes range from 1 GB to over 1 PB, while the y-axis measures the volume of structured, semi-structured, and unstructured data, commonly associated with Small Data, NoS-NoB Data, and Big Data, respectively.

The area beneath the red curve symbolises Small Data, indicating a predominance of structured data typically found in smaller quantities, ranging from 1 GB to 10 GB, depending on the specific task and application.

Under the green curve, representing NoS-NoB Data, a mix of structured, semi-structured, and unstructured data is observed. Our analysis sets the upper limit of NoS-NoB Data at 100GB, although larger volumes may sometimes fall into this category.

The section under the blue curve, representing Big Data, highlights a substantial presence of unstructured data. While many experts consider 1 TB as the starting point for Big Data, our research suggests adjusting this threshold to 100 GB. This curve demonstrates that structured data is considerably less prevalent than semi-structured or unstructured data.

Overall, the graph visually communicates how different data types distribute across various sizes, illustrating the increasing dominance of unstructured data as file sizes grow."

Tab. 1 Data distribution according to criteria

Criterion	Data Volume	File Dimensions	File Count	Data Structure	Storage Location
Small Data	Limited to a small overall amount.	Typically kilobytes (kB) to megabytes (MB).	Processes a few files.	Structured within a single table.	Stored locally in a single file.
Not Small-Not Big Data	More than Small, less than Big Data volumes.	Range from hundreds of kilobytes to several gigabytes.	Manages many files.	Mix of structured and unstructured data.	Distributed in several locations or files.
Big Data	Extremely large volumes of data.	Hundreds of megabytes to terabytes per file.	Processes millions of files.	Semi-structured and unstructured data predominates.	Stored across cloud servers or various sites.

Criterion	Data Preparation Strategy	Archiving Strategy	Risk of Data Loss	Data Organization	Analytical Approach
Small Data	Tailored by end-users for specific projects.	Time-bound storage is specific to a project.	Low risk of loss or damage.	Highly organized and searchable due to clear metadata.	Straightforward, typically single-step on a local system.
Not Small-Not Big Data	Prepared by groups or automated for wider use.	Long-term or indefinite archiving.	Higher than Small, lower than Big Data risk.	Less organized and robust metadata than Small Data.	Requires multiple methods and approaches for analysis.
Big Data	Team-based preparation, not user-centric.	Needs virtually unlimited storage.	High risk, significant impact from loss/errors.	Complex, requiring comprehensive documentation for interpretation.	Distributed analysis over multiple stages and environments.

Source: Authors

4 Conclusion

In conclusion, emerging data categories beyond traditional Small and Big Data necessitate a nuanced understanding of their characteristics and processing requirements. The proposed category, Not-Small-Not-Big Data (NoS-NoB Data), fills the semantic gap between Small and Big Data, representing data volumes that exceed conventional processing capabilities yet fall short of necessitating specialised Big Data infrastructure. NoS-NoB Data, typically ranging from 10-100 GB, poses unique challenges in processing due to its intermediate size and complexity. While it shares some characteristics with Small and Big Data, NoS-NoB Data requires tailored collection, storage, management, and analysis approaches. Tools and techniques selected for NoS-NoB Data processing should balance scalability and efficiency, leveraging advanced database systems, analytical tools, and machine learning algorithms. The graphical representation in Figure 1 underscores the distribution of data types across various sizes, illustrating the increasing dominance of unstructured data as file sizes escalate. This visualisation aids in conceptualising the distinct data categories and underscores the importance of adapting analytical strategies to accommodate the unique characteristics of NoS-NoB Data. In summary, recognising and addressing the challenges posed by NoS-NoB Data is essential for organisations seeking to harness the full potential of their data assets. By adopting tailored approaches and leveraging appropriate technologies, businesses can effectively navigate the complexities of this intermediate data category, driving informed decision-making and achieving competitive advantage in the digital age.

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References

Banafa, A. (2018, August 1). Small data vs. Big Data: Back to the basics. OpenMind. https://www.bbvaopenmind.com/en/technology/digital-world/small-data-vs-big-data-back-to-the-basics/

Chollet, F. (2021). Deep learning with Python. Manning Publications.

Davenport, T. H., & Harris, J. G. (2017). Competing on analytics: The new science of winning. Harvard Business Review Press.

