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Artificial intelligence, creativity and education: finding a new perspective

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Abstract: *This review study aims to clarify the relationship between creativity development and artificial intelligence in education. Although this is a media-emphasised topic and individual technology projects (ChatGPT, Dalee-2, Midjourney) are part of educational activities, a more comprehensive analysis of the specific emphasis on creativity still needs to be provided. The study's novelty lies in synthesising current knowledge and forming recommendations about the relationship between creativity and AI in education. The study analyses 16 documents from the Web of Science database and, based on these, identifies six broad categories for critical reflection on the phenomenon of educational practice: the need to rethink the educational environment, goals and objectives, the emphasis on AI literacy, the focus on topics related to the future and its problems, the importance of developing theoretical conceptualisation of problems and abstract models in the curriculum, the connection with computational thinking, and the integration into the whole curriculum instead of isolated courses.*

Keywords: *artificial intelligence; creativity; review study; education; ChatGPT; AI; technology in education*

1. Introduction

Technology is fundamentally transforming education (Rodés Paragarino, V., & Gewerc, 2022; González-Pérez & Ramírez-Montoya, 2022). This is not just a matter of following trends (Pelletier et al., 2022) but of making more profound and systematic changes to the very nature of education (Treve, 2021). Technology is not external but a fundamental element transforming the environment (Zhang et al., 2023; Pelletier et al., 2022; Oliveira & Souza, 2022).

Generative artificial intelligence has become a significant technology trend between 2022 and 2023 and has begun to take hold in the form of user-friendly tools. In the field of artefact creation, the most visible projects are Dalle-2 (Kang et al., 2023; Hutson & Cotroneo, 2023), Midjourney (Borji, 2022; Byrne, 2023) and for language models, undeniably ChatGPT (Deng & Lin, 2022; Shahriar & Hayawi, 2023), for which there are already many studies focused on education (Lo, 2023; Kasneci et al., 2023). These technologies will majorly impact the labour market (Zarifhonarvar, 2023; Pan & Froese, 2023).

For this reason, it is crucial to look at how ideas and models of education need to be transformed in the context of technological change (Cerny, 2022). Specifically, we want to focus on the relationship between artificial intelligence, creativity and education. It is creativity that has been associated with language models and other projects using generative AI (Jia et al., 2023; Creely, 2023), even as an educational challenge (Shidiq, 2023) or an issue of humanity (Haase & Hanel, 2023) and the development of typical human qualities and characteristics. The question of the relationship between the form of education and the use of AI to develop creativity will be a crucial focus of this study.

We know that the definition of the two key terms of our study is fluid and that each author may treat it differently. Artificial intelligence could be understood in the 1950s as a theory of human intelligence that machines can manifest, but it is not very easy to define in the current era (Bini, 2018). It can be seen as a superordinate concept of machine learning (Helm et al., 2020). Dobrev (2012, p. 2) boldly claims that "AI will be such a program which in an arbitrary world will cope no worse than a human". Turing's approach (Elkins & Chun, 2020) similarly reckons that an intelligent system is one that we cannot differentiate from a human in dialogue (Danziger, 2022; Alberts, 2022). In our study, we recognise the limitations of these definitions, which always work only with a specific facet of human activity, and we will understand artificial intelligence as a non-deterministic algorithm that uses machine learning to solve a particular set of problems.

Creativity can be a similarly complicated concept (Kampylis & Valtanen, 2010; Walia, 2019). Koestler (1981; 2014) suggests creativity occurs when two distinctly different frames of mind intersect. These are applied to a single phenomenon whose understanding differs from how we have understood it. Wallas (Sadler-Smith, 2015; Setiawani et al., 2019) links it to expertise that leads to a new idea being evaluated and succeeding in that evaluation. For this study, we can simplify creativity to a description derived from the Cambridge Dictionary: 'the ability to produce original and unusual ideas, or to make something new or imaginative', as the approaches of most of the studies we have analysed can be integrated into this definition. For a deeper analysis, we lean towards Feyerabend's (1984) understanding of creativity, which associates it with expertise, courage and originality. We will return to the meaning and structure of these simplifications and definitions at the end of this review.

There are currently (as will be shown in the Results section) a relatively large number of sub-studies that address the rise of creativity and AI in education. Still, there is a lack of a broader integrative view of the issue that can be examined from broader perspectives than just case studies or idea papers. In this study, therefore, we attempt to answer the question of the relationship between AI, creativity and education, specifically in formal education.

2. Methodology

The Web of Science (WoS) database, which collects documents from the most prestigious journals, proceedings and other sources, was used to obtain data for the review study. Thus, it provides the theoretically best quality and best-described results of current research among the databases. For the search itself, we used two selection steps. In the first step, we worked with the keywords "AI creativity education". The word education instead of learning was deliberate because the word learning occurs strongly in technology practice in the context of neural network learning or machine learning.

In this way, we obtained the first data set of 263 results. We exported keywords, fields of investigation, and abstracts in Voyant Tools for quantitative text document analysis to perform the first data analysis. This part of the research aims to provide a baseline for comparing the relevance of the results obtained for the second part of the review study. The dataset was finalised on 3 . August 2023.

To be able to go through the texts systematically, it was necessary to set additional rules for the selection of results. We, therefore, chose the following added criteria:

1. The language of the result must be English (reduction to 247 results)
2. Must be Open Access documents (reduction to 84 documents)
3. Document type - Article (reduction to 63)
4. Social Science Research Domain (reduced to 23)
5. Manual selection of irrelevant documents (reduction to 16)

Irrelevant results were applied in two sets of cases. Either the study was unrelated to the topic, even marginally, or (in the case of two studies) the articles needed to be of better quality. They were withdrawn from the journal by the publisher. They still appeared in the database. The fact that a relatively strongly selected dataset had 30% of results irrelevant shows that the topic we studied is, on the one hand, new and needs to be grasped.

On the other hand, extremely attractive in terms of keywords. At the same time, the original dataset with 263 results may have minimal relevance to the topic under study. The path of a qualitatively oriented review study is the only possible one in this context.

For the qualitative part of the review study, we looked at the research design and the focus of the study (whether it is theoretical, empirical or applied). For the critical question and findings, we did not follow the tone of the entire study but what was relevant to our research topic. Some of the studies addressed the phenomenon only marginally, so it was necessary to look at the details in the results. The original intention was also to observe the prevailing attitude of the study towards the AI phenomenon. This is not reported in the results, as it was positive or neutral in almost all studies. A completely different analytical method would have been needed for a more careful distillation.

In the table (Table 2) with the results, we list the countries, by which we mean the countries of the authors' institutions as listed in the WoS. The WoS also provides a summary of citation feedback, so the total citation feedback for some studies will be higher.

Three significant limitations of the study can be seen. 1) The too-small research sample analysed in the qualitative part reduces the possible diversity of conclusions and the plasticity of the issues reflected. 2) We only work with studies from WoS, which constitute a specific slice of reality; the study could be extended with studies from other databases (especially Scopus) or sources outside the academic environment that would be more relevant to practical issues and problems. 3) The studies are focused on only part of the world in their selection - we need studies from Africa, more documents from Europe or the Middle East and other areas. At the same time, their conception of creativity may differ from the studies in this review.

3. Results

In the first part of the results, we would like to offer a more comprehensive view of the whole issue through the lens of the two datasets mentioned above - one with 263 documents (Full) and the other with 16 selected ones (Selected). This first quantitative analysis aims to offer a basic description of the whole research set. Regarding the description of the datasets, the first Full with abstracts has approximately 54.3 thousand words and 6.2 thousand unique word forms; with keywords, we can talk about 4.5 thousand words and 1.2 thousand unique word forms. It is already clear from this overview that the thematic and content dispersion of the studies will be considerable.

Fig 1. Wordcloud of abstracts for the entire dataset.

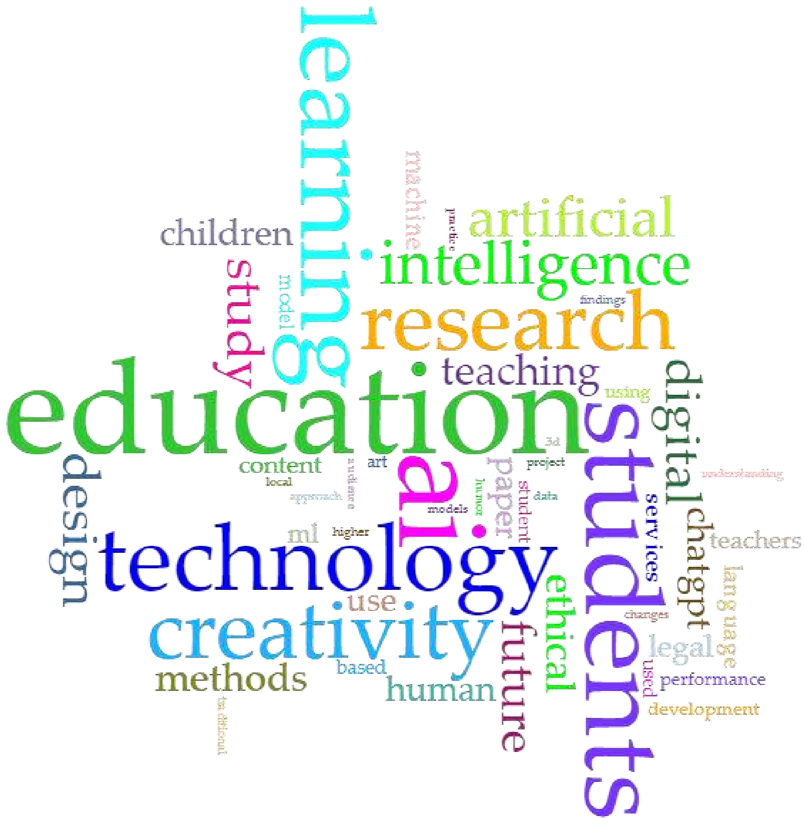

Fig 2. Wordcloud of abstracts for the sample dataset.

A comparison of Figure 1 and Figure 2 shows that the datasets are relatively similar in content (we are comparing abstracts, which already give a rather good indication of article casts).

However, compared to the former, our reduced dataset is more technical and less design-oriented, which should be considered when analysing the overall thematic focus of the studies. We also include a table (Table 1) with the most frequent keywords in the dataset analysed for a more profound overview of the research field.

Table 1. Captures data from the entire dataset from keywords with a frequency higher than 25.

Keyword - frequency	
Creativity - 111	Artificial - 44
Learning - 93	Innovation - 32
Education 93	Creative - 31
Design - 62	Thinking - 28
Intelligence - 57	Model - 28
AI - 47	Technology - 26

To illustrate the thematic landscape of the studies, we also include an analysis by discipline (Figures 3 and 4), as generated by the analytical tool integrated into the Web of Science. Their comparison shows that our selection for social sciences reduced primarily technical papers, which may not have sufficient relevance for the topic we studied. At the same time, the data show that our research is in a field at the boundary between educational sciences and computer sciences.

Fig. 3. Fields in the entire dataset.

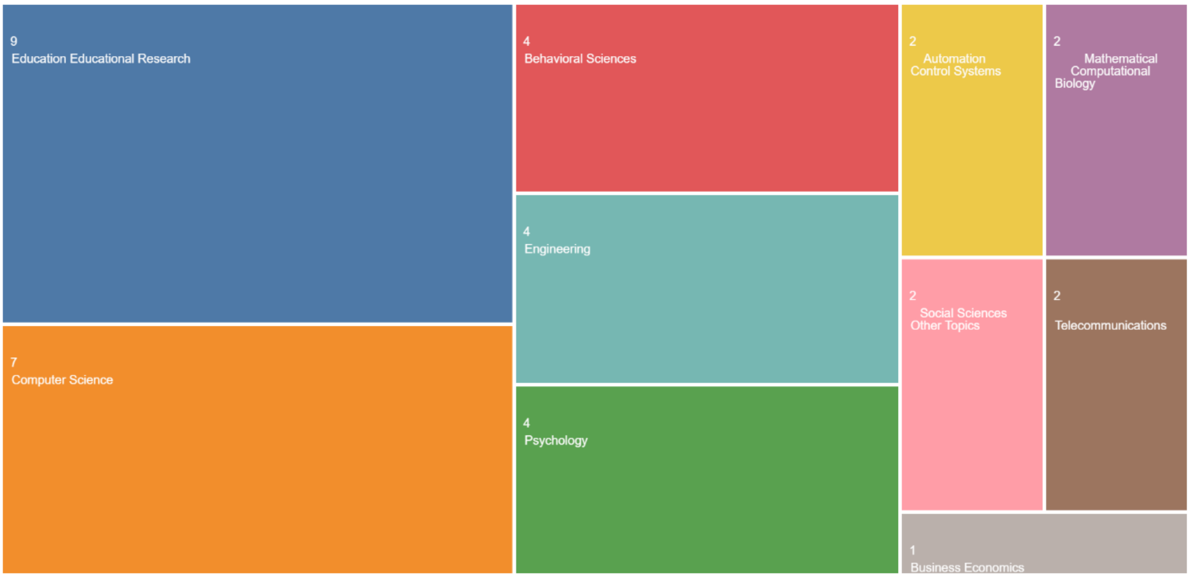

Fig. 4. Fields in the sample dataset.

In the second part of the presentation of the results, we will work with the table (Table 2) that we obtained by carefully reading the individual studies in the sample (to which Figures 2 and 4 correspond).

Table 2. Overview of studies included in the qualitative part of the review study. The abbreviations for countries in the last column are KOR - Korea, USA - United States, CHN - China, ITA - Italy, THA - Thailand, DEU - Germany, UKR - Ukraine, GB - United Kingdom,

and AUS - Australia. The abbreviation Ref. denotes the number of citations (excluding self-citations) in WoS.

Authors	Question	Methodology	T/E/A	Interesting findings	Ref	State
Marrone, R; Taddeo, V and Hill, G	What is the relationship between AI and creativity?	Focus groups, interviews	E	Students with a better understanding of AI are less afraid and more able to implement it in their creative process. AI literacy is a crucial element for the future of education.	5	AUS
Kim, J and Lee, SS	Do we need to educate when we can use AI?	Experiment	E	The study shows that it is necessary to look for areas in which the use of AI makes sense and, at the same time, to connect work with AI systems with educational support. Then, better results can be achieved in creativity, at least in art.	0	KOR
Rong, QM; Lian, Q and Tang, TR	The combination of AI and VR and their educational effects.	Questionnaire	E	Students who work with VR and AI are more creative and immersed in learning. A fundamental limitation is the need for adequate teaching practices.	2	CHN
Ritchie, G	Can computers create humour?	Theoretical study	T	The study shows that computers can create jokes or perform humour, thanks to discoveries in the field of humour itself. Good knowledge of the phenomena to be generated is a prerequisite for their successful implementation.	10	GB
Treve, M	What impact has COVID-19 brought on the transformation of higher education?	Overview study	E	COVID-19 led to a transformation of teaching methods and forms. AI represents the next natural step enabled by the pandemic. AI systems can support differentiated and individualised instruction while reducing the burden on educators.	18	THA

Iskender, A	What opportunities or threats does ChatGPT bring to tourism education.	Experiment	E	The study says we do not know much yet, so we should work with this tool as much as possible. It cannot be banned or restricted, but that does not mean it is a one-size-fits-all answer. Regarding creativity development, the study emphasises the possibility of brainstorming or focusing on more cognitively demanding tasks.	6	USA
Tang, TR; Li, PF and Tang, QH	How can AI help students with design proposals?	Experiment	E	The study shows that if education is to lead to the creation of products, AI can help achieve higher quality and more complex outputs, leading to more efficient use of time and, thus, higher quality education.	0	CHN
Dwivedi, U; Gandhi, J; (...); Kacorri, H	How can ML education help creativity?	Experiment	E	The study shows that the design of ML algorithms incorporates concepts, such as the innovative cyclic approach, that are the same as those found in theories of creativity. Thus, learning to program ML algorithms stimulates creative competence.	1	USA
Viktorivna, KL; Oleksandrovych, VA; (...); Oleksandrivna, KN	How does AI affect foreign language learning?	Questionnaire	E	The study shows that working with AI systems can reduce spontaneity and, thus, creativity, as we often focus on personalised but closed tasks.	0	UKR
Henze, J; Schatz, C; (...); Bresges, A	How to connect AI and STEM?	Questionnaire, interviews	E	The study explored broader STEM topics but also explicitly works with AI. As a result, the emphasis on combining creativity and STEM makes much sense if we want students to be able to think innovatively and find new ways. STEM does not oppose creativity but positively influences each other when		DEU

				appropriately nurtured educationally. This study presents a concrete model of such interaction.		
Jia, ZX and Yang, YF	How can AI support decision-making processes?	Machine data analysis	A	The study deals with our topic only marginally. The critical point is that education significantly impacts the ability to use technology, including AI systems, and that AI-related creativity in the areas studied is gradually increasing. It can be said that we are learning to be creative using AI.	0	CHN
Gloor, P; Colladon, AF and Grippa, F	How can AI be used to classify ethical human behaviour?	Machine data analysis	E/T	Creative groups are more emotional. Multiple studies show a strong link between positive emotion and creativity. This fact leads to a discussion about creative groups' ethical standardisation and stability and the importance of educating them.	1	ITA & USA
Davis, AE	What areas of legal practice will be spared the impact of AI?	Theoretical study	T	According to the study, lawyers will provide four services AI cannot - decision-making, empathy, creativity and adaptability. These areas must be educationally targeted as they will be challenging to replace algorithmically.	1	USA
Chun, H	What impact does 3D printing have on the education process?	Theoretical study	T	The study addresses the topic peripherally but shows that technology (specifically 3D printing) positively impacts the development of creativity and creative thinking and that AI will fundamentally influence it. We need to look for ways to continue to engage with these themes while at the same time taking advantage of the opportunities that	0	CHN

				technological change realistically brings.		
Riekki, J and Mammela, A	How to help technology educate for an innovative and sustainable world?	Theoretical study	T	AI-enabled systems force us to think about long-standing social issues more complexly and systematically, not just analytically. The study highlights the educational pivot that needs to be made if technology is to be used significantly for the benefit of humanity and not for the pursuit of petty parochial goals.	5	FIN
Shafique, R; Aljedaani, W; (...); Choi, GS	What is the role of AI in online education?	Overview study	T	Despite its title, the study only marginally deals with the topic. It understands creativity in the search for the use of AI in different areas of online education, with the understanding that the context and possibilities of a given situation must always be carefully understood.	0	KOR & USA

If we were to comment on the results from Table 2 in general, most studies are from China (4), whose authors fail to link to the international setting. These are both lower quality and less cited studies than those coming from the Western cultural circle. On the other hand, the authors from the USA have three separate articles, but another two are produced by collaboration. An analysis of the cultural background of each study may also be relevant in that different educational systems and cultures place different emphasis on the importance and role of creativity in the educational process. Therefore, the analysis of texts should be approached with an awareness of the importance of cultural differences.

Empirical studies dominate, primarily based on testing a tool or procedure and then reflecting on it. The research designs in all analysed studies were relatively simple (except for the complex survey by Henze et al. (2022). However, review studies do appear, although the samples they work with are not (as in our case) particularly large or elaborate.

4. Analysis

The analysis of the studies is guided by an attempt to formulate some key themes that may be useful for further research on the relationship between education, artificial intelligence and creativity. This section follows a qualitative approach, so the key for us is not the number of occurrences but the themes each study offers.

Some studies show that the critical issue will be redesigning the educational environment and its practices. Tang et al. (2022) point out that artificial intelligence makes it possible to work with topics and projects that would be unattainable in standard class time or school assignments. Education through these technologies can be closer to practice and, at the same time, help with motivation. However, such a transformation expects a fundamental change in how educational lessons are designed. Victoriana et al. (2022) is our review's only negatively oriented study. This is not due to a negative attitude towards AI but because its inappropriate use in school education can lead to the creation of closed, uncreative tasks, which suppresses the meaning and educational usefulness of the whole technology. We need to change mindsets and frameworks to achieve good results. This is also confirmed by the study of Henze et al. (2022), who work with the development of a new educational framework and try to show that new technologies (specifically AI) allow for better work with imagination, creativity and discovery learning, and can lead to improvisation and quality learning if they are well used and logically implemented in the educational curriculum. If AI is to help creativity, new frameworks for its use, not minor applications in existing practice, must be sought.

The second important aspect of developing creativity about AI in education is the ability to work with AI tools and systems. The phenomenon sometimes referred to in the literature as AI literacy is a prerequisite for working creatively with these tools. Marrone et al. (2022) say that the better students know the tools, the less fearful they are of using them and the more creative their application can be. Similarly, Jia and Yang (2022) stress the importance of knowing the tools to make effective decisions and use them. Kim and Lee (2023) emphasise that knowledge of the tools allows one to look for areas in which AI makes sense and in which it does not. Good sub-tool knowledge is a prerequisite for developing creative thinking with AI, creating a sense of confidence and an experiential base essential for creativity.

Other studies touch on the theme of the future - creativity is oriented not to the present but to the space of the future, to the change of work positions, procedures, processes, and transformation of society. So, we can see the social aspects of these tools. Davis (2020) asks about the legal profession's future and emphasises four 'new' areas that must be developed educationally - decision-making, empathy, creativity and adaptability. In all of these, the possibility of AI is evident, but simultaneously, the emphasis is on the presence of humans and their responsibility. Riekki and Mammela (2021) see the importance in that these tools and technologies will enable understanding of context in broader perspectives; education needs to focus on understanding context and contexts and the possibility of collaboration to solve complex and otherwise intractable problems and challenges. Iskender (2023) points out that we are still waiting to see the impact of these technologies. However, the way forward is to refrain from banning them but to engage in critical discussion and analysis, looking for ways to foster creativity through technology.

The advent of AI can mean something other than the loss of the need to understand theoretical concepts and problems. It is not about the end of classical education in which machines will replace humans but about the ability to use AI to apply and reflect on models. Ritchie (2013) shows that AI allows us to work with humour when we understand it sufficiently. Gloore et al. (2022) create models of ethical behaviour and then test them with AI. These technologies allow students to work more actively with their ideas if they understand well the world to which they relate, which is also the conclusion of Henze et al. (2022). Shafique et al. (2023) emphasise an excellent knowledge of the context and theories that constitute the fundamental prerequisite for AI systems' creative and meaningful use.

A specific perspective is offered by the study of Dwivedi et al. (2021), who points out that the ability to create one's machine learning models (i.e., to use artificial intelligence by having learners create or adapt the tools or algorithms themselves) is structurally identical to creative thinking. Programming AI for a specific task means understanding the context and having AI literacy. The authors believe that combining this with the ability to write code enables fundamental creative thinking.

It should also be remembered that AI does not form an isolated entity but often acts in the context of other tools and technologies; separating it from the rest of the tools and applications in research and school practice can have strong simplifying effects. Trewe (2021) points out that the whole phenomenon of AI must be seen in the particular educational and social field we find ourselves in since the COVID-19 pandemic. The latter has opened up a space for the transformation of education, and AI is entering this transformation as one of the factors. Above all, Trewe sees its future in the possibility of greater customisation of teaching, again a phenomenon that has opened up and is developing rapidly in the context of the pandemic. Rong et al. (2022) see AI as a tool to better work with the positive educational aspects of virtual reality. Similarly, Chun (2021) links AI to the possibility of better use of 3D modelling and its positive impacts on the educational profile of students.

5. Discussion

Our analysis described six specific themes or aspects of the relationship between AI, creativity and education. Here we would like to put them in a broader context. The topic of teaching and AI has been described in the literature about education for a long time (Wong et al., 2020; Eaton et al., 2018; Zhai et al., 2021; Beck et al., 1996). What is new - and what emerges from our study - is that educational grasp is not easy and will require more than simply extending lessons, including new lessons or courses (Ouyang et al., 2022). We need some paradigm shift in education to be creative (Cerny, 2022).

Developing AI literacy (Ng et al., 2021; 2021a; Perchik et al., 2023) is essential for creativity education. If students cannot work with the tools, understand how they are shaped and the theoretical models and limits behind them, or lack ethical reflection on the phenomenon (Zhang et al., 2022), the positive impacts on creativity will be very limited. The development of new educational programmes and courses must not only be linked to informal education but should also gain sufficient space in both universities (Southworth et al., 2023) and lower levels of education (Olari & Romeike, 2021; Casal-Otero et al., 2023).

At the level of reconceptualising considerations of curriculum structure, there is also the theme of understanding the actual content or models that students could work with further or be used as theoretical underpinnings for working with AI, a theme related to looking to the future. In the literature, this theme can be seen well in the field of geography education (Burkholder, 2022; Davidson et al., 2023), where many studies focusing on the use of AI tools also appear (Chang & Kidman, 2023; Kim, 2023). From a broader perspective, we can see studies on the ability to solve large and complex problems through AI (Bao & Xie,2022; Zheng et al., 2022). These studies show that AI allows us to tackle many classical topics or problems from a completely different perspective and will force us to abandon the idea of a classical epistemically complete reality in favour of conceptual design (Floridi, 2019).

The development of computational thinking (Grover & Pea, 2013; Aho, 2012) has also been increasingly addressed in studies tracing its relationship to AI and machine learning (García et al., 2019; Tedre, 2022). It should be emphasised that we differentiate between programming, which increasingly in its primary forms can be done by AI systems (McNutt et al., 2023; Becker et al., 2023), but the goal is to develop a particular way of thinking that is associated with creativity (Israel-Fishelson & Hershkovitz, 2022).

We see the temptation to reduce AI education to partially isolated courses as fundamental (DeNero & Klein, 2010; McGovern et al., 2011; Hu et al., 2023). Indeed, education in this area requires an integrative approach to lead to a closer relationship between AI and creativity. It is the specific applications (Eriksson et al., 2020; Mazzone & Elgammal, 2019; Miller, 2019) that lead to arguably the most exciting results, both directly in the domain being practised and in education (Ali et al., 2019; Zhai et al., 2021).

6. Conclusion

This is not the case. However unambiguous the media image of the phenomenon we have analysed might be. On the one hand, there is a large number of studies that address and reflect on the topic in some way; on the other hand, it can be said that - within all the studies analysed - there is more of a focus on the particulars than a systematic vision of the whole that works with a more demanding systematic theoretical approach. The remarks that can be found in the studies of Treve (2021) that there is and will be a transformation of educational reality that we do not yet see or understand, or Davis (2020), who asks what will change and seeks general reflections on humanity and its uniqueness, are so far the fundamental underpinnings of the whole discussion.

Our aim at the beginning of the study was to analyse the sub-themes that could be used as a basis for constructing a course focusing on the development of AI literacy about creativity. However, it turned out that not only was it impossible to respond adequately academically to such an assignment, but we needed a broader theoretical definition of the whole issue.

The relationship between the philosophy of education (Noddings, 2018) and the philosophy of information, as considered by Floridi (2019; 2014), needs to be considered, seeking a broader theoretical anchoring of the whole issue. Studies show that the need for more critical reflection on the phenomenon of creativity about technology is one of the significant barriers to further research. The studies understand creativity exclusively (at least in our selection) as an individual phenomenon, as an activity of an individual primarily detached from society. Even perhaps the most far-reaching study in this area, Tang et al. (2022), envisages a strongly individualised conception of creativity. Similarly, the vague definition of AI is not only a technical or conceptual problem but primarily a philosophical-pedagogical and didactic one; if we are not clear enough about what AI is and how we want to reflect it, then we cannot expect to implement it in school subjects in a genuinely challenging way (Palouš, 2008), to change the way we think and solve problems (Riekki & Mammela, 2021).

Nevertheless, we believe that our study has provided some essential novelty points for further research and theoretical reflection on the whole phenomenon, which can be seen as necessary conditions for the development of the relationship between creativity and artificial intelligence in the context of education:

- AI literacy is a prerequisite for developing creativity. It is not possible to pit technology and creativity against each other. One is impossible without the other.
- Creativity presupposes the presence of abstract synthesising system models and the ability to think deeply and understand the world. This aspect should be emphasised as much as possible in education in place of factual or procedural knowledge and skills.
- Creativity about AI enables new problems and challenges students perceive as necessary and future-oriented.
- It is advisable to think about the development of computational thinking in school, not just algorithmisation and programming. Emphasis should be placed on general mental models and ways of solving problems.
- The topic of AI, if it is to be related to creativity, cannot be taught as an isolated stand-alone subject but must be integrated into various subjects in the curriculum.

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Cybersecurity awareness among university students

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Abstract: *Due to the widespread integration of ICT in education, both the participants in the teaching-learning process and the educational institutions themselves have become increasingly susceptible to cyber threats. It is imperative to implement adequate protective measures for several compelling reasons. Information security awareness plays a pivotal role in the overall defense strategy. For this research paper, I evaluated the level of security awareness among a particular group of students. The results are consistent with the international research results. Among the findings, the two most problematic areas are password management and not performing sensitive activities other than our computer.*

Keywords: *information security; cybersecurity awareness; e-learning security; online threats*

1. Introduction

Cybersecurity awareness is briefly defined as "*the degree of users' understanding about the importance of information security, and their responsibilities to exercise sufficient levels of information control to protect the organization's data and networks*." (Shaw et al., 2009)

Rahim, Hamid, Kiah, Shamshirband, and Furnell concluded that cybersecurity awareness plays two significant roles: (i) alerting individuals using the internet about cybersecurity concerns and potential threats (ii) improving their comprehension of cyber threats, encouraging them to adopt security measures when using the internet wholeheartedly. (Rahim et al., 2015) The U.S. National Institute of Standards and Technology (NIST) distinguishes between awareness, training, and education. In their definition, learning is a continuum that starts with awareness, builds to training, and evolves into education. (Wilson et al., 2003) According to NIST Special Publication 800-16, awareness is defined as: "*Awareness is not training. The purpose of awareness presentations is simply to focus attention on security. Awareness presentations are intended to allow individuals to recognize IT security concerns and respond accordingly.*" (Wilson et al., 1998) For a successful increase of Awareness, Siponen highlights the importance of identifying, quantifying, and understanding the background for "human errors." In his concept, two categories relating to the problems of awareness are framework and content. The framework is more of an engineering discipline and a matter of explicit knowledge, while the content is a more informal interdisciplinary field of non-engineering.

Furthermore, the goal of increased awareness is to minimize the "user-related" faults and maximize the efficiency of security techniques from the user's perspective. (Siponen, 2000) Other studies assessed the users' consciousness based on a simple model that classifies the groups of users according to their skills and awareness: naive, typical, and conscious. Then, probabilities are assigned to each class, describing the likelihood of committing dangerous reactions in case of a cyber-attack. An interesting finding is that even with minor skill differences, making the users more conscious of their reactions can significantly enhance cybersecurity at a particular organization. (Hadarics et al., 2018; Bognár et al., 2018; Nagy et al., 2020)

The following outline will guide the remainder of the paper. In this paragraph, we will delve into the term cybersecurity awareness. Paragraph II will examine pertinent international studies regarding students' cybersecurity awareness. Paragraph III will focus on the cybersecurity awareness research conducted at the University of Dunaújváros, including its findings. The conclusions on the results will be presented in paragraph IV and some final thoughts in paragraph V.

2. International studies on university students' cybersecurity awareness

Al-Janabi and Al-Shourbaji conducted a 26-question survey in Middle Eastern higher education institutions in 2014. The research aimed to measure the level of information security awareness among teachers, university students, and employees (n=760)—questions covered areas such as email security, phishing, internet security, anti-virus programs, and data backups. The results showed that the participants need more knowledge in the daily practical application of information security principles. For example, the target groups must be aware of information security incidents and their consequences. (Al-Janabi, & Al-Shourbaji, 2016)

Moallem conducted a 10-question survey of students at two California state universities in 2017 and the first quarter of 2018 using the Qualtrics application (n=247). The goal was to assess the online security awareness of students studying in Silicon Valley, a highly technocratic environment. The results showed that although students know that Internet use can be traced and that their data is unsafe even on university systems, few use two-factor authentication or complex account passwords. Another finding was that educational institutions need to be more actively involved in raising students' awareness of, for example, how to protect themselves from a potential cyber-attack. (Moallem, 2019)

Senthilkumar and Easwaramoorthy investigated the cyber security awareness of university students in Tamil Nadu in 5 different cities in India – Chennai, Salem, Coimbatore, Vellore, Madurai (n=380). The goal was to measure students' security preparedness in 4 areas: virus attack, phishing, password strength, and abuse on the social network. The results showed that the student's exposure to the sources of danger appearing through social networks is the greatest. However, there is also a substantial deviation in the level of awareness related to passwords, so the authors point out that although the general information security awareness level is adequate, the mentioned areas need improvement. (Senthilkumar & Easwaramoorthy, 2017)

Mai and Tick's research compared the information security awareness, knowledge, and behaviour of university students in Hungary and Vietnam (n=313). The analysis was conducted using a questionnaire data collection method based on the answers of 313 university students in the two countries. The results showed that, regardless of the country, most students need more material knowledge about information security, and the practices used are also inadequate; for example, they ignore the security settings when using a smartphone. Based on the discussed research results, the authors emphasize the importance of formal security awareness education, which can directly support students in proper defense. (Mai & Tick, 2021)

Gabra et al. conducted a quantitative survey to identify students' awareness and enthusiasm to learn cybersecurity in Nigerian Universities (n=367). The results showed that university students need to gain basic cybersecurity knowledge. Among the questions is that of password management result analysis, which shows 204 said No, 139 said yes, and 22 said maybe to using hard-to-guess passwords. Regarding the question on opening an email sent from an unfamiliar person, the result shows that 219 said yes out of 367, 110 said no, and 36 said maybe. This result indicates that most students need to learn about phishing attacks. (Gabra et al., 2020)

In conclusion, these studies underscore the global significance of enhancing cybersecurity awareness within educational institutions. Addressing these issues is crucial to prepare students, teachers, and employees better to navigate the digital landscape securely and protect sensitive information in an increasingly interconnected world.

3. Cybersecurity awareness research at the University of Dunaújváros

3.1. Background

Studies consistently show that students from diverse backgrounds who use the internet and computers often have limited awareness of cybersecurity risks. Moreover, there is no standard way to evaluate the viewpoints and preferences of online users on cybersecurity measures. To address this gap, Erol et al. developed a comprehensive scale to assess internet users' attitudes and behaviours related to cybersecurity. The validity of this scale was examined through factor analysis, resulting in the emergence of the "Personal Cyber Security Provision Scale." This scale comprises five distinct factors and demonstrates strong compatibility and reliability, making it a valuable tool for assessing users' perceptions and practices in cybersecurity. (Erol et al., 2015)

3.2. Methodology

The Personal Cyber Security Provision Scale (PCSPS) questionnaire consists of 25 questions grouped by the following categories: Protecting privacy (10 questions); Avoiding the untrusted (4 questions); Precaution (5 questions); Protection of payment information (2 questions); Leaving no trace (4 questions). All questions are straight, except the group protecting privacy, which are reversed. The answer options are 1 to 5 on a Likert scale in the following order: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always. The questionnaire consists of 5 additional questions on top of the PCSPS originals. Three are related to gender, age, and the field of studies; the last two are related to general safety in cyberspace. For data collection, Google Forms was utilized, while analysis was done using IBM SPSS Statistics v25.

3.3. Participants and sampling

The target population consisted of undergraduate students at the University of Dunaújváros. Due to the study's exploratory nature, convenience sampling was used to recruit students from the entire university, irrespective of their course. Participants recruited were pursuing a university degree in seven fields of study to increase the variability of the sample: IT, and Engineering. A total of 15 students participated in this research, 12 male and 3 female. From the study field perspective, 13 respondents came from the technical area and 2 from the informatics area.

3.4. Results

The questions about data protection were reversed, leading to reversed results. The median score was 4 on the 5-point Likert scale (Table 1, Diagram 1); most affirmative answers were given to the statement "I share my personal information on the internet, when necessary" and the combined password-related statements of "I set easy to remember passwords," and "I make sure all my internet passwords are the same." Respondents often use easy-to-remember passwords to access multiple services, which puts them at risk for simultaneous attacks if any one account is compromised.

The median score was 4 on the 5-point Likert scale regarding avoiding the untrusted. (Table 1, Diagram 1) However, the "I do not accept friend requests from strangers on social media" statement received the least positive responses. We must be cautious when accepting social media requests from unknown individuals, as it can lead to spam, scams, and cyberbullying.

The precaution area scored 3.8 out of 5 on the Likert scale. (Table 1, Diagram 1) The statement that received the least number of affirmative responses was "I change web browser security settings". It is important to note that unknown or uncontrolled browser settings can lead to various risks, such as malicious extensions, online activity tracking, and automatic data storage of cookies and other personal information.

The lowest median score of 2.5 on a 5-point Likert scale is linked to payment information protection. (Table 1, Figure 1) The respondents revealed that they conduct their banking and online shopping from sources other than their computers. This practice increases the risk of data compromise due to unknown security settings, unauthorized or malicious software, viruses, or other hidden harms associated with that specific computer.

The score for leaving no trace is the second lowest, at 3.5 out of 5. (Table 1, Figure 1) According to a survey, people were least likely to agree with the statement, "I change my passwords regularly while using the internet." This presents a potential risk as if the computer is lost or stolen, and the old passwords could still be revealed, which puts the user's accounts at risk. Additionally, unchanged passwords could make it challenging to discover if the account has been compromised.

Table 1. Descriptive statistics of the cybersecurity awareness research at University of Dunaújváros.

	Protecting privacy INV	Avoiding the untrusted	Precaution	Protection of payment information	Leaving no trace
N	15	15	15	15	15
Mean	3,9067	3,6	3,6933	2,6333	3,55
Std. Deviation	0,53648	1,18322	0,5175	1,27429	0,59911
Median	4	4	3,8	2,5	3,5
Minimum	2,7	1	2,6	1	2,25
Maximum	4,8	5	4,2	5	4,5

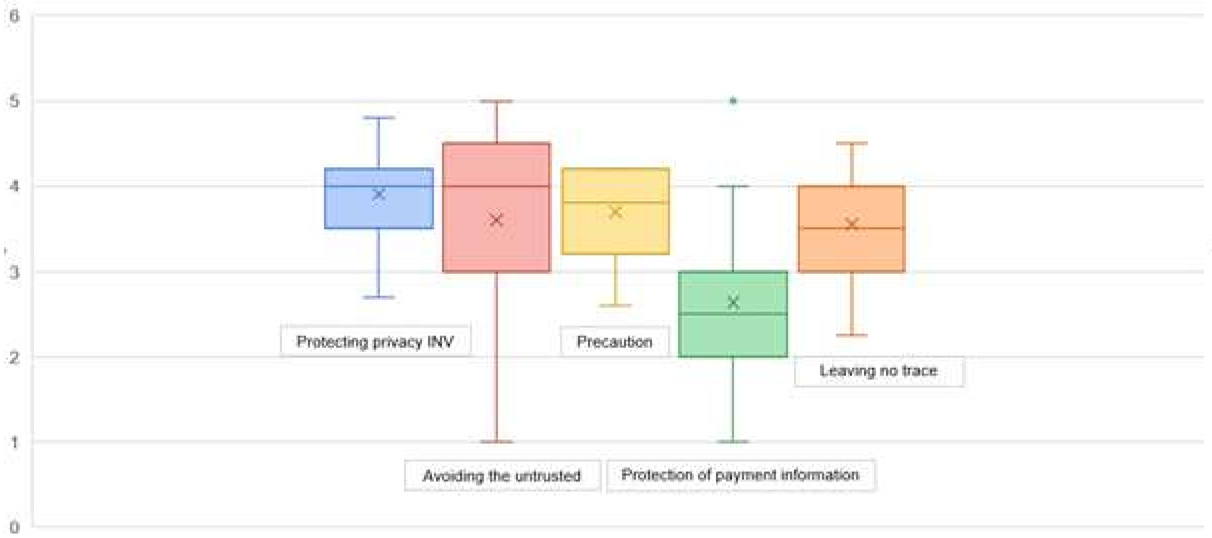

Figure 1. Box plot of the cybersecurity awareness research at University of Dunaújváros.

In response to the statement, "I feel generally safe in cyberspace," 73.3% of respondents answered yes or mostly yes. However, this also means that over a quarter of respondents do not or mostly do not feel safe in cyberspace. (Table 2, Figure 2)

Table 2. I feel that I am generally safe in the cyberspace.