Duarte, F. (2023, December 13). Amount of data created daily (2024). Exploding Topics. https://explodingtopics.com/blog/data-generated-per-day

EDUCBA. (2023, June 15). Small Data vs big data: Top 10 useful comparisons you need to know. https://www.educba.com/small-data-vs-big-data/

Gartner_Inc. (n.d.). Definition of big data - Gartner information technology glossary. Gartner. https://www.gartner.com/en/information-technology/glossary/big-data

Inmon, W. H., Linstedt, D., & Levins, M. (2019). Parallel processing. Data Architecture, 81–87. https://doi.org/10.1016/b978-0-12-816916-2.00012-7

Mishra, D. (2019, June 24). What is Big Data and why do we need Hadoop for Big Data? SAP Blogs. https://blogs.sap.com/2019/06/24/what-is-big-data-and-why-do-we-need-hadoop-for-big-data/

Serrant, D. (2023, August 19). How can one tell if their dataset is small, medium, or big? Quora. https://www.quora.com/profile/Daryle-Serrant

Schmidt. P. (2024). NotSmall -Not Big Data (NoS-NoB Data) v kontexte dátovej vedy, OZ5V, Bratislava

Taylor, P. (2023, September 14). Most popular database management systems 2023. Statista. https://www.statista.com/statistics/809750/ worldwide-popularity-ranking-database-management-systems/

Walker, B. (2017, November 23). Big Data Strategies Disappoint with an 85 percent failure rate. Digital Journal. https://www.digitaljournal.com/tech-science/big-data-strategies-disappoint-with-85-percent-failure-rate/article/508325

MODEL PREPARATION TOOL BASED ON AUTOMATIC MACHINE LEARNING FRAMEWORK IMPLEMENTED AS A WEB APPLICATION

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Abstract
In modern days, plenty of data sources can bring additional information to their owners. However, not many of them can evaluate these sources because they lack knowledge in scientific domains such as statistics, mathematics, etc. Our paper aims to solve this kind of problem, and we created a tool that implements additional steps to ease this process. In our previous work, we implemented a data-cleansing utility. The second step is to choose the appropriate model according to the given data. In the first chapter, we describe the problem at an overall level; in the second chapter, we introduce the methodology used; the third chapter describes the project on its own and the obtained models; and the last one involves the conclusion.

Keywords
python, data science, automl, auto-sklearn, dataset

1 Introduction

In recent years, we have witnessed the rapid rise of new technologies and the upgrading of existing ones, and thus, a huge amount of data they generate. There are plenty of solutions available on the market, some of them for free and some of them are paid. This paper will not describe these applications because of the wide range, which is not our paper's aim. For example, more about free and paid solutions can be found at Mueller et al. 2019, Baumer et al. 2017, or Gearheart 2020. Those authors cover the two most used languages in data science (R and Python), and the last one covers a paid software solution called SAS. These three are very well known and used, but there are a lot of others like SPSS from IBM company and much more. Further in the text, we will introduce some of the most used technologies, but our main goal is to use Python with specialised libraries to create our application. Our goal was to create and implement such an application, where users with standard capabilities can upload his/her datasets and make all basic operations on them like data cleansing and first overall analysis of the dataset, consequently saving the dataset with processed modifications, model generation, and testing. First of all, the whole process of data science is to provide consistent data, but in real-world scenarios, this is impossible because of the possibility of duplicity, erroneous data, and abnormal or inconsistent data (Qinglei et al., 2017).

1.1 First steps in data science

As mentioned above, Qinglei et al. describe the process of preparing data for another evaluation. Without these important steps, the final result could be distorted; therefore, the decision could be wrong, and the whole process would be a waste of time. The first steps taken on the provided dataset should cover data deduplication, deleting erroneous ones, finding

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missing data, and correcting them by numbers with either neutral or average ones. There could also be other methods, but in our paper, we use three forms of replacing missing data: the first is providing zero values, the second average ones and the third is deleting whole rows of data because no other methods are suitable. The user can try all the methods independently to evaluate which method suits his/her needs. After processing all the data, we can choose the appropriate model to apply to our dataset. Choosing the proper one, we describe it later in our work.