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
No, not at all	1	6.7	6.7	6.7
Mostly no	3	20	20	26.7
Mostly yes	8	53.3	53.3	80
Yes, fully	3	20	20	100
Total	15	100	100	

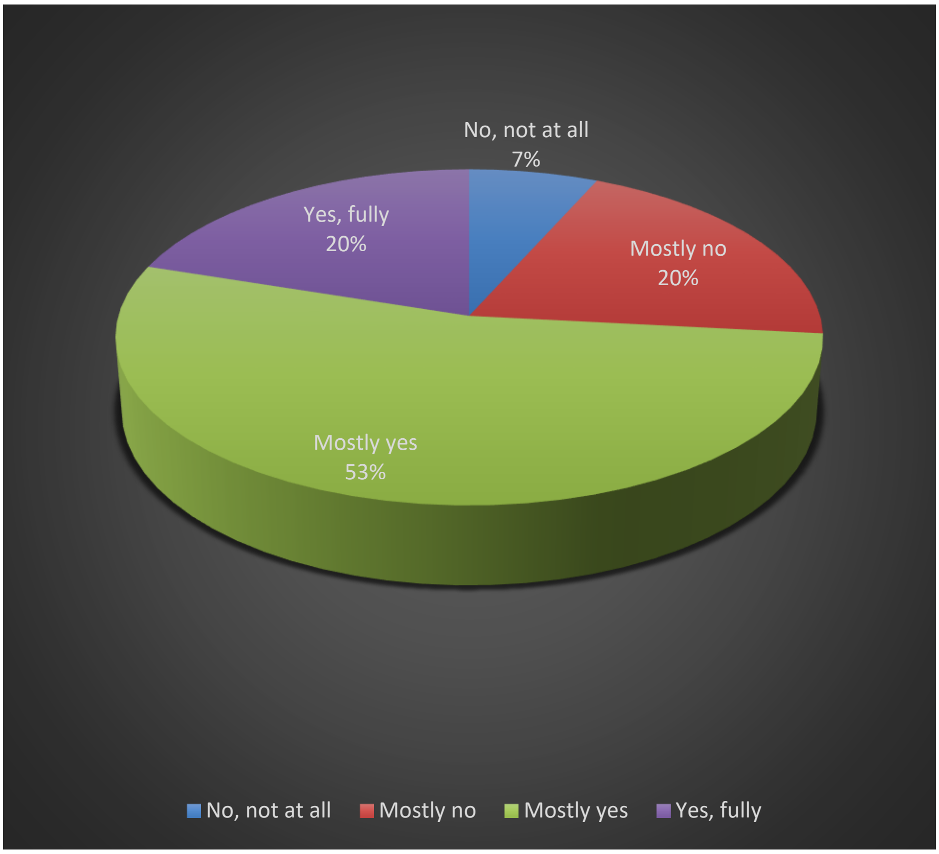

Figure 2. I feel that I am generally safe in the cyberspace.

According to the survey, 53.3% of individuals claimed to have never experienced any information security incident, such as hacking, fraud, online abuse, harassment, or virus/ransomware attack. However, the remaining 46.7% of respondents stated that they have been a victim of such an attack at least once. (Table 3, Diagram 3)

Table 3. I have been the victim of an information security incident (fraud, hacking, harassment, online abuse, virus / ransomware attack, etc.)

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
Never	8	53,3	53,3	53,3
1 or 2 times in my life	6	40	40	93,3
It has happened 3 or more times	1	6,7	6,7	100
Total	15	100	100	

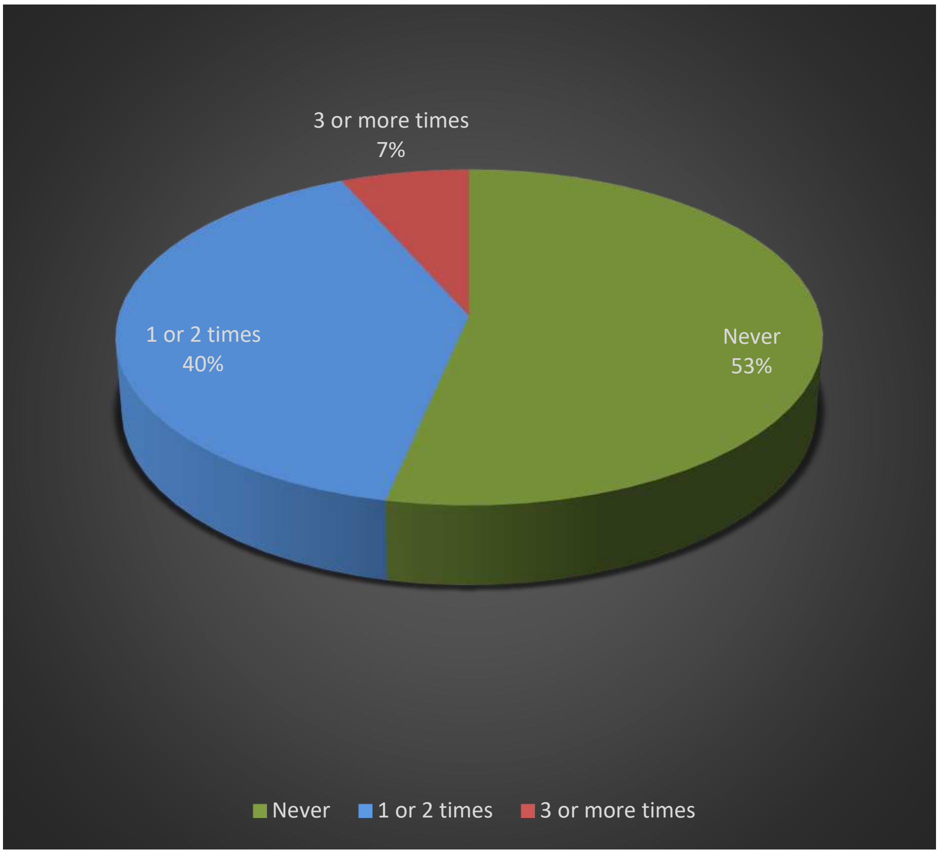

Figure 3. I have been the victim of an information security incident in my life.

4. Discussion

Teachers, students, and schools are more vulnerable to cyberattacks due to the increased reliance on digital tools and platforms for teaching and learning. The teaching-learning process participants must be adequately trained because a lack of awareness can result in risky online behaviors that make them more susceptible to cyber threats. It should also be considered that inappropriate safety-conscious behaviour can affect individuals and an entire educational institution.

This research was prepared only for a small group of students from a single institution. However, it fits in with the results of international research from the point of view of the need to increase general security awareness (Al-Janabi & Al-Shourbaji, 2016; Moallem, 2019; Mai & Tick, 2021). Among the findings, the two most problematic areas are password management and not performing sensitive activities other than our computer.

A further research opportunity is to compare the obtained results with data collected in a broader sample. On the other hand, the security awareness of instructors and the information security organization of educational institutions.

5. Conclusion

This sample shows that a limited group of students at the University of Dunaújváros can be considered more aware of information security in the light of the examined areas, but there are exceptions to the trend. The average age of the respondents was 20.73. One problematic area is that the responding students typically bank or shop online from other computers that are not their own. Although it cannot be clearly stated that this carries a high risk in every single case, it is still possible that the workstation in question has lower security settings or, for example, is already infected or activities can be tracked on it, and is, therefore, more likely to be considered dangerous. The development of competences and a better knowledge of technological solutions can help identify threats more effectively (Demeter & Kővári, 2020).

Another group of potential risks tends towards passwords. Respondents often use the same password for multiple services, use easy-to-remember passwords, and change their Internet passwords less frequently. These results are consistent with the international research results mentioned at the beginning of this study i) Moallem's findings that despite students knowing the Internet's risks, they still use low security measures, e.g., complex passwords even on public university systems (Moallem, 2019) ii) Senthilkumar and Easwaramoorthy found that there is a variance in awareness levels related to passwords (Senthilkumar & Easwaramoorthy, 2017) iii) Gabra et al. found that only a minority of respondents use hard-to-guess passwords. (Gabra et al., 2020). Farkas et al. (2014) are concerned with the secure and efficient transmission of data in sensor networks, the educational research emphasizes the need for secure digital platforms for teaching and learning. Both could benefit from the integration of secure protocols and systems.

Finally, an attention-grabbing result is that half of the respondents have already been victims of an information security incident, and a quarter do not feel safe on the internet. This is a growing concern as instances of online harassment are on the rise. According to a study by Lindsay and Krysik, the rate of online harassment has more than doubled since Finn's study in 2004. The Annenburg Public Policy Center also found that 43.3 percent of individuals have experienced online harassment, compared to 16.2 percent and 15.8 percent in previous studies. (Lindsay & Krysik, 2012).

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Supervision and Optimization the Application of Manufacturing Resources with the Support of IoT Devices and Technologies

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Abstract: *This study was conducted at a multinational furniture company, aligned with Industry 4.0 standards, where a cyber-physical system (CPS) was already implemented with its respective hardware and software components. The primary purpose of the CPS is to gather data on the consumption of production resources such as energy, water, and compressed air, and to oversee the operational processes within the company. Initially, data collection was solely focused on the energy utilization of the production machinery and the produced workpieces. However, over time, we have evolved the cyber-physical system to broaden the data collection spectrum. This expansion was imperative to encompass the energy and other related parameters of the production support equipment, alongside the water consumption metrics. The subsequent phase of the research delved into exploring avenues to foster energy-conscious work practices. With the activation of the analytical application, the financial ramifications of superfluous energy consumption could be ascertained, and the proficient functioning of the production machinery could be real-time monitored via computers stationed within the facilities. Consequently, this setup serves to motivate employees towards adopting more energy-efficient work habits.*

Keywords: *Industry 4.0; data analysis; energy management; production optimization.*

1. Introduction

Industrial revolutions have been taking place around the world for nearly 240 years. The first industrial revolution dates to the 1780s, when the first mechanised looms were established and the first factories with steam engines were opened. The second industrial revolution took place at the end of the 19th century, when electricity was used to power the machinery in the factory. A highlight from the second industrial revolution was the introduction of the conveyor belt in a slaughterhouse in Cincinnati (USA), which allowed the distribution of labour there. If we compare the technological features of the first and second industrial revolutions, we can see how much progress has been made in industrial companies over the last 100 years. The outbreak of the third industrial revolution also had to wait about 100 years. It is estimated to have started in 1969, when the first programmable logic controller was created, enabling automation in factories [1]. In addition, there was rapid development in IT and electronics in almost all manufacturing sectors. This rapid progress brought us to the threshold of a next industrial revolution in the 2000s [2]. The start of the fourth industrial revolution is still debated, but the term was first used in 2011 at the Hannover Expo. If we look at all four industrial revolutions together, we can see how much technological progress has been made in a short period of time in the industrial sector almost all over the world [3]. We have moved from steam-driven machines to computer or artificial intelligence-driven machines, from manually recorded production and other data to digitised data and data stored in the cloud. As for technological progress, it is important to note that over the years, human work has been replaced by robots in many areas. This is often seen as a negative factor, because it has led to the loss of many jobs, but in fact it is a huge help in production and speeds up production processes [4]. For example, if we look at the automotive industry, one or more robots can move heavy car parts from point A to point B, assemble them, and perform other tasks in much less time than humans. Of course, there are other advantages to the presence of robots in the fourth industrial revolution, as it is still happening in time. This includes, for example, the use of cloud services, advances in IT and network security, continuous data measurement, whether it is about any environmental factor such as temperature, humidity, or even industry-related processes such as production piece count, power consumption, condition monitoring [5]. Nowadays, we can really measure everything in the production of a product and back it up with numbers. So, if we look at the example of a piece of furniture, we can say how much electricity and other resources (water, compressed air, heat) were used in the production of a perfectly normal wooden dining chair. From these numbers, it is also possible to determine the exact cost of raw materials and resources directly and indirectly included in the value of a product. Previously, indirect costs could only be determined according to some dividing method or by estimation based on experience, but now we are able to calculate the amount of increasingly accurate indirect costs with calculations based on data [6].

During our research and work, we used the opportunities provided by the fourth industrial revolution, or more popularly known as "Industry 4.0", to apply new methods at a furniture industry company that is already moving in the direction of this kind of development [7].

Our main goal is to measure consumptions of the furniture manufacturing company’s resources and detect operations and devices which are working wasteful. A cyber-physical system has been built for reaching that aim. In the beginning (2016/17), we collected data about the electricity consumptions (useful and useless). Later, the system and its database have been extended to measure and collect data about other resources' consumption (water, indirect electricity use etc.). These parts of the system are introduced in this section besides the technical references and scientific citations.

In the second section, we demonstrate our data collecting, analysing, and reporting techniques related to the manufacturing and its supporting processes. Dashboards, indicators, and methods are defined to monitor and control the consumptions of resources.

In the third section, we demonstrate our results. By the company's water consumption, we have identified a part (fire service practice), where a problem has raised that we solved with the help of cyber-physical system. After that, a useless compressor was identified by our data collecting and representing system. Furthermore, by the efficiency of compressors, we define a key performance indicator that should be taken above a limit. The extractor and its exhaust fans support the machines, so they connect to the manufacturing in an indirect way. Their indirect consumptions (and working costs) are directly connected to machines by our calculation method. The next phase of the research was the examination of the use of cloud services in an industrial environment and the possibilities of encouraging energy conscious work. We found a solution to move parts of the cyber-physical system to the cloud. With the analytical application operating in the cloud, the costs of useless energy consumption can be calculated, and the efficient operation of the production machines can be monitored in real time on the computers in the plants. This way, the employees are encouraged to work more energy consciously.

Finally, we summarise our work, results, and paper.

1.1. The initial steps of the research and the configuration of the cyber-physical system

In the 2016/17 financial year (from September to August), there was an opportunity to collaborate with a multinational furniture industry company, where the main goal was to modernize the company's IT system, including the hardware and software environment, according to the current industrial innovation trends. For this purpose, a cyber-physical model system was built, which is the basis for the company to operate according to the criteria of Industry 4.0 [8]. For this reason, a framework for monitoring and managing energy consumption was developed, which allows the comparison of energy consumption data with actual production data. This enables operational decision-makers to monitor and manage the performance of production machines and their associated systems, and thus make more effective strategic decisions. The physical aspects of the initial cyber-physical system include electricity metering sensors, network cables and switches, server hardware. In terms of the software part of the system, it includes: a Supervisory Building Control and Data Acquisition system (SCADA), an enterprise management system, a database management system, a business intelligence system [9][10].

This is where the cyber-physical system was designed and built. The concepts, architecture, and data flow directions of the system can be seen in Figure 1.

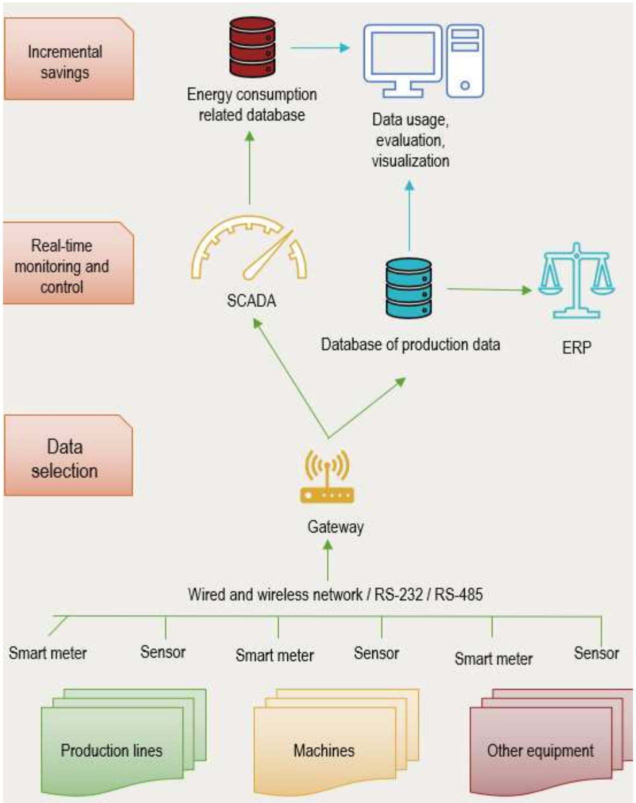

Figure 1. Structure of the cyber-physical system in 2017

It can be seen in the previous figure that sensors have been installed for production machines and other production support devices, which are equipped with MODBUS TCP/IP or Remote Terminal Unit (RTU) interfaces, particularly suitable for central data acquisition in industrial systems. Sensors record key electrical parameters such as currents, voltages, power factors, parameters describing power and energy values and more. The sensors transmit data to the SCADA system and the Enterprise Resource Planning (ERP) system via the company's internal network. We then connect the production and energy consumption data using business intelligence software, which also generates various reports and statements. These illustrate trends and the close correlations between data sets.

In the 2017/18 financial year, the system was physically expanded in addition to increasing availability and reliability. In the previous sample system, about 10 machines and equipment were installed and measured, but this year the number of measured and tested equipment rose to over 100. For this, not only the sensors were needed, but also the networks at the company had to be expanded. From a software point of view, new reports were generated to track both useful (produced) and useless (operated but not produced) energy consumption of the machines in 10-minute intervals (Figure 2) [11].

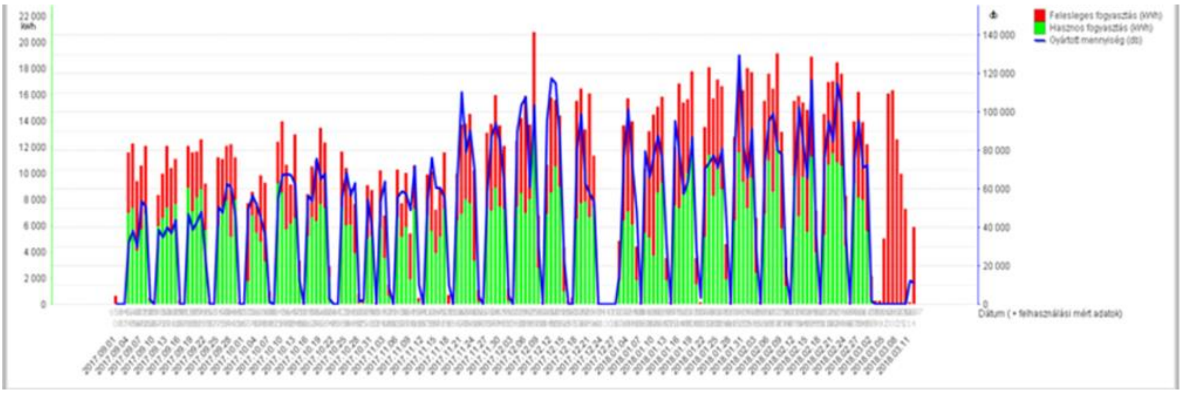

Figure 2. Measured consumption and production data for the 2017-2018 financial year (September 2017 to March 2018) in the framework (blue line: number of pieces produced, green part of column: useful electricity consumption, red part of column: useless electricity consumption; useful: production occurred, useless: no production occurred)

By monitoring the electricity consumption, the increasingly wasteful operation of a piece of equipment was revealed (Figure 3), so that preventive maintenance (or replacement) could be carried out as an operational measure.

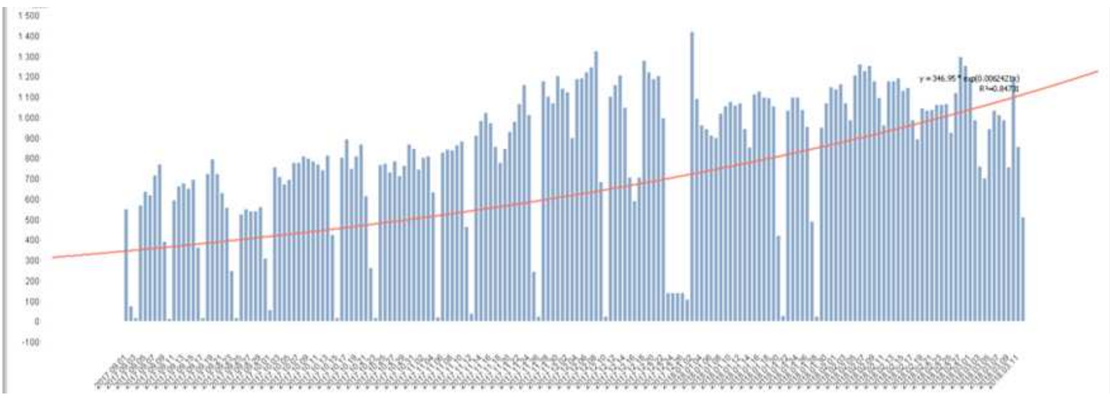

Figure 3. Daily energy consumption and trend line for a given equipment from September 2017 to March 2018

At the end of this phase (2018), the efficiency values of a production machine were compared, in other words, how many pieces of product it could produce from one kWh of energy consumption (Figure 4).