1.2 R Language

R is a programming language and environment designed for statistical data analysis and graphical display. It is an implementation of the S programming language under a free license. Because it is free, R has already overtaken the commercial S in terms of users and has become the de facto standard in many areas of statistics. The functions of the R environment can be extended using libraries called packages. For version 3.6.2, were 15,325 available in the CRAN central repository as of January 2020. An example of a frequently used package is ggplot2 for data visualisation. R is used from the command line, but several GUI frontends exist, such as RKWard, RStudio, and R Commander. R is also linked or used in commercial software, e.g., in the SPSS environment, users can directly write and run programs in the R language over open data.

R provides various statistical and graphical techniques, including linear and nonlinear modelling, classical statistical tests, time series analysis, clustering, and more. R is easily extensible with features and packages, and the R community is known for its active updates (Kaplan et al., 2017). Many standard R functions are written in the R language, making it easy for users to track algorithmic changes. The code can be linked to C, C++, and Fortran for computationally intensive tasks and called at runtime. Advanced users can use C, C++, Java, .NET, or Python to manipulate R objects directly. Another strength of R is static graphics, which can generate graphs suitable for scientific publications, including, for example, mathematical symbols. Dynamic and interactive graphics are available through additional packages (Lewin-Koh, 2015).

1.3 SAS application

SAS (formerly Statistical Analysis System) is an integrated system of software products the SAS Institute produces. It serves both as a database system in companies and as a tool for analysis and business use of data, and on the other hand, it is also used for statistical data analysis in science and technology. It is modular software, so the customer can use only the parts that suit him. SAS includes its programming language, also referred to as SAS. SAS software implements the whole lifecycle of analytics. It comprises data administration, which involves data cleansing and preparation. The second step is an analytic platform comprising various software tools and artificial intelligence; the last step is data quality management (Blokdyk, 2019). This platform is paid for and chosen by individuals not often, but it is widely spread in commercial areas.

1.4 Python language

Python is a dynamic, interpreted language. It is sometimes classified among the so-called scripting languages, but its possibilities are greater. Python was designed to allow the creation of large, full-fledged applications (including a graphical user interface see, for example, wxPython, which uses wxWidgets, or PySide and PyQT for Qt, or PyGTK for GTK+).

Python is a hybrid (or multi-paradigmatic) language; that is, it allows you to use not only an object-oriented paradigm when writing programs but also a procedural and, to a limited extent, a functional one, depending on what suits you or is best for the given task. Because of this, Python has excellent expressive capabilities. The program code is short and easy to read compared to other languages.

A distinctive feature of the Python language is productivity in terms of the speed of writing programs. This applies to both the simplest programs and very extensive applications. In the case of simple programs, this property is manifested mainly by the brevity of the notation. For large applications, productivity is supported by features that are used in large-scale programming, such as native support for namespaces, use of exceptions, standard tools for writing tests (unit testing), and more. High productivity is associated with the availability and ease of use of a wide range of library modules, enabling easy solutions to tasks from several areas (Jaworski et al., 2021).

Considering all the conditions that must be met, we decided to use Python language with all the packages provided, as the wide support of a community of developers, and the last fact was that this language is also widely spread in the commercial sphere.

1.5 Streamlit package

Streamlit is a free, open-source, all-python framework that enables data scientists to quickly build interactive dashboards and machine learning web apps with no front-end web development experience required. If you know Python, then you are all equipped to use *Streamlit* (Li, 2022). It is a cost-free product, consisting of all needed to build interactive web pages with charts, maps, sliders, and other useful tools. You can create dashboards and other interactive content with a few lines of code. It employs its web server, so the application is ready.

1.6 Pandas and matplotlib packages

In our application, we used, amongst others, a package called *Pandas* and *Matplotlib*. *Pandas* is an open-source Python package that provides several data analysis tools. The package has several data structures that can be used for various data manipulation tasks. It also has a variety of methods that can be used to analyse data, which is useful when working on data science and machine learning problems in Python. This package is widely used in data analysis and for working with external data like Excel worksheets, JSON (JavaScript Object Notation) files, CSV (comma-separated values) files, etc. Package contains extended capabilities for working with rows and columns altogether without having to use loops; functions are used instead, so we can call this type of programming paradigm functional programming. Python is a mix of procedural, object-oriented, and functional access, as has already been mentioned.