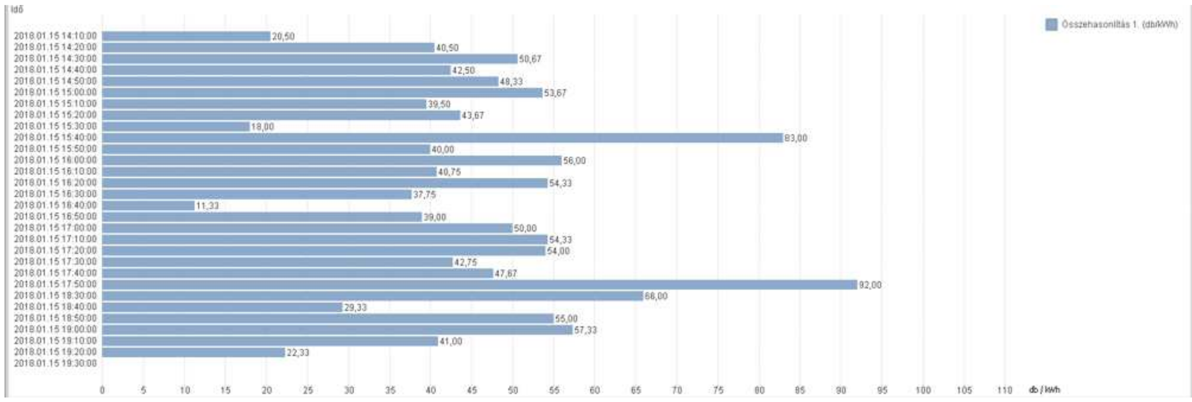

Figure 4. Production efficiency for a given product and machine: how many workpieces were produced using 1 kWh of electricity

Background to the research: a cyber-physical system was developed to collect and analyse electricity consumption data throughout the factory. In addition, it was possible to compare the energy consumption data with the production data, so that trends showing the comparison between production and electricity consumption (pcs/kWh, kWh/pcs, m^2/kWh) can be viewed for a given period or filtered for a given production machine. In the beginning, only number of pieces was recorded, but now the system has been refined to the extent that the number of pieces is not sufficient or does not always tell us much, because it does not matter whether the machine is working on a small board or a few square metres of work. It is easy to see that this does not mean the same amount of work, so a refinement was necessary [11].

1.2. Development of the cyber-physical system and transformation of the database

After defining the future goals of my research, the first task was to design and implement, step by step, the hardware and software improvements to the existing cyber-physical system. The development of the cyber-physical system was necessary because we no longer wanted to measure only the electricity consumption of the production machines, but also to connect all other production support equipment (exhaust fans and compressors) to the network and measure their energy consumption and other data. To do this, we also needed to install sensors to measure consumption and/or production parameters [12]. The company's specialists willingly assisted in the acquisition and installation of the sensors, so this phase was completed relatively quickly. After the necessary configurations, it was already possible to measure the electricity consumption data of the exhaust fans and compressors. For these machines, it was important to measure several parameters, so we also started to measure the air cubic metre extraction and emission volumes, also using sensors. Our main goal was to use the data input, just as we did for the production machines, to make different analyses and, together with the company management, we wanted to know more about the resource use of the factory's operations.

The question may arise why we started looking at the performance of compressors and exhaust fans, when the main role in production is played by production and working machines and products. The reason is simple: all the other equipment alongside the production machines proved to be quite large consumers of electricity, but the company could only have guessed this, there was no proof. When we had been collecting data for these machines for a year or two, we managed to produce an annual analysis which shows very clearly that exhaust fans are indeed the biggest energy consumers, but that the consumption of compressors is also significant. Figure 5 shows the company's total electricity consumption in 2020, which totalled more than 12 million kWh. The figure also shows that of these 12 million kWh, 3.8 million kWh were consumed by exhaust fans and more than 4 million by production machines. Compressors accounted for 1.3 million kWh, which is outstanding on an annual basis compared to other consumers. When we saw that exhaust fans were consuming so much, we had new goals for the research. Initially, it was not possible to relate the electricity consumption data of exhaust fans to their production performance. For this reason, the main purpose was also to study the useful and useless energy consumption of extraction fans. In the case of exhaust fans, useful electricity consumption means that the exhaust fan was running while the machines were producing products; useless electricity consumption means that the machines were not producing any products while the exhaust fan was running. To convert indirect costs into direct costs, a few modifications and extensions to the cyber-physical system were necessary [13].

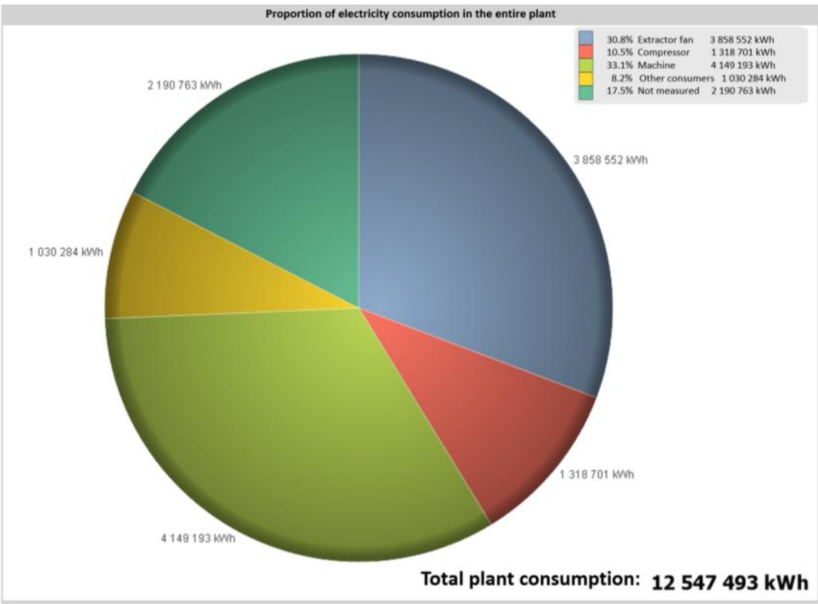

Figure 5. Electricity consumption in 2020

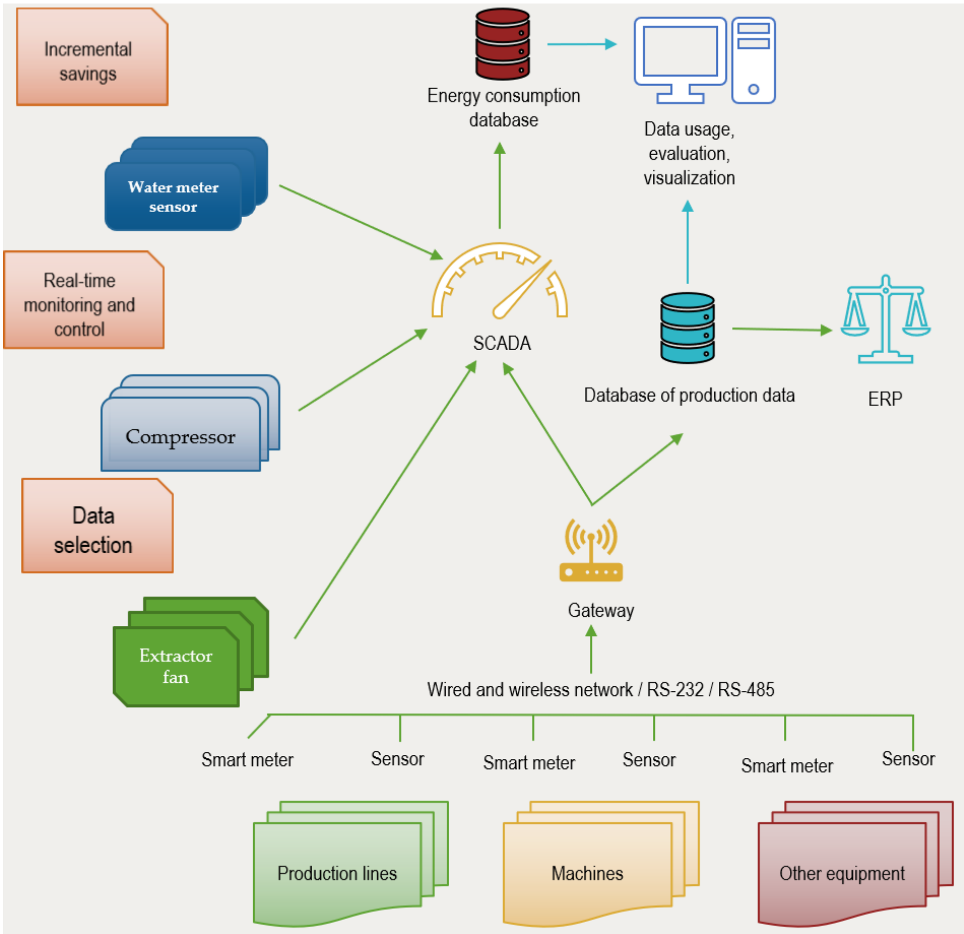

Figure 6. Construction of the extended cyber-physical system

Figure 6 illustrates the architecture of the extended cyber-physical system and the direction of data flow. Here it can be seen that new equipment has been added (compressors and extractors) and water consumption is also included as a measurement parameter, which can be monitored in the SCADA system [14]. Thus, the measured data of the consumption of additional resources (besides electricity) used in the production can be stored and monitored in the database of the SCADA system.

At the beginning of the research, a separate database had to be created at the company to store historical data (Figure 7), as the data structures in the internal database of the SCADA software were not suitable for efficient and fast work. In addition, the conversion was also intended to allow the energy consumption data to be linked to other systems (e.g., ERP) and to allow the storage of data on extractor fans, compressors, and water consumption in the database.

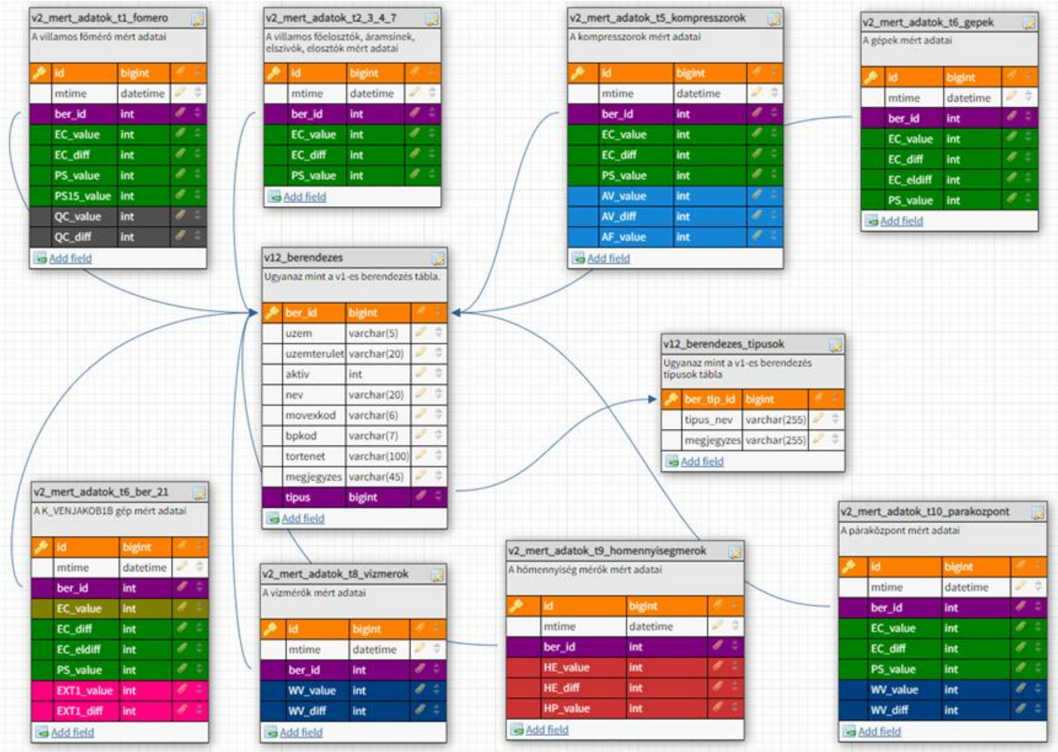

Figure 7. Database structure from 2021

2. Methods

In this section, the data collecting and analysing methods will be introduced to get scientific results.

2.1. *Monitoring the company's water consumption*

Water entering the company's territory supplies two plants and the office buildings. We classified the incoming water into three main groups, the first is the so-called social water, within which we distinguished between wastewater and so-called domestic water consumption

[15]. The other large group is the water used during production, which appears in the form of water vapor, which is also part of social water. The third group includes the fire service water usage, which in the best case only takes place when there are fire drills in the factory area.

The company uses almost the largest amount of water during production. Humidification during production is essential in furniture manufacturing, as the production of various furniture components requires a predetermined humidity and moisture content. The factory makes furniture elements from three types of wood: beech, birch, and oak. All three types of wood have the same required moisture level, so it is not necessary to change the amount or intensity of water vapour emission during the processing of each type of wood, but this can be done at a uniform rate and volume. On the other hand, it should be noted that different amounts of water vapor must be provided in different areas to achieve the minimum moisture content of the workpieces. For example, workpieces move relatively quickly in a production machine, while they are in the same place in the warehouse, thus, the humidification of the plant and storage areas must be ensured in a different way. For the data collection, it was not necessary to separate the amount of water vapour emissions in relation to the three tree species, but all emissions were collected and analysed together. The results related to water vapor emissions are presented in the following figures.

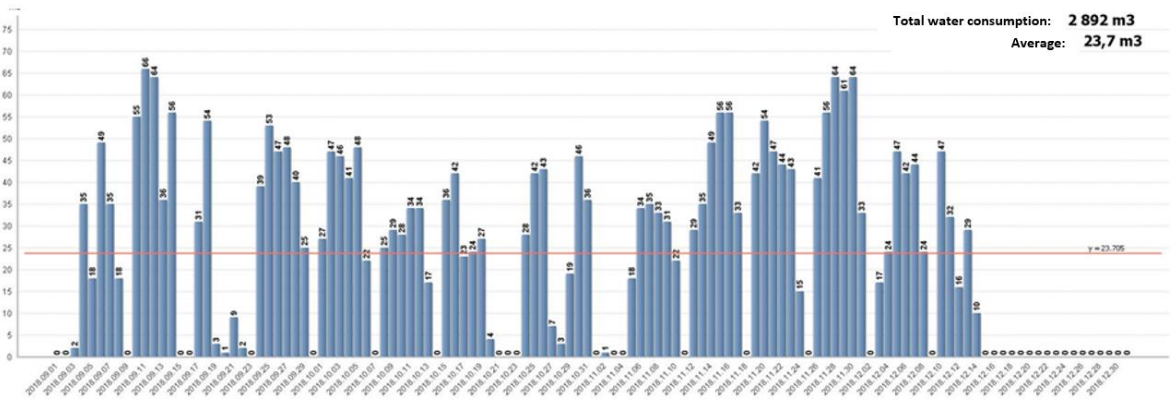

Figure 8. Water vapor emissions from September to December 2018

Figure 8 shows the amount of water vapor used in plants in a daily breakdown in the period from September 1 to December 31, 2018. It can be clearly seen from the columns of the diagram that the emission of water vapor occurs uniformly. Those with a value of zero are days that were weekends and holidays, so production was not running. This uniform use of water vapor can be observed until March 2020, when the shutdown caused by COVID-19 intervened. This period is shown in Figure 9.

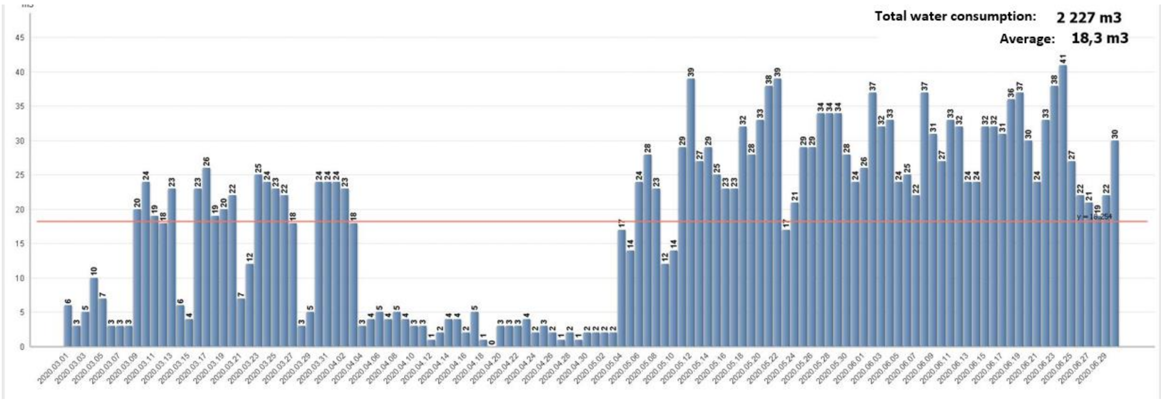

Figure 9. Water vapor emissions during the first COVID-19 period (March 1 to June 30, 2020)

In Hungary, online working was introduced from March 15, 2020. As the diagram shows, the actual COVID-19 shutdown at the company occurred in April, which lasted for a month in a very strict manner. After this period, production returned to normal, and even on weekends (Saturdays and Sundays), work was in full speed. It is also noticeable that water use on weekdays has increased compared to the months at the beginning of the year. From this, we conclude that the loss of work and production in April was continuously made up on weekends to be able to fulfil the orders.

2.2. Monitoring the energy consumption and other parameters of production support equipment

The next major topic of our research was the examination of the energy consumption and other parameters of the production support equipment, more precisely the compressors and exhaust fans operating in the plants. The use of compressors and extractors is essential because compressors provide the compressed air needed to operate some production machines. Exhaust fans are mainly responsible for keeping the environment of the machines clean and stable, because a large amount of dust and wood chips are generated during the processing of wooden furniture elements. This accumulated waste must be removed from the machining areas as efficiently as possible [16]. In the case of compressors, we also monitored the number of cubic meters of air produced and compared it with electricity consumption. In the case of exhaust fans, we managed to make major changes to the cyber-physical system. Thanks to our results, we are now able to monitor not only the electricity consumption and the area volume (m^2) of workpieces produced for a single production machine, but we can also partially charge the electricity consumption of the exhaust fans directly to the production machines. These measured parameters are presented in Figure 10.

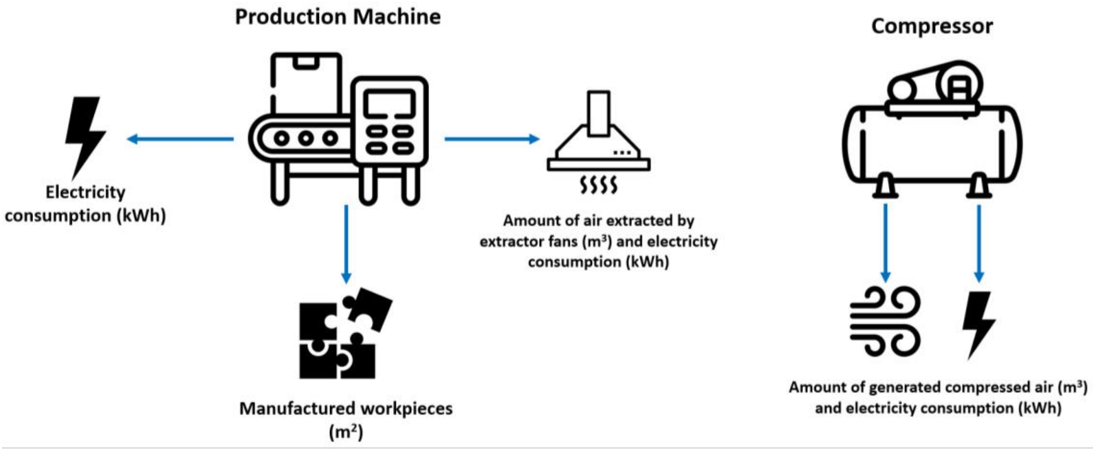

Figure 10. Measured parameters of a production machine and a compressor

2.2.1. The energy consumption and compressed air emissions of compressors

The compressor is the equipment responsible to produce compressed air. Compressed air is a secondary energy carrier, which is mainly used in industry for the mechanical operation of work machines, machine tools, and industrial robots [17]. The furniture company in our research also has several production machines that require compressed air to operate. At the beginning of the research, we had no information on the amount of compressed air emitted, and very limited information on the consumption of electricity, so together with the company's employees, we considered it important to examine the compressors operating in the plants.

In the company's plants, there are several compressors that are connected to one compressor housing (Figure 11). Before the start of our work, only the compressor housings were equipped with sensors, which measured the electricity consumption data of all compressors in aggregate. In order to ensure a successful and efficient outcome of the study, it was agreed that additional sensors should be installed at each compressor. The sensors installed on the compressors can measure how many cubic meters of compressed air they generate and how much electricity they consume, broken down into equipment.