Matplotlib is a plotting library available for the Python programming language as part of NumPy, a numerical data processing resource. Matplotlib uses an object-oriented API to insert plots into Python applications (Nelli, 2018). In our application, it is used to display a histogram plot.

2 Methodology

Based on the literature review we have chosen the framework already mentioned in the text before. According to Richards, “Streamlit shortens the development time for the creation of data-focused web applications, allowing data scientists to create web app prototypes using Python in hours instead of days.” (Richards, 2021). According to Nokeri, “Secure web apps and deploy them to cloud platforms" (Nokeri, 2021). We also decided to deploy our application into the cloud infrastructure in Oracle Cloud. Now, let us describe the steps to fulfil our goal.

1 We decided to develop an application that allows users to upload their data files and perform basic tasks to clean them up. This approach is called „data cleansing", and according to Nauman „„ Data cleansing is a complex set of tasks that takes as input one or more datasets and produces as output a single, clean data set" (Nauman et al., 2022). This process takes a vast amount of time, so we decided to lessen this amount of time by reducing some tasks involved in data cleansing. After data cleansing, we will try to find an appropriate classification model applied to our dataset.
2 After some research, we decided to use web technology due to its widespread use and ease of use with web browsers.
3 Consequently, we decided to use the web framework *Streamlit* based on *Python* language technology.
4 Developing source code to implement applications.
5 Test and deploy on the local server.
6 Final application deploying on Oracle cloud infrastructure on Linux virtual machine.

3 Environment preparation

a. *Prerequisites*

We needed to take mandatory steps to achieve the final goal. First of all, we have to download Streamlit libraries from the home website of the project. The website has installers suitable for various operating systems and architectures. After choosing the appropriate one, follow the instructions to finish the installation process. To achieve this task, implementors should be aware of administering Windows, Linux, or MacOS operating systems. When the installation is successfully done, we can start the Streamlit framework. If everything works fine, we get a link and port on which the web server listens. The user is then redirected to the web browser, where the application will reside when completed. The steps described above are necessary to do otherwise, implementation will not be possible.

b. *Choosing the appropriate dataset*

Our application is now fully suitable for all datasets. We aimed usage of this application on datasets that mostly contain numerical values organised in rows and columns. So, we prefer a standard form of dataset known widely as Excel sheet or LibreOffice sheet but exported to CSV format. Other types of datasets that mostly contain string values are not suitable. We implement various encoders for categorical values, which will employ algorithms that convert categorical values to groups of numbers, allowing them to function properly. We used the sonar.csv dataset for this type of machine learning computations retrieved from GitHub to maintain a proper approach to our project. Dataset sonar.csv contains data describing whether echoed-back acoustic signals belong to mine (M) or rock (R) reflection patterns.

c. *Choosing the appropriate model*

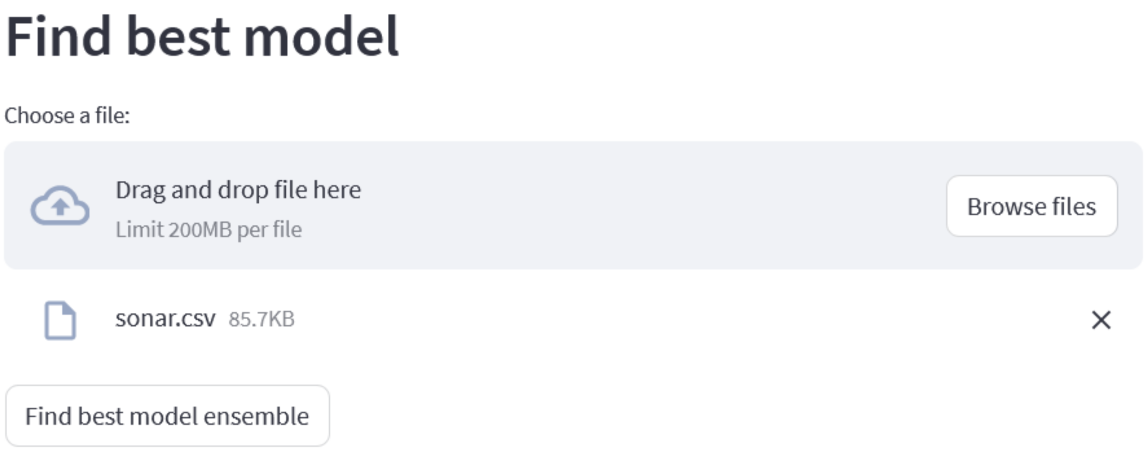
Our project is divided into several parts: the first one is data cleansing and simple brief graphical analysis based on histogram plots, the second part is model selection, and the final part comprises model testing. Testing selected models will not be included in this paper.