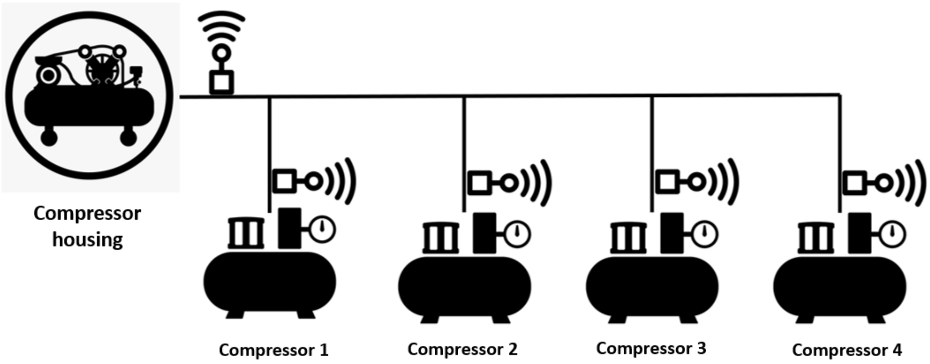

Figure 11. Construction of a compressor housing

Regarding the compressors in the plants, it is also important to know that each of the company's two plants has a large compressor house, to which a total of 8 compressors are connected, 5 in plant A and 3 in plant B. In the two plants, not all compressors are running at the same time, so for example only three of the eight compressors are running at any one time and two are in standby or off mode. This is a method of efficiency and energy management because there is a load balancing device that monitors the operation of the compressors to ensure that they are roughly balanced: that there is no possibility of a compressor being over- or under-utilised.

2.2.2. Exhaust fans energy consumption related calculation method

The other large group of equipment we examined, in addition to compressors, were the exhaust fans. Our main goal with the exhaust fans was to be able to charge their electricity consumption to the production machines they support. In order to achieve our goal, it was also necessary to install sensors in the beginning. New sensors were installed for the shutters, which measured the state of the shutters (open or closed). In addition to the condition monitoring sensors, consumption sensors were also installed to measure electricity consumption.

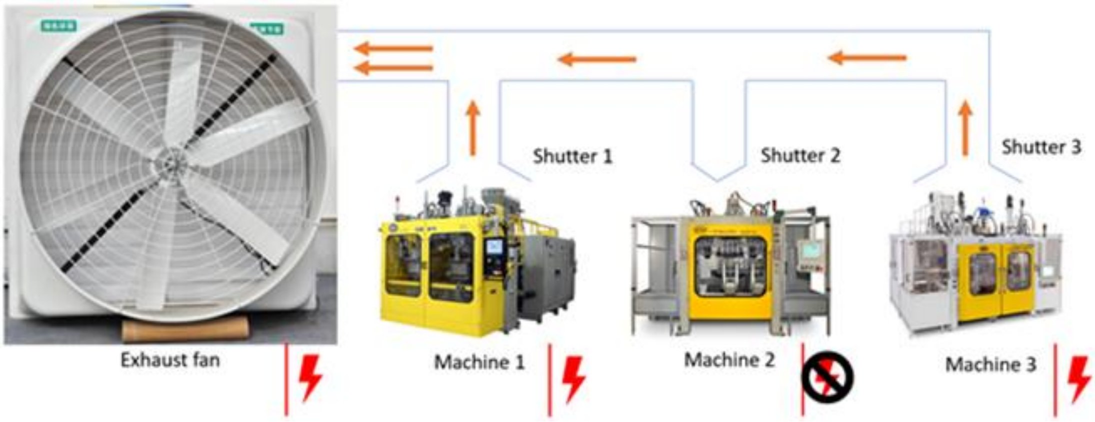

Figure 12. Main part of extended system

Figure 12 shows an exhaust fan device, which consumes electricity when it is working and exhausts air from three machines, when their shutters are open. In the example shown in Figure 5, the first and the third shutter are open, the second shutter is closed. If a shutter is open, then a partial electricity consumption of exhaust fan will be added to the related machine's electricity consumption data. If a shutter is not open, it means that the production machine is not in operation, so it does not need extraction and can be excluded from the calculation.

Improvements also had to be made in the cyberphysical system (its SCADA and database management system) to display our newly measured values. Then, in the SCADA system, we connected the extractors to the supported production machines, and this made it possible for the energy consumption of the extractors to be charged to the given production machines. With this, we can determine how efficient the operation of a particular extractor was during production [19][20].

In this section, the formula for the exhaust fans' partial electricity consumption will be defined. With our extended cyber physics system, we are now able to perform calculations in which we obtain energy consumption data that can be directly loaded onto the machines from the indirect energy consumption data of the exhaust fans. To achieve our goal, we need to know the partial electricity consumption of the extraction equipment for each shutter and production machine. We determined a formula that gives the partial electricity consumption to i^{th} shutter in each period (10-minute):

$$E_{S_i} = \begin{cases} \frac{E_{EX_j} * t_i * C_i}{\sum_{k=1}^{l} t_k * C_k} & \rightarrow if\ \exists k : t_k > 0 \\ 0 & \rightarrow otherwise \end{cases} \quad (1)$$

Equation (1) contains the following elements:

- E_{S_i}: The partial electricity consumption of the i shutter of j exhaust fan (kWh).
- j: Identification of the related exhaust fan.
- i: Identification of the related shutter.
- l: The number of shutters of j^{th} exhaust fan, and $1 \leq i \leq l$
- E_{EX_j}: The total electricity consumption of the j exhaust fan (kWh).
- t_i: The number of minutes (maximum 10), when the i shutter was open.
- C_i: The capacity of the i shutter (m^3/h).

After we get the indirect electricity consumption values (above), they are added to the related machines' electricity consumption values (below). Then we get the direct values, which contain the indirect (partial) consumption values:

$$E_i = E_{M_i} + E_{S_i} \quad (2)$$

Equation (2) contains the following elements:

- i: Machine (or shutter) identification (these are equivalent in this case).
- E_i: Direct electricity consumption (with indirect value) of i machine.
- E_{M_i}: Electricity consumption (without indirect value) of i machine.
- E_{S_i}: Indirect electricity consumption value of i machine.

The SCADA system was extended with equation (1) and (2), which was implemented in the form of programming. Thanks to our calculations, we obtained the direct energy consumption values.

The system will include large machine lines connected to an exhaust fan via not just one, but several (the maximum number will be 20 in 2022) shutters. In such cases, the indirect fractional consumption will first be summed and then the sum added to the direct consumption of the machine. In this case, equation (2) is modified as follows:

$$E_i = E_{M_i} + \sum_k E_{S_{j_k}} \quad (3)$$

Equation (3) compared to equation (2) j^{th} contains the partial consumption of all.

3. Results and discussions

After the introduction of data collecting and analysing methods, the related results will be discussed in this section.

3.1. Water consumption: examination of the amount of water used during fire service control

As we introduced the related method in the section 2.1, one problem of the data has been identified while monitoring the company's water consumption.

It is a national fire safety requirement and rule that all companies (not just industrial companies) should have the possibility to carry out fire safety inspections and fire drills. Consequently, the amount of water used for fire drills in the factory area is separate from the amount of water used for measurement. These exercises usually take place several times in the spring and summer months. During the research period, fire service water consumption was largely consistent, but there were occasional outliers. One of these events took place in May 2018, where we proposed an actual operative intervention with the help of our data collection. This period and event are illustrated in Figure 13.

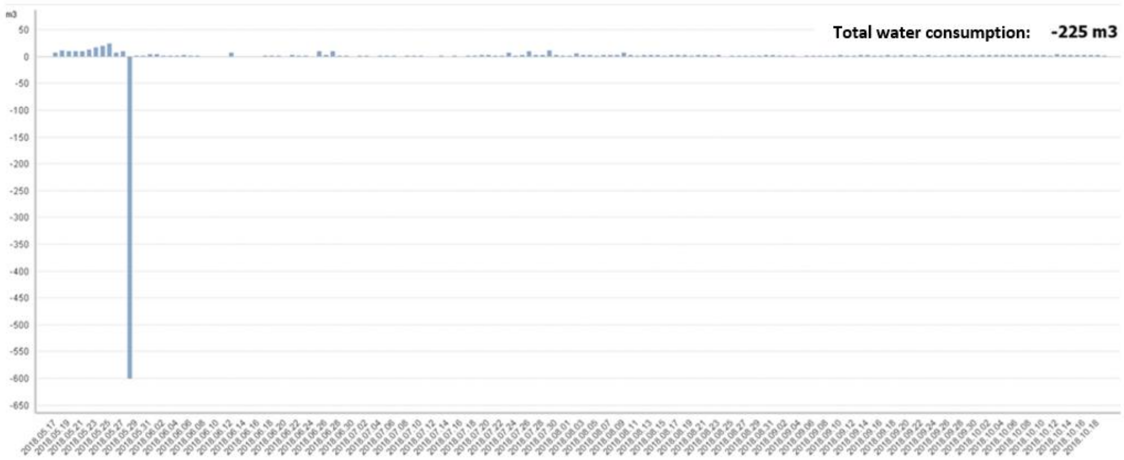

Figure 13. Fire service water consumption from May to October 2018

Figure 13 shows that at the beginning of the examined period, the amount of water consumption gradually increased, while there was no firefighting practice. Two possibilities have been identified as causes of the unjustified water use: one is the existence of a broken pipe and the other is a malfunctioning meter. The second solution was the correct one, the malfunctioning meter had sent false data to the system. The faulty meter was then replaced, and it was found that the new meter had a lower initial value than the old one, but this "error" could be corrected simply by overwriting the negative initial value in the database. After that, the data from the water use by fire service was consistent. The extension of our system also helped to solve the problems detected in water consumption, as we now knew and displayed not only one data per day, but 144 data per day.

In this way, the data problem related to the water consumption can be easily eliminated with the cyber-physical system.

3.2. Results related to energy consumption and compressed air emissions of compressors

In the section 2.2.1, the method of using compressors in the factory was introduced. In the following, we are focusing on the compressors useless and useful energy consumption in relation to their compressed air production.

We prepared several reports on the energy consumption of each compressor and the amount of compressed air generated. Such a report can be seen in Figure 14. In the figure, the horizontal axis is the date. The vertical axis on the left shows the energy consumption in kWh: these are the green and red bars. The green bars show the useful energy consumption, which for compressors means that they produced compressed air during the period. The red columns show the useless energy consumption when the compressors were running but not producing compressed air. The vertical axis on the right shows the amount of compressed air generated, which is illustrated by the blue dashed line on the graph. This value is given in Nm^3, which is the Normal Cubic Meter. Normal Cubic Meter means one cubic metre of Gas at reference conditions of 0°C and 1,01325 bar [18].

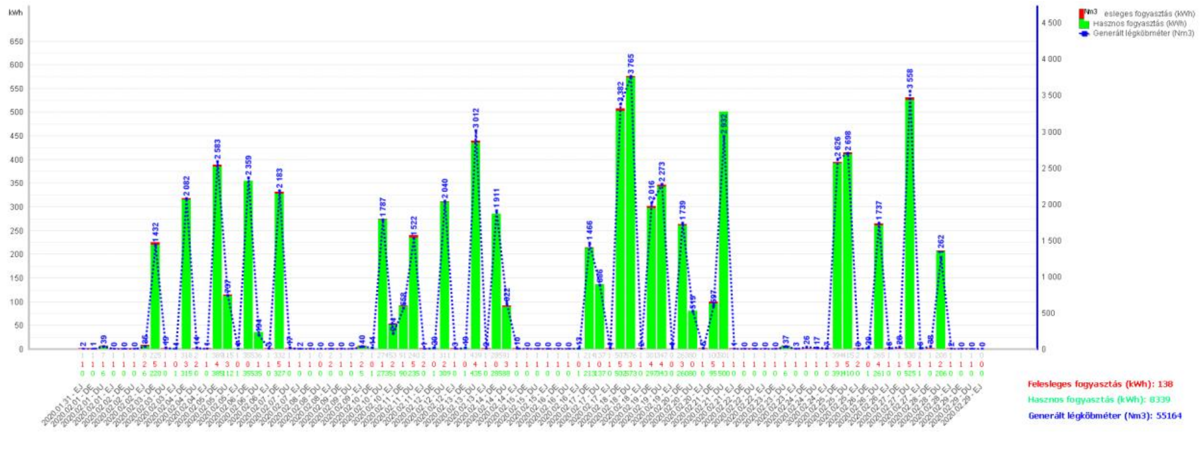

Figure 14. Compressor energy consumption and amount of generated compressed air in February 2020

The example shows that in February, the total volume of emitted cubic meters of air is 55,164 m3, the useful energy consumption is 8,339 kWh, and the useless consumption is 139 kWh. Where 0 values are visible, there were weekend days when there was no production, or another compressor was in operation. This compressor works quite efficiently as its useless power consumption is very minimal. In the database, we can also filter the periods down to 10 minutes, so we can examine the operation of the compressors even more precisely. Thanks to this, during our analysis we came across a compressor that did not work efficiently. The consumption data of this compressor are shown in Figure 15. It can be seen that this compressor had a much higher useless energy consumption, so it was on but not producing compressed air.

Figure 15. Consumption of an inefficient compressor broken down into shifts

This high level of useless operation could have been caused by breakdowns, neglect of maintenance, or simply by the people working on the shift being irresponsible and leaving the compressor on. We report our discovery to the company's management, who took the necessary steps to ensure the compressor was working properly.

The efficiency of compressors is mathematically described by the specific energy consumption index. Thanks to this, a new KPI was added to our system, which compares the consumption ratio of compressed air and electricity generated by a given compressor (Nm^3/kWh), so it shows how many cubic meters of compressed air a given compressor can generate using 1 kWh of electricity. The specific energy consumption performance indicator shows how efficiently the compressors use electricity. The following figures show the performance of a given compressor in a given period.

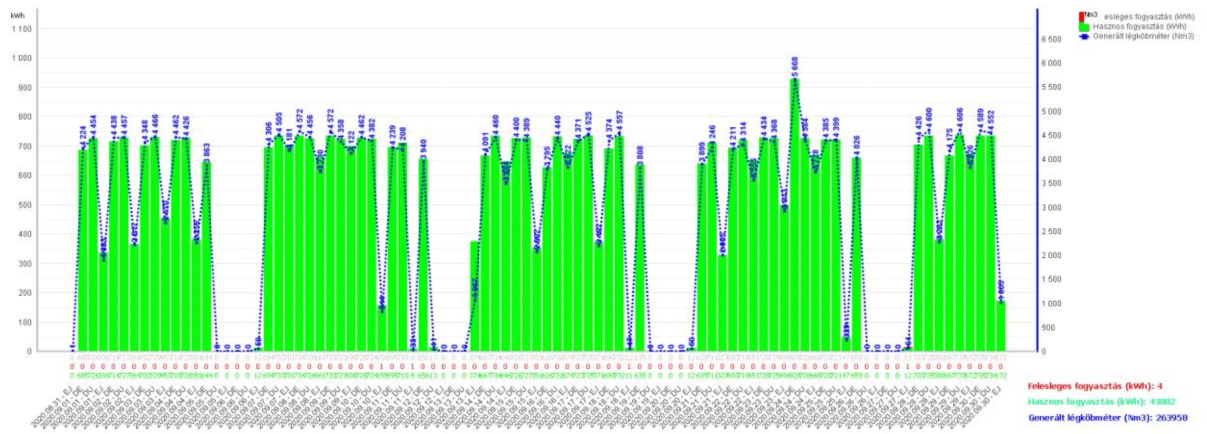

Figure 16. Energy consumption and amount of air cubic metres generated by a compressor in September 2020

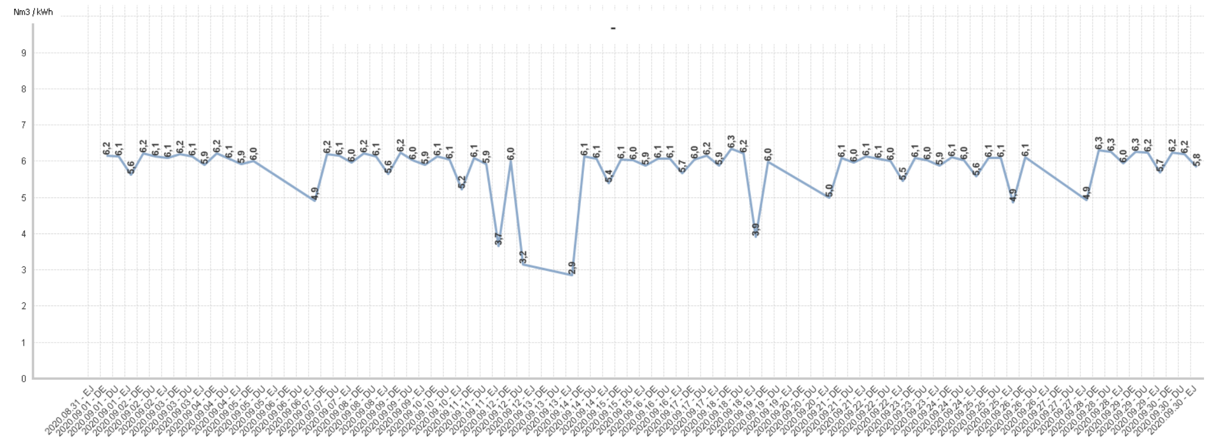

Figure 17. Specific energy consumption of a compressor in September 2020

Figure 16 and Figure 17 show the consumption of electricity and cubic meters of air and the specific energy consumption of one compressor of one plant. If we look at both figures, we can see that this compressor is working efficiently, as the performance indicator value is consistent during operation almost throughout the month. At 0 values, the compressor was not in use.

3.3. Exhaust fans energy consumption related results

In the section 2.2.2, the methodology was defined about the conversion of the extractors' indirect energy consumption (from the viewpoint of production) into direct values to the machines. In this section, a sample calculation will be introduced about the working about the extractors. After that, the data analysis' results will be presented about the live operation of the factory's extractors and their connected machines.

3.3.1. Illustration of methodology through a sample calculation

We provide a sample calculation with given and sample values. A given exhaust fan's constant values related to the shutters:

- Shutter 1 capacity [S1]: 36,550 m^3/h
- Shutter 2 capacity [S2]: 14,500 m^3/h

A given exhaust fan electricity consumption:

- In the first 10 minutes [T1]: 18 kWh
- In the second 10 minutes [T2]: 17 kWh

"Shutter 1 is open" status (we indicate the first 10 minutes with T1 and the second 10 minutes with T2):

- In [T1]: 2 min
- In [T2]: 4 min

"Shutter 2 is open" status:

- In [T1]: 3 min
- In [T2]: 5 min

Measured electricity consumption by machines:

- In [T1]:
  - E_{M1}: 25 kWh
  - E_{M2}: 10 kWh
- In [T2]:
  - E_{M1}: 30 kWh
  - E_{M2}: 13 kWh

Proportionate electricity consumptions of the exhaust fan per shutters and time frames (indirect consumption values): Substituting these values in equation (1), the following results are obtained:

- $E_{S1,T1} = 11.29\ kWh$ (Within first 10 minutes)
- $E_{S2,T1} = 6.72\ kWh$ (Within first 10 minutes)
- $E_{S1,T2} = 11.36\ kWh$ (Within second 10 minutes)
- $E_{S2,T2} = 5.64\ kWh$ (Within second 10 minutes)

Calculated direct electricity consumptions (machine) and indirect consumption values (exhaust) per time periods: Substituting these values in equation (2), the following results are obtained:

- $E_{M1+S1,T1} = 36.29\ kWh$

- $E_{M2+S2,T1} = 16.72\ kWh$
- $E_{M1+S1,T2} = 41.36\ kWh$
- $E_{M2+S2,T2} = 18.64\ kWh$

In this way, we get the direct electricity consumption values, which contain the indirect consumptions of exhaust fans.

The presented methodology has been validated in live operation: both the complex input data obtained during operation and our calculations have been verified and can be said to give correct results.

3.3.2. Results of real operational calculations

The results of the calculations are stored in the database every 10 minutes, and we have also extended the data displays of the production machines.

Figure 18 shows the electricity consumption of the machines and the sub-consumption data of the exhaust fans electricity connected to them. The data comes from one week in August 2020. We consider it important to first illustrate a report made from 2020 data, because at this stage of the research it was not yet possible to measure the operation of all the shutters in the plant. For this reason, the diagram shows "missing" (light green and light red) columns related to exhaust fans, highlighted with black square. In the diagram, the green bars represent the useful energy consumption during operation when the machines are producing products, so the operation of the machine and exhaust fan is profitable for the company. The red bars represent useless energy consumption when the machines did not produce products, therefore the operation of the machine and extractors is a loss for the company. For each column, the lighter green (useful) and the lighter red (useless) indicate the consumption values indirectly consumed by the extractors, and thus ultimately charged directly to the machine by our methodology. The numbers in blue represent the production volumes (m^2). Only the machines that were the largest consumers of electricity in a given week are shown in this graph. Figure 19 shows the corresponding metering values from Figure 18.

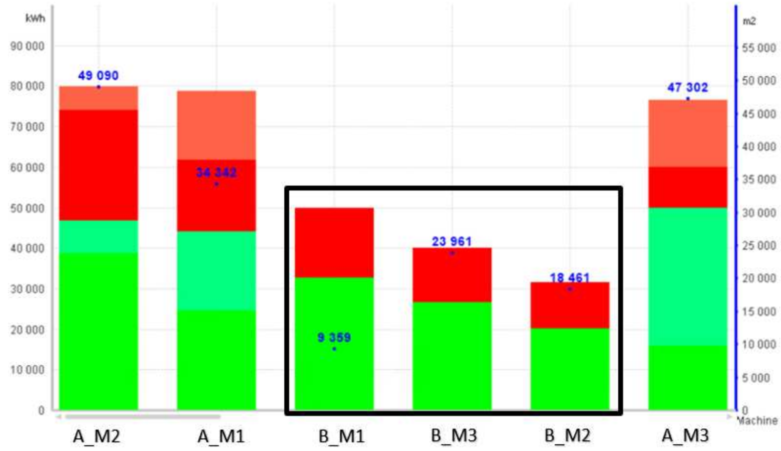

Figure 18. Useful and useless energy consumption of production machines and exhaust fans

Machine ID		A_M2	A_M1	B_M1	B_M3	B_M2	A_M3
Useless energy consumption (kWh)	Indirect extractor fan	5.781 41,5%	17.053 46,9%	0 0%	0 0%	0 0%	16.556 32,8%
	Indirect production machine	27.288 41,3%	17.748 41,8%	17.218 34,6%	13.462 33,6%	11.301 35,90%	10.151 38,9%
Useful energy consumption (kWh)	Direct extractor fan	8.155 58,5%	19.309 53,1%	0 0%	0 0%	0 0%	33.975 67,2%
	Direct production machine	38.713 58,3%	24.677 58,2%	32.573 65,4%	26.551 66,4%	20.180 64,1%	15.943 61,1%
Production volume (m²)		49.090	34.342	9.359	23.961	18.461	47.302

Figure 19. Measurement values related to Figure 18

After August 2020, the installation of new sensors for the shutters of additional extraction fans began. There are 6 exhaust fans working in the two plants of the company, 3 per plant. After the newly installed sensors provided enough data for further analysis to the database, we were able to prepare new analyses. The following figures (Figure 20 and Figure 21) show more recent statements relating to the consumption of extractors and production machines already in 2022.

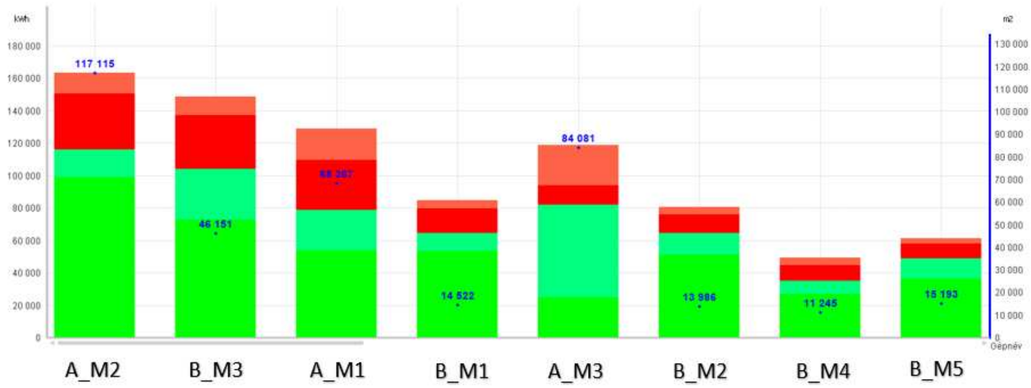

Figure 20. Useful and useless energy consumption of production machines and exhaust fans in October 2022

Machine ID		A_M2	B_M3	A_M1	B_M1	A_M3	B_M2	B_M4	B_M5
Useless energy consumption (kWh)	Indirect extractor fan	12.897 43,1%	11.166 26,4%	19.475 44,3%	4.932 30,5%	24.706 30,1%	4.565 25,9%	4.849 35,9%	3.207 20,3%
	Indirect production machine	34.272 25,7%	33.511 31,6%	30.835 36,3%	15.389 22,5%	11.823 32,4%	11.412 18,2%	9.316 26%	9.181 20,2%
Useful energy consumption (kWh)	Direct extractor fan	17.011 56,7%	31.080 73,6%	24.482 55,7%	11.248 69,5%	57.452 69,9%	13.032 74,1%	8.646 64,1%	12.602 79,7%
	Direct production machine	99.015 74,3%	72.654 68,4%	54.023 63,7%	53.134 77,5%	24.655 67,6%	51.291 81,8%	26.496 74%	36.360 79,8%
Production volume (m²)		117.115	46.151	68.367	14.522	84.081	13.986	11.362	15.193

Figure 21. Measurement values related to Figure 20

Figure 20 shows the useful (green column parts) and useless (red column parts) energy consumption of the largest energy-consuming production machines and the exhaust fans that directly support them. The figures in blue are the total volumes (m^2) produced by the machines in one month. The main difference compared to Figure 18 is that much more machines are shown with their extractor sub-consumptions (light green and red). Figure 21 is a summary table showing the sub-consumption values and quantities produced (m^2) for each production machine and its associated extractor, as in Figure 19.

A new efficiency index has also been added to the system, which is related to the consumption of electrical energy of the hoods. The values in the Figure 22 diagram show how many kWh of electricity were consumed to produce 1 m^2 of wood (or piece of furniture). In the future, management may target a value to be kept to during production, but here again, it is worth considering, for example, the size of the timber and the power level of the machine while processing the workpieces.

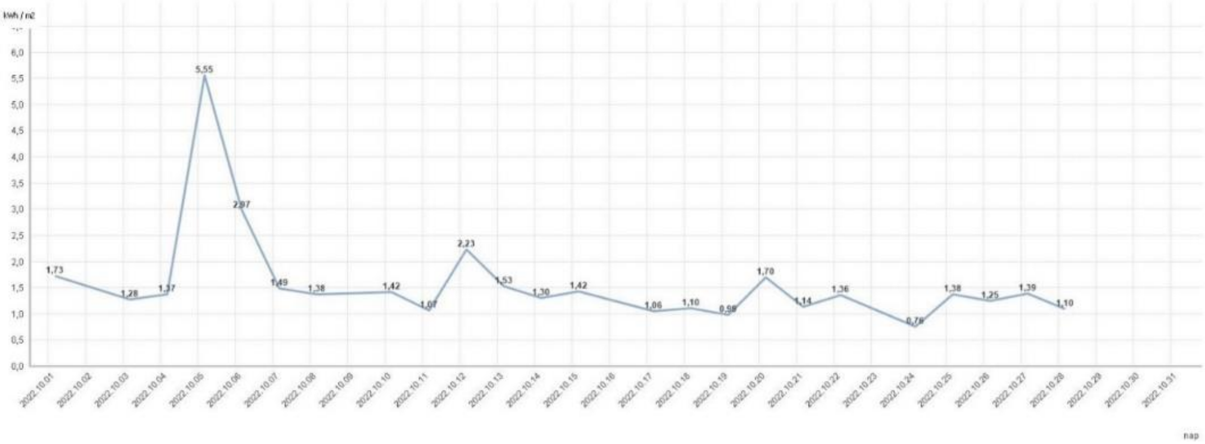

Figure 22. Specific energy consumption of machine A_M2 (kWh/m^2) in October 2022

Thanks to our research and development, we were also able to assign the related production machines to the individual exhaust fans in the system, and proportionally allocating the consumption of the exhaust fans to each associated production machine.

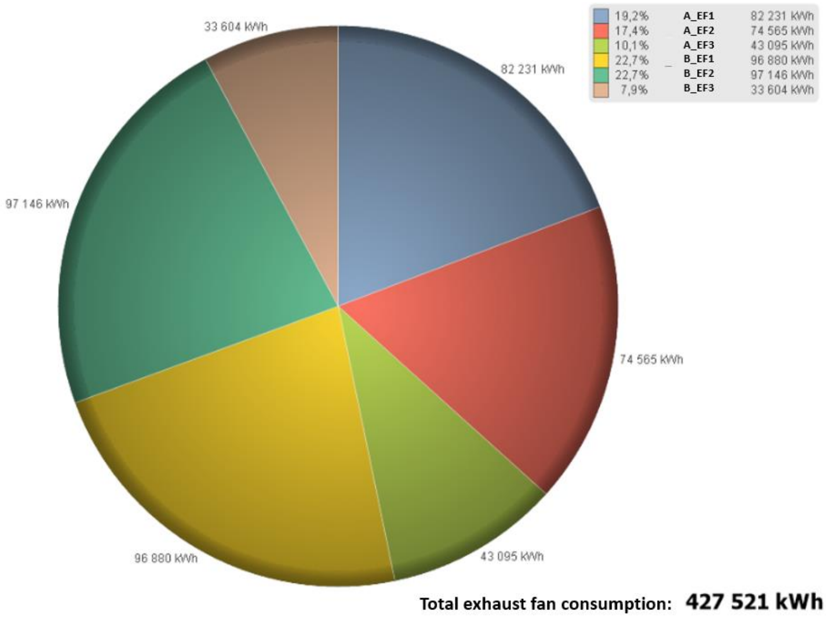

Figure 23. Total consumption of exhaust fans in October 2022

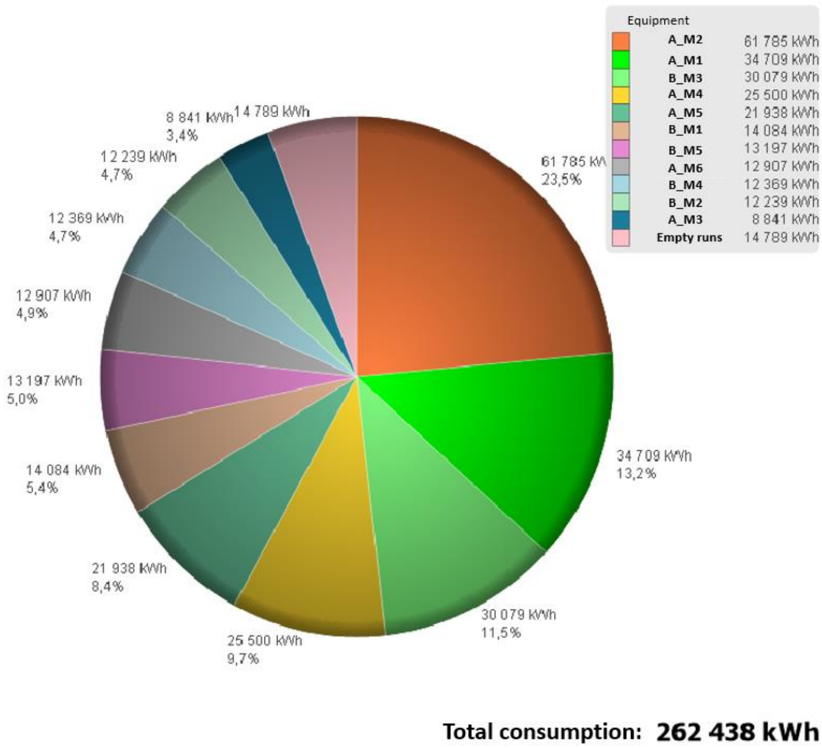

Figure 24. Exhaust fan consumption ratio by machines

Figure 23 shows all exhaust fans and their consumption in October 2022, while Figure 81 shows the consumption ratios of all exhaust fans projected onto individual production machines.

Figure 24 shows that the total consumption is much lower than the consumption of all exhaust fans (Figure 23). The reason for this is that not all exhaust fans (and all shutters) have yet been assigned production machines in the system, so these data are missing. In addition, the "empty runs" that are necessary, for example, to start and stop the extractors, must be taken into account. However, these are part of the technological process, since we cannot "save" the start-up and stop phases, which are associated with higher consumption for such large extractors.

Since the beginning of the research, we have achieved significant results with our work in relation to exhaust fans. However, the development cannot stop here, as there are still plenty of opportunities to carry out further research and obtain new results that are also useful for production. It is essential that each shutter of each extractor is equipped with a sensor, which is also connected to the cyber-physical system, and that the production machines missing from the system are assigned to them. A further objective could be to investigate the electricity consumption of the extraction fans for specific production processes and for specific types of wood, also in relation to the machines. If these developments were to be carried out in the future, it would be possible to reach a level where it would be possible to estimate very precisely the indirect cost of producing a specific product or group of products in terms of the electricity used [21][22].

3.4. Energy efficiency improvements for cost optimization and energy consciousness

In addition to monitoring the use of production resources (electricity, water, compressed air), it is important for us to achieve increasingly efficient, optimal factory operation and management. In addition, we can also fulfil an expectation that was pointed out to us several times as a shortcoming during our research: it was the presentation of electricity losses due to useless operation as concrete costs. This certainly constitutes an economic aspect of our research.

However, avoiding such wasteful activities, extra costs and losses can only work if we focus on energy consciousness in production. We assessed the circumstances of this and carried out a research and development project, as a result of which we encourage everyone from operatives working next to the machines to managers (and ultimately researchers) to operate more energy-consciously. To carry out this research, we have upgraded our cyber-physics system and are displaying to workers in near real time their own or other workers' energy efficiency.

Nowadays, energy consciousness plays an extremely important role in operations, which proves the relevance and importance of this part of our research [23].

3.4.1. The financial aspect of energy consumption

In Hungary, there is an Industry 4.0 model factory where production losses were measured in terms of the number of units of a particular brand of car, because the managers said that the workers were not able to estimate the amount of money that was being shared with them for information. In fact, nowadays a person who is not necessarily competent (i.e., not an electrical engineer or a professional) cannot imagine in real life what a loss of 10-100-1000 kWh might cost a company. For this reason, the sample company's managers saw it better to express the value of a car. Around 2015, the price of a car of that make was set at 2.5 million HUF, so if they wrote out that they had lost 4 cars for that year, which meant 10 million HUF. In order to be able to do the same for the furniture industry company, we must first know the amount of energy consumption expressed in HUF (or EUR). The situation is further complicated by the fact that we did not have to assess the losses incurred in production, but the deficits in resource management (mainly energy). We were able to use the cyber-physical framework presented earlier, but instead of business intelligence software, we used a self-developed web application to display the data and published and deployed it to the cloud.

As we are business informatics experts, it was definitely one of our goals to look at the financial side of resource use. We set another goal in this regard, which was to get to know the company’s financial losses resulting from the electricity consumption. In this way, much more tangible information can be provided to the company's employees than "just" how many kWh usages was useless (non-productive) during the periods (especially at the end of the months).

The application was based on the existing data collection and display framework. Losses due to electricity consumption were known at annual / monthly / daily / shift / 10-minute intervals, but the losses were only defined in kWh. The application can combine the collected 10-minute electricity consumption with the hourly rates received from the electricity provider. Since the prices are received in EUR, the application multiplies them with the daily exchange rate of the Hungarian National Bank, and in this way, we get exactly how many HUF each machine or piece of equipment wasted in a given month, day or even a shift. Example calculations made by the application are presented in the following figures. Since it is a test operation, we can only retrieve the data for a selected month (May 2020). During the development of the application, it was considered that the data for this one month was sufficient, as for research purposes it is not important for us to know what the electricity price was at that time, but to understand the structure of the data set. As a result, we were able to develop an application for it that can extract the values from it.

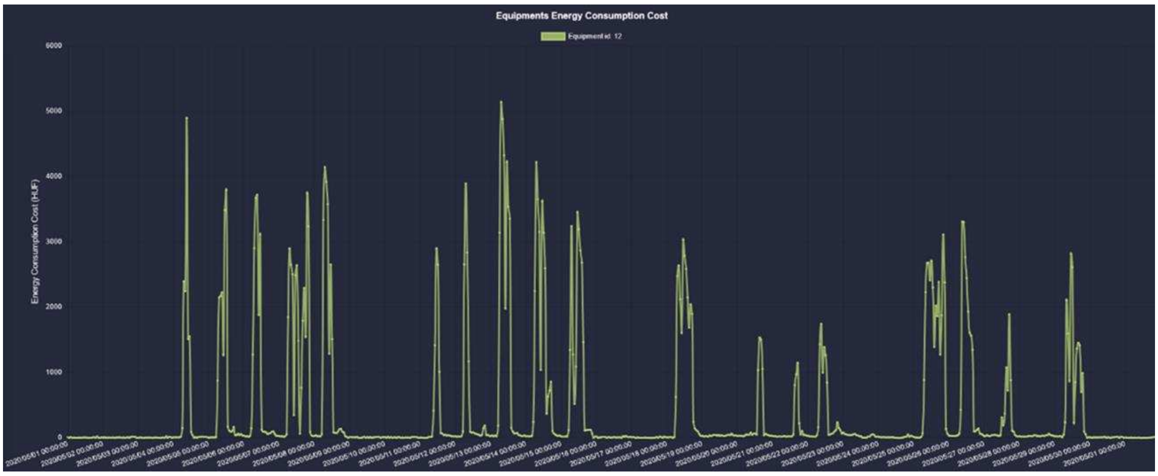

Figure 25. The costs of the operation of a selected production machine in a given month, broken down by hours

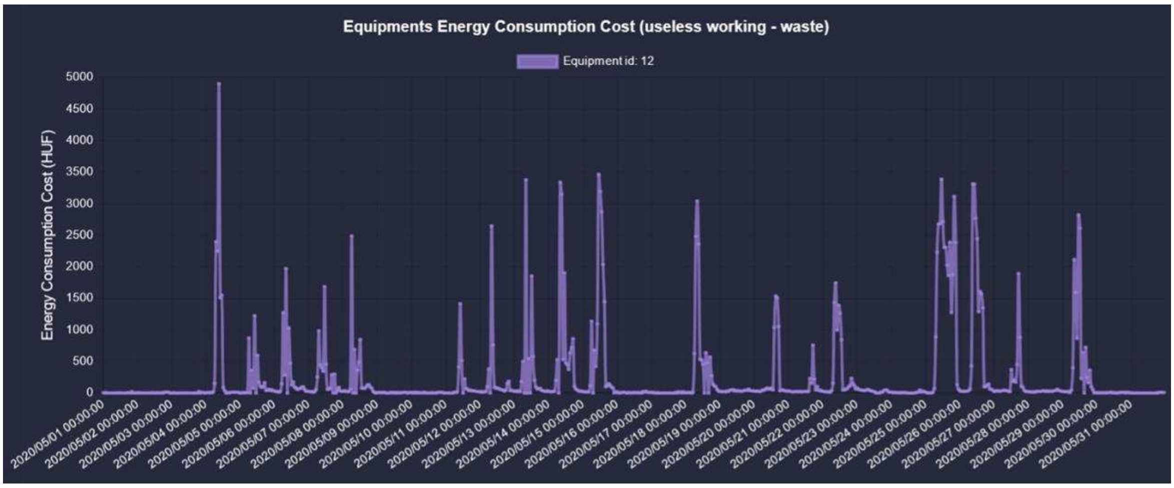

Figure 26. The cost of energy consumption of a specific equipment (with loss-making operation)

Figure 25 shows the cost of unprofitable operation of a production machine and its supporting equipment. It is noticeable that during this period it operated at a relatively unprofitably (Figure 26) compared to the total costs.

We have also examined the data from an economic and financial perspective, so that the consequences and costs of inefficient operation can be more easily understood by the company's management and even by its other employees.

3.4.2. Energy-conscious working in plants

In addition to achieving the objective of calculating the costs of unprofitable operations, we also started another task, which we also solved with a web application. This application checks, monitors and displays a key performance indicator that can inform the operators on the production line about their current performance and alert them if something is not right and needs their intervention. The key parameter we have chosen is the amount of kWh needed to produce one m^2 of furniture board, as this is the ratio that best describes the efficiency of production and the one for which we have measured data. For this ratio, a threshold value must be determined for each production machine, below which the performance can be considered unprofitable, and intervention is required or expected.