Choosing the appropriate model is a very complex and difficult process, which comprises choosing the suitable type of estimator and appropriate algorithm, selecting hyperparameters and their values and also their different combinations, and so on. The machine learning industry is thus very complex to be understood by one person. When you look at machine learning algorithms, there is no unique solution or one approach that fits all. Several factors can affect your decision to choose a machine-learning algorithm (Harlalka, 2018). Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns, and make decisions with minimal human intervention (Gradillas, 2021).

Our application is written as a web application with a very easy and intuitive interface, so any user with minimal knowledge of statistical methods or machine learning algorithms can use it for his data. We decided to implement classifier estimators only with prepared classifiers in the training dataset; this is called supervised learning; other types of learning we didn't use in our work are unsupervised learning and reinforcement learning.

For the complexity of such an application, we implemented a classification algorithm only, but the implementation of regression algorithms is planned for future implementation. Our application offers data cleansing, model search, and application of models found by automated machine learning. As depicted in Figure 1 user must provide the file in CSV (comma-separated values) with the pre-classified dataset to train the model on. Subsequently, the dataset is uploaded to the server, and searching for the model will start.

Figure 1: Model selection user's interface



Source: own elaboration

At this point, we must remember that this part is very sensitive because we have to choose the right amount of reasonable time to perform computations. We tested auto-selected models within a minute limit to testing because we trained models on small datasets, and we were limited by the hardware resource given to the server. This type of computation depends on the number of computer processors and the size of an operational memory. We tested our computations also on a notebook with eight cores and sixteen gigabytes of memory, but the server we used had one core and six GB of memory. Therefore, we have to choose parameters to avoid unreasonable time to get results. Our solution is prepared for server usage because of the web application type of service. We recommend using our application in a server environment with a minimum of four cores and eight gigabytes of memory to get reasonable results in a reasonable timespan for larger datasets. We set the time to a fixed value (for us, it was five minutes); this time is the same for every hardware configuration, but here applies the clause that the more efficient the hardware, the more tested algorithms (figure 2 bolded text).

Figure 2: Finding the best model

```
auto-sklearn results:
  Dataset name: c1241e23-271b-11ee-80b0-00155de7a23f
  Metric: Accuracy
  Best validation score: 0.913043
  Number of target algorithm runs: 128
  Number of successful target algorithm runs: 113
  Number of crashed target algorithm runs: 14
  Number of target algorithms that exceeded the time limit: 1
  Number of target algorithms that exceeded the memory limit: 0

Accuracy: 0.7391304347826086

{66: {'model_id': 66, 'rank': 1, 'cost': 0.08695652173913049, 'ensemble_weight': 1.0,
'data_preprocessor':
<autosklearn.pipeline.components.data_preprocessing.DataPreprocessorChoice object at
0x7fc011c5eb80>, 'balancing': Balancing(random_state=1, strategy='weighting'),
'feature_preprocessor':
<autosklearn.pipeline.components.feature_preprocessing.FeaturePreprocessorChoice
object at 0x7fc0116867f0>, 'classifier':
<autosklearn.pipeline.components.classification.ClassifierChoice object at
0x7fc00e6c63a0>, 'sklearn_classifier': LinearSVC(C=493.6813394002163,
class_weight='balanced', dual=False,
    intercept_scaling=1.0, random_state=1, tol=0.05050518248614478)}}
```

Source: own elaboration

d. A brief look at the code

When the user wants to use the model auto-selection feature, he/she must upload the source CSV data file to the server. As the application's creators, we can tune model outcomes with so-called hyperparameters. This part of model creation is called hyperparameter tuning; only the application creators can now manipulate them. In future versions of the application, we can allow users to modify some parameters to a limited extent, like entering other times as we present in our application (five minutes). This should be carefully done because entering a higher value of the time limit can cause a massive workload to be applied to the server. Figure 3 shows a code snippet showing automated machine-learning Python code with hyperparameters in bolded font.