When we defined the main requirements for energy consciousness, the primary goal was to make the operators more energy efficient by paying more attention to their work, so that they could produce less wasteful operations and improve their energy efficiency. In practice, the subsystem is used to encourage workers to work more energy consciously [24]. This is also important because the company must comply with the ISO 50001 standard.

The application provides the possibility to see the values of the selected efficiency indicator (kWh/m^2) for the operator's machines in near real time. The system will continuously show the evolution of the indicator for the operator's machine and even alert him if it is not performing properly (for example: he should turn off the machine because it is not producing).

The appearance of the home page is simple and clean, as an operator must see the essence, they should not be distracted by any design elements, but the different colours will be important during use. The application works in near real time, which means that after logging in a production machine receives real performance indicators every 10 minutes, but here we have sped up the process and generate example data every few seconds to show the application in action. We have started an example run with example data that can illustrate both efficient and loss-making operation. Figure 27 shows the efficient operation.

Figure 27. Efficient operation (the value is above the limit)

Random values between 1-5 are generated for the efficiency ratios every 5 seconds. In the example, the limit was set to 2.5. It can be seen that the efficiency ratio was below the limit, but if the most recently measured values are correct, the kWh/m2 ratio is acceptable, then there is nothing special for the worker operating the machine. In Figure 28, we can already see a more wasteful operation (we switched the random number generation between 1-3). The operator can already see from the background colour of the application that he is operating the producer's machine wastefully, intervention may be necessary.

Figure 28. The latest ratio shows wasteful operation (below limit)

Figure 29 shows that the most recently measured values were below the limit, so it is necessary to intervene in the operation. The intervention may be to put the machine in a standby state or stop it, or start production, if possible. Here, in addition to the red background colour, the operator also receives a message warning him about wasteful operation. We have defined a threshold value (specifically three), which means that it still "accepts" indicators resulting from 3 measured values below the limit, so the background colour will only be yellow, but if a value below the limit is received after that, it will already turn red and the also a warning message.

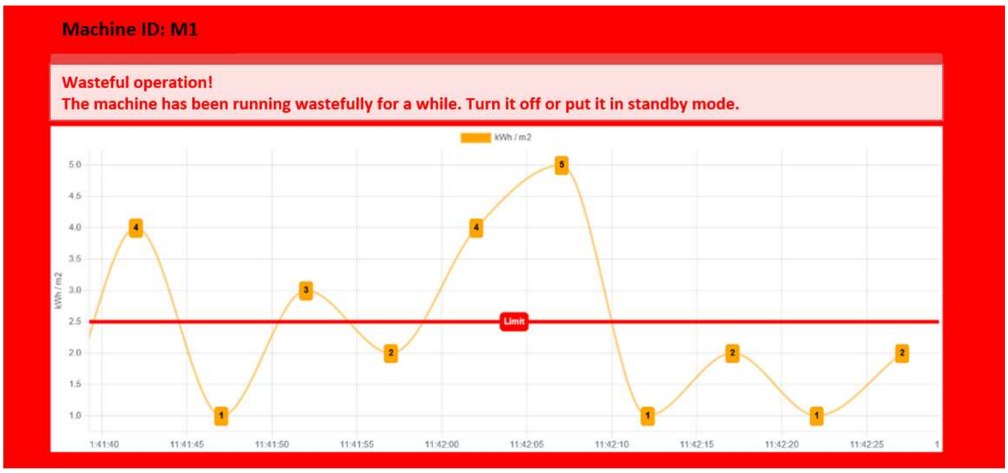

Figure 29. Indication of prolonged wasteful operation

Figure 30. Return to the correct operation

If the wasteful operation of the machine returns to an acceptable level above the limit, we automatically return to the default state and the operator no longer receives a warning (Figure 30).

Overall, it can be said that by developing the application, our common goal with the company was to try to get the operators to work more energy-consciously, thus achieving efficient operation with less energy loss. In addition, additional user groups (managers) also benefit from the development.

4. Summary

In the last few years, a cyber-physical framework has been implemented at a furniture manufacturing company to monitor in near real time the electricity consumption data related to machines and equipment. Where necessary, various calculations were used to convert indirect consumption into direct consumption, so that the consumption of the exhaust fans was passed on to the production machines and thus directly connected to production costs. By examining the water consumption on a daily basis, we discovered anomalies in the system and proposed solutions to them. From an efficiency perspective, we have also compared the compressors' production and consumption, so that they can be aligned with a new key performance indicator in usage in the company. We analysed the energy efficiency from several perspectives. First, we compared the consumption with the electricity prices and, especially for the useless consumption data, we highlighted how much unnecessary costs the unprofitable operation generated for the company. On the other hand, we focused on educating employees about energy consciousness. With the help of our application, a person operating a production machine can see in near real time how efficiently the machine he handled worked in the last 10 minutes. If the operation of the machine was not efficient, the application initially warns the worker about this, but if the wasteful operation continued, it suggested operative intervention.

We can continue the development of the system and, with it, the creation of further scientific results. This ensures progress towards better energy efficiency and optimal operation.

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A Possible Framework for Examining Student Performance

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Abstract: *Learning analytics is most often used to predict whether a student will succeed in a course or training. This helps identify students who need support to avoid failing or dropping out of school. The measurement, collection and examination of data is an indispensable tool not only for industry, but also for all educational institutions, based on which a deeper understanding and optimization of the educational process becomes possible in order to use resources and tools more effectively. In Hungary, with the transfer of universities to foundation management, the need for efficiency increased. The University of Dunaújváros (UOD), an independent higher education institution in the Central Hungarian region since 2000 and operating as a university of applied sciences since 2012, is also an indispensable tool for increasing efficiency. In this thesis, we define the educational analysis research framework applied in connection with the subject of Mathematics 1, one of the defining subjects of technical and economic training. The system realized as a result of the research enables UOD to use the most effective tools when planning the courses, thus making the most favorable use of its resources.*

Keywords: *student success; learning analytics; prediction*

A hallgatói eredményesség vizsgálatának egy lehetséges keretrendszere

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Absztrakt: *A tanuláselemzést leggyakrabban arra használják, hogy megjósolják, hogy egy hallgató sikeres lesz-e egy kurzuson vagy egy képzésen. Ez segít azonosítani azokat a hallgatókat, akiknek szükségük van támogatásra, hogy elkerüljék a bukást vagy az iskola elhagyását. Az adatok mérése, gyűjtése és vizsgálata nemcsak az ipar, de minden oktatási intézmény számára nélkülözhetetlen eszköz, mely alapján az oktatási folyamat mélyebb megértése és optimalizálása válik lehetségessé a források és eszközök hatékonyabb felhasználása érdekében. Magyarországon az egyetemek alapítványi irányításba kerülésével a hatékonyság igénye fokozódott. A Dunaújvárosi Egyetem (DUE), a közép-magyarországi régió 2000 óta önálló, 2012 óta alkalmazott tudományok egyetemeként működő felsőoktatási intézménye számára is nélkülözhetetlen eszköz a hatékonyság fokozásában. Jelen dolgozatban a műszaki, gazdasági képzések egyik meghatározó tantárgya, a Matematika 1. tárgy kapcsán* *alkalmazott oktatáselemzési kutatási keretrendszerét határozzuk meg. A kutatás eredményeként megvalósuló rendszer lehetővé teszi, hogy a DUE a kurzusok tervezése során a leghatékonyabb eszközöket alkalmazza, így a forrásait a legkedvezőbben hasznosítsa.*

Kulcsszavak: *hallgatói sikeresség; tanuláselemzés; előrejelzés*

1. Bevezető

A felsőoktatás tanulmányozása az oktatásügy kiszélesedésével, a felsőoktatásnak mintegy „közüggyé" válásával került előtérbe (Kozma, 2004, p. 1), majd a felsőoktatás expanziójának megindulása magával hozta a hallgatói lemorzsolódások vizsgálatait is (Pusztai & Kovács, 2021, p. 40). A hallgatói szerepben való sikeresség, illetve az ellenpólusát jelentő lemorzsolódás mögött rendkívül sok és komplex tényező áll, melyeket jellemzően pszichológiai, szociológiai és intézményi-szervezeti, esetleg közgazdasági szempontok irányából vizsgálnak (Szemerszki, 2018, p. 16).

Ezek a kutatások nemcsak egyéni, de társadalmi érdekeket is szolgálnak (Demcsákné & Huszárik, 2020). A hallgatói sikeresség, ill. lemorzsolódás helyzetével az Európai Bizottság szakemberei (European Commission, 2015) és sok neves hazai és külföldi felsőoktatási intézmény is foglalkozik (Bognár et al., 2021) közvetve vagy közvetlenül, és talán nincs is olyan felsőoktatási intézmény, amelyik többé vagy kevésbé ne foglalkozna a jelenséggel. A felsőoktatásba belépők és a diplomát szerzők arányának növelése az „Európa 2020" stratégia célkitűzései között is szerepelt (Rajcsányi-Molnár, 2016), majd 2021 februárjában az Európai Unió oktatási miniszterei újfent megállapodtak szakpolitikai együttműködésük 2030-ig szóló stratégiai keretrendszeréről. Öt stratégiai céllal párhuzamosan hét referenciaértéket deklaráltak, melyek közül egy a felsőfokú oktatásra, a felsőfokú végzettséget megszerzőkre vonatkozik: a felsőfokú avagy ISCED 5–8 végzettséggel rendelkezők kívánt arányát a 25–34 éves korcsoport minimum 45%-ában határozták meg 2030-ra – az eredményeken belül a nemek és a külföldi–belföldi születés szerinti megoszlást is górcső alá véve (European Commission, DGEYSC, 2022).

Az Unió tagországainak 2020-as eredményeiben a férfiak és a nők közötti arányokat összehasonlítva az látható, hogy az uniós átlagos arány a nők körében 10,8 százalékponttal magasabb, 46%-os, míg a férfiak körében csak 35,2%-os. A 2021-es Education and Training Monitor megállapítja, hogy a nők minden uniós országban nagyobb valószínűséggel szereznek felsőfokú végzettséget, mint a férfiak (Kővári, 2022). Magyarország a maga 30,7%-os arányszámával pedig az egyik legutolsó a tagállamok között a felsőfokú végzettséggel rendelkezők rátája tekintetében (European Commission, DGEYSC, 2021), mindamellett hogy a nők aránya ebben a korcsoportban 11,1 százalékponttal haladta meg a férfiakét, ami valamivel az uniós átlag felett volt.

Az uniós elvárásoknak megfelelően a felsőfokú végzettséggel rendelkezők számának megoszlását a hallgatók külföldi-belföldi állampolgársága tekintetében is vizsgálni kell. Az európai mobilitási oktatáspolitika, a külföldi tanulási lehetőségek növelhetik a felsőoktatásban résztvevők létszámát a külföldi hallgatók bevonzásával. Az elmúlt években erőteljes expanzió volt érzékelhető ezen a területen. A Tempus Közalapítvány vezetői összefoglalója (Tempus, 2018) szerint 2006-ban a magyarországi hallgatók 3,9%-a, 2011-ben már 6,1%-a, 2016-ban pedig 9,6%-a volt külföldi állampolgárságú, ami közel 11 ezer főt jelentett. Azaz, ezen tíz év alatt majdnem két és félszeresére nőtt a külföldi hallgatók aránya a magyar felsőoktatásban. Mindazonáltal azt is meg kell jegyezni, hogy ehhez a relatív részesedéshez a belföldi születésű hallgatók létszámának több mint egyharmados visszaesése is hozzájárult. Így a külföldi hallgatók létszámának emelkedése csak egy kismértékű kompenzációs tényezőként tudott hatni az összlétszámra.

Az Oktatási Hivatal Diplomás Pályakövető Rendszerből nyert 2020-as gyorsjelentése szerint ugyan a diplomások elhelyezkedési kilátásai jók, de a felsőoktatásban a lemorzsolódás továbbra is magas. Az alapképzésben résztvevő hallgatók több mint egyharmada nem szerez diplomát, és különösen magas a lemorzsolódás az informatikai, mérnöki és természettudományi szakokon. (European Commission, DGEYSC, 2021) A továbbtanulási lehetőségek közötti választás esetében ugyancsak jelentős maradt a nemek közötti eltérés, és a nők továbbra is alulreprezentáltak az informatikai és műszaki-mérnöki szakok területén. Emellett a felsőfokú végzettséggel rendelkezők aránya 48,6 százalékponttal magasabb azon fiatalok körében, akiknek a szülei magasabb iskolai végzettségűek (European Commission DGEYSC, 2022).

Ez a dolgozat a felsőoktatási lemorzsolódás és a hallgatói sikeresség vizsgálatának egy lehetséges módját kívánja bemutatni. Több szempontból vizsgáljuk ennek tényezőit a tanítási–tanulási folyamatban, az oktatók tanítási (Ujbányi et a., 2019) és a hallgatók tanulási módszerei (Nagy et al., 2020), valamint a hallgatók karakterisztikus jellemzői tekintetében (Gőgh et al., 2021). A felsőoktatási tanulmányok során az első félévek kritikus időszakot jelentenek a hallgatók számára. A műszaki és gazdasági képzéseken ehhez a matematika tantárgyak erőteljesen hozzá tudnak járulni egyrészt mint különösen nehéznek tartott, másrészt mint alapozó, a képzés elején megjelenő tantárgyak (Nagy, 2018).

A mai felsőoktatásban a tanítási–tanulási folyamat meghatározó tényezői az online tanulástámogató keretrendszerek (Learning Management System: LMS) mint a képzési tartalom átadási felületei (Takács, 2023). Az oktatók itt teszik elérhetővé a hallgatók számára a tanuláshoz szükséges, általában szöveges vagy multimédia alapú tananyagokat, útmutatókat. Mindazonáltal, ezeket a virtuális tereket már széleskörben használják nemcsak bemeneti tartalmak, hanem tanulási tevékenységek, tanulói aktivitások gyűjtőhelyeként is, például tesztekhez és interaktív feladatokhoz, vagy akár a többirányú, általában aszinkron kommunikációhoz (Nagy & Horváth, 2023). Ezek a rendszerek, felületek lehetővé teszik a teljesen online, de segítik a vegyes (blended) típusú, illetve a jelenléti oktatási módszereket is. Az oktatók – az intézmény által meghatározott keretek között – bizonyos fokú autonómiával rendelkeznek abban, hogy ezeket a felületeket, funkcióikat, tartalmaikat hogyan használják, hogyan illesztik az oktatási folyamatba, milyen módszereket alkalmaznak (Namesztovszki & Kovari, 2022). A hallgatók hasonlóképpen eldönthetik, hogy ezeket a tartalmakat hogyan használják saját tanulási folyamatukban. Az ezekkel a tartalmakkal történő tevékenységeket tekintjük a hallgatók tanulási aktivitásainak, úgymint az oktatási anyagok megnyitása, letöltése, videók megtekintése, tesztek, feladatok elvégzése, pontszáma, kommunikációban való részvétele stb. Ezeket az aktivitásokat, mint a tanulási folyamatban a tanulók viselkedési jellemvonásait, a hallgatói karakterisztikák egy részének tekintjük.

A hallgatók sikeres tanulmányi előmenetelében azonban rendkívül fontos tényező, hogy „mit hoz magával” a hallgató. Megközelítésünkben ez a másik szegmense a hallgatói karakterisztikáknak. *Bourdieu* reprodukciós elméletének elfogadása mentén feltételezzük, hogy a hallgatók belépéskori, elsődlegesen társadalmi, gazdasági és kulturális tőkéjének felmérésével valószínűsíthetjük a hallgatók egyéni esélyeinek szintjét a képzésen való bennmaradás tekintetében, hisz a „hozott” társadalmi egyenlőtlenségek a habitus által determináltan átörökítődnek (Meleg, 1996). Ennek megfelelően a hallgatók demográfiai, szocioökonómiai és -kulturális jellemzőit tekintjük a hallgatói karakterisztikák további összetevőinek.

2. Irodalmi háttér

A hallgatói lemorzsolódásnak viszonylag nagy irodalma van, bizonyos tekintetben ez nehezíti is a releváns irodalmak fellelését. Hazai viszonylatban és neveléssszociológiai megközelítésben kiemelkedőek a debreceni kutatócsoport munkái.

Mellőzhetetlen az Oktatási Hivatal 2020-as összefoglaló tanulmánya, ami kifejezetten a felsőoktatási lemorzsolódás vizsgálatairól nyújt alapvető és viszonylag friss adatokat, információkat, statisztikákat a teljes magyarországi helyzetről a 2011–2019. közötti időszakra vonatkozóan. Vizsgálataikban többek között megállapítják, hogy a reál jellegű informatikai, műszaki és természettudományi képzések vezetnek a lemorzsolódásban. (Demcsákné & Huszárik, 2020)

A nemzetközi szakirodalom tekintetében elsődlegesek az Európai Bizottság felsőoktatással foglalkozó szakpolitikai dokumentumai, kutatóinak, kutatócsoportjainak uniós és országos szintű jelentései, tanulmányai. Az oktatás és képzés szociális vonatkozásaival foglalkozó szakértői hálózat (NESET: Network of Experts on Social Aspects of Education and Training) által az Európai Bizottság számára készített 2013-as jelentésében Quinn (2013) kiemeli a részidős hallgatók (levelező tagozatosok), a férfiak, de elsődlegesen a bizonytalan társadalmi-gazdasági háttérrel rendelkező hallgatók veszélyeztetett helyzetét. Hat alapvető okot jelöl meg a lemorzsolódás fő okaiként: társadalmi-kulturális, strukturális, politikai, intézményi, személyes és tanulmányi tényezőt. Az Európai Bizottság Oktatás és Képzés csoportjának munkatársai (European Commission, 2015) jelentésükben három szintre osztják a tényezőket: állami, individuális és intézményi szintekre.

Az *Oktatási és Képzési Figyelő* 2022-es összehasonlító jelentése többek között arra hívja fel a figyelmet, hogy a felsőoktatás bővülése elfedi a továbbra is fennálló egyenlőtlenségeket, az extenzió a nemek közötti szakadék növekedésével járt együtt a nők javára. Azonban az is látható, hogy a nemek közötti különbségek már jóval a felsőoktatás előtt megjelennek és az oktatási pályán előre haladva szélesednek tovább. Ezt tükrözi az új belépőkre, a beiratkozásokra és a befejezésre vonatkozó adatok többsége is (Gábos et al., 2022). A továbbtanulási lehetőségek közötti választás esetében ugyancsak jelentős maradt a nemek közötti eltérés, és a nők továbbra is alulreprezentáltak az informatikai és műszaki-mérnöki szakok területén. Emellett a felsőfokú végzettséggel rendelkezők aránya 48,6 százalékponttal magasabb azon fiatalok körében, akiknek a szülei magasabb iskolai végzettségűek. (European Commission DGEYSC, 2022)

A Dunaújvárosi Egyetem viszonylatában megkerülhetetlen az egész téma, a helyi kontextus és előzmények megismerése a 2014–2018. között megvalósított *Hallgatói Sikerességet Támogató* (HASIT) program és annak köteteinek tanulmányozása. A hatkötetes kiadványnak legfőképp az első (Monitoring rendszer) (András et al., 2016a) és az ötödik (Mérések, kutatások) (András et al., 2016b) részét vélem hasznosíthatónak, de a negyedik (Hallgatói motiváció) (András et al., 2016c) és a hatodik (Felsőoktatási tanácsadás) (András et al., 2016d) rész is tartalmaz értékes információkat, javaslatokat. A monitoring rendszer jó kiindulási alapot jelent, azonban továbbgondolásra javasljuk, mert ugyan a Neptunban rögzített megbízható adatokat használ, (mint az órákon jelenlévő hallgatók aránya, a félévközi feladatokat, félévet sikeresen teljesítő hallgatók aránya; szakdolgozatot beadó hallgatók aránya), de a Neptun alapvetően nem tanulástámogató rendszer, így jelenleg a rendelkezésre álló funkciókkal nem képes sokféle tartalmi elem, hallgatói tevékenység rendszerezésére, megosztására, így az oktatóknak – azon kívül, hogy rögzítik a feladatok eredményeit –, nincs lehetőségük egy komplett tananyagcsomagot létrehozni, és azt összességében kielemezni.

A tanulástámogató rendszerek képesek a tanulók tananyagfelhasználási tevékenységeinek rögzítésére. Az ezen felületeken történő tanulói aktivitások vizsgálatával, a tanuláselemzéssel (Learning Analytics, Educational Data Mining) kapcsolatosan elsősorban angol nyelvű irodalmakra támaszkodunk. Kiindulási alapot a Society of Learning Analytics Research társulás *Handbook of Learning Analytics* kiadványa (Lang et al., 2022) nyújt. Leginkább a külföldi jó gyakorlatokat keressük, mert Magyarországon ezek a tevékenységek még kevéssé elterjedtek. Elsősorban azokat a felsőoktatási és nyitott egyetemi (open university) jó gyakorlatokra szeretnénk rátalálni, amik egyrészt a tanuláselemzés módszereit használják a lemorzsolódással veszélyeztetett hallgatók kiszűrésére, másrészt a hallgatók megtartására kidolgozott technikákról szólnak. Ezek között azon nemzetiségek munkáira vagyunk kiemelt figyelemmel, melyek nagyobb létszámban megjelennek Egyetemünkön a releváns képzési területeken.