Figure 3: Python code snippet with parameters

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, random_state=1)
model = AutoSklearnClassifier(time_left_for_this_task=5*60, per_run_time_limit=30, n_jobs=8, ensemble_kwargs={'ensemble_size': 1})
model.fit(X_train, y_train)
```

Source: own elaboration

As shown in Figure 3, we are searching for the best classification model, and we can tune some arguments to achieve our goal. Beyond other possible parameters, we are using time_left_for_this_task, where we set the overall time to run the whole program; we can say the more time, the better the results. In our research, we chose a reasonable time to be set to five minutes because our dataset was not big enough to set a higher value. We performed tests with the newly generated model on the same dataset without classification labels. The generated model classified the same data as the original dataset with prelabeled data rows. This can be considered as the best result to achieve. We would get a highly precise classification if we got a similar dataset. We have to consider that the final model could be overfitted if we strongly push for the highest accuracy of the model beyond a reasonable manner. Another parameter is ***per_run_time_limit***, which limits the run time for one tested model, and we set it to thirty seconds, after which the cycle is terminated and another cycle with different parameters is used. The final parameter in our script is ***ensemble_size***, which means several finally generated models ordered from the best to the worst. The figure below shows the three best models generated after we set the number to three.

From the given result (Fig. 4), we see the first three models ordered from the first RandomForestClassifier as the best one and the second and third *MLPClassifier* (Multi-layer Perceptron classifier) as the best models to use with our training dataset. The second and third places use the same classifier and, therefore, are distinguished by different arguments called hyperparameters enclosed in parenthesis that *AutoSklearnClassifier* chose as the best ones for our scenario.

Figure 4: Finding the best three models

```
auto-sklearn results:
  Dataset name: fd2992cc-28db-11ee-804a-00155de7adf2
  Metric: Accuracy
  Best validation score: 0.913043
  Number of target algorithm runs: 139
  Number of successful target algorithm runs: 120
  Number of crashed target algorithm runs: 18
  Number of target algorithms that exceeded the time limit: 1
  Number of target algorithms that exceeded the memory limit: 0

Accuracy: 0.782608695652174

{14: {'model_id': 14, 'rank': 1, 'cost': 0.15217391304347827, 'ensemble_weight': 0.3333333333333333, 'data_preprocessor':
```

```
<autosklearn.pipeline.components.data_preprocessing.DataPreprocessorChoice object at 0x7f5b4c0b9fa0>, 'balancing': Balancing(random_state=1), 'feature_preprocessor': <autosklearn.pipeline.components.feature_preprocessing.FeaturePreprocessorChoice object at 0x7f5b4be94700>, 'classifier': <autosklearn.pipeline.components.classification.ClassifierChoice object at 0x7f5b4c0af970>, 'sklearn_classifier': RandomForestClassifier(criterion='entropy', max_features=15, n_estimators=512,
                       n_jobs=1, random_state=1, warm_start=True)}, 53: {'model_id': 53, 'rank': 2, 'cost': 0.13043478260869568, 'ensemble_weight': 0.3333333333333333, 'data_preprocessor': <autosklearn.pipeline.components.data_preprocessing.DataPreprocessorChoice object at 0x7f5b4bfbe730>, 'balancing': Balancing(random_state=1, strategy='weighting'), 'feature_preprocessor': <autosklearn.pipeline.components.feature_preprocessing.FeaturePreprocessorChoice object at 0x7f5aecffec70>, 'classifier': <autosklearn.pipeline.components.classification.ClassifierChoice object at 0x7f5aecffe790>, 'sklearn_classifier': MLPClassifier(alpha=8.440979695014983e-05, beta_1=0.999, beta_2=0.9,
              hidden_layer_sizes=(157, 157, 157),
              learning_rate_init=0.0002774746616573728, max_iter=128,
              n_iter_no_change=32, random_state=1, validation_fraction=0.0,
              verbose=0, warm_start=True)}, 79: {'model_id': 79, 'rank': 3, 'cost': 0.08695652173913049, 'ensemble_weight': 0.3333333333333333, 'data_preprocessor': <autosklearn.pipeline.components.data_preprocessing.DataPreprocessorChoice object at 0x7f5b4bfacc70>, 'balancing': Balancing(random_state=1, strategy='weighting'), 'feature_preprocessor': <autosklearn.pipeline.components.feature_preprocessing.FeaturePreprocessorChoice object at 0x7f5aed24d1c0>, 'classifier': <autosklearn.pipeline.components.classification.ClassifierChoice object at 0x7f5aed44f700>, 'sklearn_classifier': MLPClassifier(activation='tanh', alpha=2.89664380675713e-05, beta_1=0.999,
              beta_2=0.9, hidden_layer_sizes=(50, 50, 50),
              learning_rate_init=0.00019621972402090513, max_iter=256,
              n_iter_no_change=32, random_state=1, validation_fraction=0.0,
              verbose=0, warm_start=True)}}
```


Source: own elaboration

e. Retrieving final results

The web application returns the first best model in a brief information window and offers a button to download all the models with their hyperparameters ranked from one to the maximum models defined in the parameter ensemble_size. The web application generates a binary file in the background with serialised models used in the process of creating the best models. This data is subsequently deserialised and loaded into the application in the final step, which consists of deploying the model on another dataset without knowing its classification hyperparameters used with the scikit-learn package.

4 Conclusion

Our paper aimed to allow people with less machine learning knowledge to ease the model preparation process. Our secondary goal was also to make an application that would be dataset-independent (meaning no special names for columns and rows), so anyone with any dataset saved in CSV format could upload the dataset to our server. These goals were fulfilled and there remains the third – much more difficult part to further process prepared (cleansed) data. In brief, these steps would comprise feature selection, various model testing, and finally, applying a winning model to our dataset. We've already implemented these steps in Python using the auto-sklearn package specifically designed for these data science tasks. The final step in creating our application is to implement a possibility to test the generated model on the user's data by simply uploading them to the server, and subsequently, the saved model (generated model) will be applied to data using the Python library scikit-learn. After completing the task, they will be offered the file to download with classification results.

Resources

Blokdyk, G. (2019). SAS Software a Complete Guide - 2019 Edition. Emereo Pty Limited.

Gearheart, J. (2020). End-to-end data science with Sas: A hands-on programming guide. Sas Institute.

Gradillas, R. (2021). Machine Learning Algorithms: How to Choose the Right Kind of Machine Learning Model. Independently Published.

Harlalka, R. (2018). Choosing the Right Machine Learning Algorithm. Retrieved July 20, 2023, from https://medium.com/hackernoon/choosing-the-right-machine-learning-algorithm-68126944ce1f

Jaworski, M., & Ziadé, T. (2021). Expert Python Programming: Master Python by learning the best coding practices and advanced programming concepts. Packt.

Kaplan, D., & Horton, N. J. (2017). Modern Data Science with R. CRC Press, Taylor & Francis Group.

Lewin-koh, Nicholas. (2015). CRAN Task View: Graphic Displays & Dynamic Graphics & Graphic Devices & Visualization. cran.r-project.org.

Li, S. (2022, January 14). Streamlit hands-on: From zero to your first awesome web app. Medium. Retrieved July 30, 2022, from https://towardsdatascience.com/streamlit-hands-on-from-zero-to-your-first-awesome-web-app-2c28f9f4e214

Mueller, J. P., & Massaron, L. (2019). Python for data science for dummies. Wiley.

Nauman, F., & Herschel, M. (2022). An introduction to duplicate detection. Springer Nature.

Nelli, F. (2018). Python data analytics: With pandas, NumPy, and Matplotlib. Apress.

Nokeri, T. (2022). Web App Development and Real-Time Web Analytics with Python: Develop and Integrate Machine Learning Algorithms into Web Apps. Apress.

Richards, T. (2021). Getting Started with Streamlit for Data Science: Create and deploy Streamlit web applications from scratch in Python. Packt Publishing Ltd.

SPRINGER Verlag, SINGAPOR. (2018). Data science: 4th International Conference of Pioneering Computer Scientists.

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