3. Javasolt módszertan a hallgatói sikeresség vizsgálatára

A felsőoktatás világának változásával, annak új szakaszában az expanzió egyértelműen visszafordult, és a kapacitások üresedő hallgatói helyekkel, lemorzsolódással találták szembe magukat. A Debreceni Egyetem Felsőoktatási Kutató és Fejlesztő Központja (CHERD-H) 2017 és 2021 között ezt a jelenséget kezdte el vizsgálni a *Társadalmi és szervezeti tényezők szerepe a hallgatói lemorzsolódásban* című komplex kutatásukban. A hallgatói deficithipotézisből kiindulva vizsgálataikban a hallgatók három, a tanulmányi haladási útjuk szempontjából jól körülhatárolható típusát figyelték meg: normál haladók, csúszó-passziválók és korrigálók. Kutatási munkájukkal olyan többdimenziós tényezőrendszert rajzoltak fel, mellyel hasznos támpontokat adnak úgy az oktatáspolitikai szakembereknek, mint a témában érintett felsőoktatási szereplőknek vagy érdeklő kutatóknak. Vizsgálják a lemorzsolódás rizikóforrásait, az eltérő kockázatú hallgatói csoportokat, valamint számba veszik a hallgatók rizikó- és erőforrásait. A bemutatott vizsgálatok javarészt a 2018/2019-es tanévben, Kelet-Magyarország és a közeli kárpát-medencei térség országainak felsőoktatási intézményeiben felvett, nagymintás hallgatói kérdőívek adatbázisára támaszkodnak.

Pusztai Gabriella és Kovács Klára (2021) azokat a tényezőket elemzik, melyek a hallgatók perzisztenssé, rizikóssá vagy lemorzsolódóvá válásának esélyeit befolyásolják. Az OECD 2019-es adataiból indulnak ki, majd a 2018-as mintában arra keresik a választ, hogy ezek a hallgatói csoportok milyen jellemző tulajdonságokat mutatnak társadalmi hátterük és intézményi integrációjuk viszonylatában. Eredményeik erősítik azon elméletek érvényességét, miszerint azoknak a hallgatóknak, akiknek gyengébb az inter- és intragenerációs kapcsolathálója, nagyobb esélyei vannak a lemorzsolódásra. Felhívják a figyelmet többek között a költségtérítéses, munka mellett tanuló, férfi hallgatók, valamint a felsőoktatásban elsőgenerációs és az elégtelen anyagi körülményekkel bírók veszélyeztetettségére.

4. Egy konkrét adatgyűjtés bemutatása a hallgatói sikeresség vizsgálatának elemzésére a Dunaújvárosi Egyetemen

A matematika tárgyak hallgatóinak kérdőíves felméréseit 2020-ban kezdődtük. A vizsgálatokat egyrészt a pandémia miatti online oktatásra való áttérés tapasztalatainak összegyűjtése céljából (Cserné Pekkel & Kocsó, 2021), másrészt a mesterséges intelligenciát használó prediktív tanuláselemzések kiegészítéséhez végeztük (Kocsó & Bognár, 2021). Így vannak már adataink és azokból levont következtetéseink, de a kérdőívek még kevéssé tartalmazták a téma hazai és nemzetközi irodalmának eredményeit, valamint konzisztenciájukban is pontosításra, bővítésre szorultak ahhoz, hogy valóban pontosíthassák a hallgatói sikeresség/lemorzsolódás előrejelzését.

A szakirodalmak feldolgozásával párhuzamosan a kérdőívet is fejlesztjük. Nulladik lépésként a korábbi Google Forms és a Moodle v3.7 felületéről áthelyeztük a Moodle 2021 óta használt v3.9-es felületére.

A teljes kutatás longitudinális. Kvalitatív, kvantitatív, beavatkozásmentes és beavatkozással járó elemeket is tartalmaz, több alkutatásra osztható:

1. A Dunaújvárosi Egyetem tantárgyszintű hallgatói eredményességének kvantitatív vizsgálata a hallgatói Neptunban rögzített demográfiai és egyéb képzési jellemzői,

valamint a tantárgyak adott féléves paramétereinek, jellegzetességeinek összefüggéseiben a matematika tárgyakon a 2017/2018/1. félévétől a 2021/2022/2. félévéig.

2. A 2020/2021–2022/2023-as tanévekben három kvantitatív beavatkozásmentes, majd egy félévben beavatkozással járó elővizsgálatként önkéntes, anonim online kérdőíves, ill. teszt formátumú felmérések a Moodle felületén a párhuzamosan folyó szakirodalmi elemzések eredményeivel bővítetten a hallgatók jellemzőinek feltárására. A teszt formátumú felmérés folytatása a 2023/2024/1. félévében. Ezek a vizsgálatok rétegzett mintavétellel a magyar nyelvű nappali és levelező, valamint az angol nyelvű nappali tagozatos hallgatók csoportjaiban történnek. Az önkéntesen hozzájáruló hallgatók válaszait/jellemzőit összevetjük az adott félévi végleges (Neptunból nyert) eredményükkel statisztikai összefüggések feltárása céljából.
3. Kvalitatív vizsgálatként a 2023/2024-es tanévben matematika tárgyat oktató kollégákkal strukturált interjút készítünk önkéntes alapon.
4. Kvalitatív tartalom-, ill. dokumentumelemzésként vizsgáljuk a Moodle tanulástámogató rendszer adott féléves tartalmait párhuzamosan a kérdőíves vizsgálatokkal.
5. Beavatkozással járó kvantitatív vizsgálatként elemezzük a matematika tantárgyakat felvett hallgatók Moodle-kurzusbeli aktivitását az első, majd meghatározott intervallumban történő belépés, és kiválaszott tevékenységek teljesítése szintjén.

4. 1. A hallgatói adatok és eredmények visszamenőleges statisztikai elemzése

Kvantitatív, beavatkozásmentes vizsgálatként visszamenőleg elemezzük a 2017/2018/1. félévétől a 2021/2022/2. félévéig az adott félévben matematika tantárgyat felvett hallgatók adatait, tulajdonságait és eredményeit. Ezen adatokat az Adatkezelési és adatvédelmi szabályzatnak megfelelően, jegyzőkönyvezetten kértük. Az előzetes egyeztetések alapján egy összesen 2121 fős mintával dolgozhatunk. Ezek a Neptunból nyert adatok a hallgatók személyes adatait nem, de az alábbiakat tartalmazzák:

- születési év,
- nem,
- munkarend (tagozat),
- képzés (szintje és nyelve),
- finanszírozási forma,
- hányadik tárgyfelvétel,

- megszerzett érdemjegy (bejegyzés),
- bejegyző.

Statisztikai összefüggéseket keresünk a fenti hallgatói adatok és az érdemjegyek, valamint az egyes félévek oktatási jellemzői (pl. online/offline óratartás arányai) és a hallgatói eredmények között, melyek alapján az előrejelzésekhez használható következtetéseket kívánunk levonni.

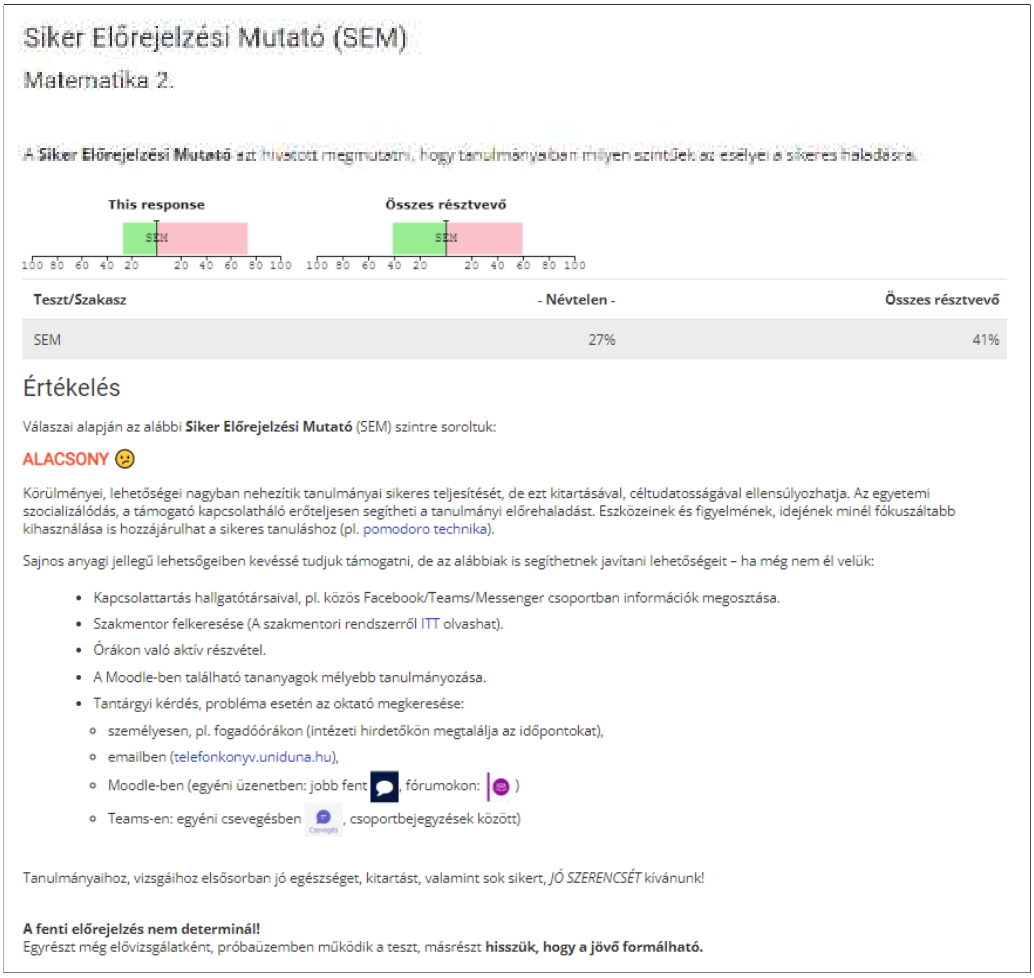
4. 2. A hallgatói jellemzők vizsgálata

A hallgatók jellemzőinek vizsgálatára kérdőíves kutatást végzünk. A mintatanterv szerint haladó hallgatók az első három félévben egymás után vesznek részt a Matematika 1-2-3. tantárgyak kurzusain. Az eredeti elképzelés szerint – annak érdekében, hogy ne legyen olyan hosszú a kérdőív, és nagyobb legyen a kitöltési hajlandóság – a kérdéseket a három félévre eloszlatva, különböző fókusszal három kérdőívben terveztük lekérdezni a hallgatókat. Az elővizsgálatok e félévi kitöltési száma viszont azt a tanulságot hozta számunkra, hogy mégis egy nagy, teljeskörű kérdőív szükséges a tanulmányok megkezdésének a legelején – számítva arra, hogy a kezdeti lelkesedés akkor még inkább él a hallgatókban és szívesebben töltenek ki egy kérdőívet, mint később másodikat, harmadikat, hasonló céllal. A 2. és a 3. félévben azonban nyomon követjük a kurzusszintű előrehaladást és azon hallgatókat, akik ehhez hozzájárulnak Neptun kódjuk megadásával. A kérdőív kérdései a hallgatók, 1. d. pontban részletezett demográfiai, szocioökonómiai és -kulturális jellemzőit kívánják feltárni. A teszt kitöltése önkéntes, anonim és csak egyszer tölthető ki (visszatétel nélküli minta).

Ez a kvantitatív vizsgálat abban is módosult, hogy eredetileg beavatkozásmentesként indult, de a végcél tervezetében beavatkozással járó akciókutatásként határozzuk meg, mivel a kérdőívet átdolgoztuk teszt formátumúra. Ez annyit tesz, hogy a hallgatók válaszait (jellemzőit) pontozzuk, ami alapján kapnak egy mutatószámot, és amit besorolunk egy várható teljesítési szintre: alacsony, közepes, magas. Ezzel nemcsak mi nyerünk adatokat, de egyben a hallgatók is azonnali eredményhez, kiértékeléshez, továbbá az önálló tanulási tevékenységeikhez és a kapcsolati tőkéjük megerősítése érdekében tanácsokhoz juthatnak (2. ábra). Ez erősítheti a kitöltési hajlandóságot, az érdekeltségüket, bevonódásukat, valamint annak a problématerületnek az áthidalását is jelentheti, hogy a visszajelzést csak az arra nyitott hallgatók kapják meg. Az értékelési eredmények a szint megjelölésén túl a mostani és a következő próbaüzemben meglehetősen általánosak, inkább a tájékoztatás a céljuk, és hangsúlyozottan tartalmazzák a próbaüzemmód jelleget és azt, hogy az előrejelzés nem determinál.

A teszt a Siker Előrejelzési Mutató (SEM) nevet kapta. A szakirodalmakban és előzetes megközelítésünkkel a lemorzsolódással veszélyeztetetteket „keressük", de szeretnénk a fókuszt a sikerességi tényezők felé irányítani, hogy pozitív üzenetet hordozzon magában a teszt is. És bár valóban fontos, hogy észrevegyük, kinek van szüksége plusz segítségre, ezzel az is cél, hogy az eredményekből kinyerjük, mik a sikerességi tényezők.

A névválasztás mögött ugyancsak meghúzódó cél a kitöltési hajlandóság növelése. Ennek megfelelően pedig olyan értékelési szemszöggel dolgoztuk ki, mely azon válaszokra, hallgatói jellemzőkre ad pontot, amik segítik a tanulmányi előrehaladást. A pontok súlyozása – mintegy hipotézisként – egyrészt szakirodalmi elemzések, korábbi országos és nemzetközi kutatások eredményeit építi be, másrészt az Neptunból nyert visszamenőleges adatok statisztikai elemzésén alapul. A teszt eredménye szerint a hallgatót *magas*, *közepes* vagy *alacsony* SEM szintre soroljuk. Az értékelésben jelenleg megkapja a saját SEM számát, a tesztet addig kitöltő hallgatótársai eredményének átlagát, erről két egyszerűbb bipoláris gráfot, valamint rövid értékelő gondolatokat, és javaslatokat lehetőségeinek javítására (pl. kihez tud fordulni problémáival, tanulásmódszertani tanácsok stb.). A kiértékelés természetesen még további fejlesztést igényel.

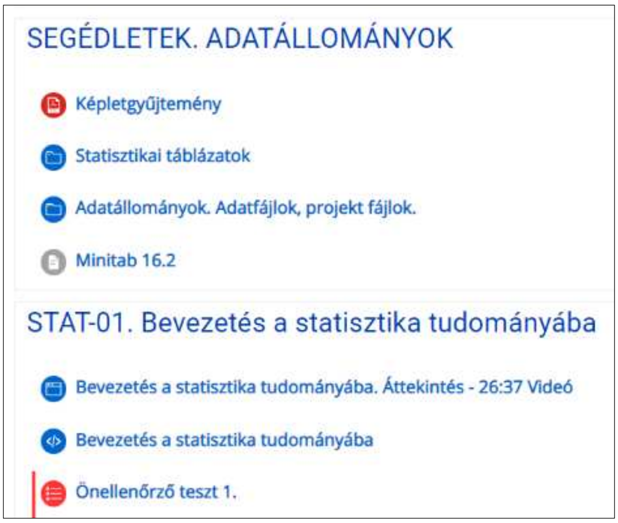


1. ábra SEM teszt visszajelzés "alacsony" szint esetén

4. 3. A Moodle-kurzusok tartalmának elemzése

A DUE Moodle tanulástámogató rendszerben minden egyes tantárgyhoz tartozik egy felület, melyen a tananyagforrások (resources) és a tevékenységek (activities) elhelyezhetők és elérhetővé tehetők a hallgatóknak. Ezek a hivatalos tantárgyakhoz tartozó Moodle-kurzusok. Az, hogy ezeket az oktatók milyen tartalommal töltik meg, általánosságban változó. Van olyan kurzus, ami az oktató által összeállított, kifejezetten a tananyaghoz készült írásos tartalmakat, előadás diákat, ezekhez készült előadás videókat és gyakorlati, számítógépes szoftverhasználatot bemutató, magyarázó videókat tartalmaz, de vannak olyanok, amik tematikusan kevésbé összerendezettek, és inkább csak tananyaggyűjteményeknek tekinthetőek, saját vagy nem saját készítésű forrásokat tartalmaznak.

Ezeknek a tanulási felületeknek a megismerése, tartalomelemzése (mintegy dokumentumelemzése) elengedhetetlen ahhoz, hogy átlássuk a hallgatók számára feldolgozandó forrásul szolgáló tananyagoktípusokat, az oktatók által alkalmazott módszereket.



2. ábra Részlet a Mérnöki matematika 2.
Moodle-kurzus tartalmából

4. 4. A hallgatói aktivitások statisztikai elemzése

A tanulástámogató rendszerekben a hallgatók egyéni tanulási aktivitásainak naplózása lehetőséget teremt az ún. tanuláselemzések lefolytatására. A Moodle-kurzus minden résztvevőjének, tehát a tantárgyat felvett összes hallgató aktivitását, tevékenységteljesítését figyelemmel tudjuk kísérni. Ennek mentén ez egy beavatkozásmentes kvantitatív vizsgálat, ami a teljes alapsokaságot mintául használja. Célja, hogy az inaktív, vagy gyengén teljesítő hallgatókat mielőbb kiszűrhessük.
A legegyszerűbb szintje ennek a belépésfigyelés, majd az aktivitásfigyelés további szintjei, amikor az adott Moodle-tartalmakhoz beállítjuk, hogy a rendszer rögzítse a hallgató aktivitásait: megnyitotta-e a linket, megtekintette-e a videót, elvégezte-e az adott tesztet, és azt milyen eredménnyel stb. A legbonyolultabb, már a rendszer belső programozását is igénylő módja, mikor pontosan meghatározzuk, hogy mely hallgatói aktivitásokat, tartalomfeldolgozásokat rögzítse a rendszer, és az alapján egy mesterséges intelligenciát és perdiktív analitikát használó gépi tanulási (Machine Learning: ML) modellt dolgozhatunk ki. Egy ilyen modellt dolgozott ki (Bognár & Fauszt, 2022) kifejezetten a Matematika 2. egyik Moodle-kurzusának tartalmához, de ahogy munkájukban is írják, vannak korlátai a modellnek, ami az előrejelzés megbízhatóságát gyengítik. Ezt a modellt egészíti ki a SEM

teszt időfüggetlen változókként használva a hallgatók válaszait, jellemzőit, amivel javíthatók a modell előrejelzési megbízhatósága. Az új félévenként nyert adatok – azaz a hallgatói aktivitások, jellemzők és érdemjegyek – tovább javíthatnak a predikciókon. Így a modellt minél több féléven keresztül „tanítjuk", annál jobb előrejelzéseket tehet, hogy a korábbiakhoz hasonló hallgatók milyen várható eredménnyel teljesítik a kurzust. További modellek megalkotása akár konkrét Moodle-kurzushoz, akár csak generális Moodle-tartalomhoz (pl. általában véve a videó, kvíz stb. tartalmakhoz) csak multidiszciplináris együttműködésben (programozóval, rendszergazdával, statisztikussal együtt) valósulhat meg (Zawacki-Richter et al., 2019; Bates et al., 2020), ami túlmutat a kutatás korlátain, azonban a hallgatói aktivitások figyelésének egyszerűbb formáit nem mellőzhetjük a kutatásban.

4. 5. A hallgatói féléves érdemjegyek

A vizsgaidőszakok zárásával kell összevetni az adott félévi matematika kurzusokon elért hallgatói eredményeket a SEM tesztek válaszeredményeivel és a tanuláselemzési statisztikákkal. Ekkor tudjuk összekapcsolni a félév során szerzett információkat a hallgatói karakterisztikákról a félév legvégére szerzett érdemjegyükkel azon hallgatóknál, akik ehhez hozzájárultak Neptun kódjuk megadásával a SEM tesztben (nem kötelező kérdéselemként). A Neptunból az érdemjegyüket az Adatkezelési és adatvédelmi szabályzatnak megfelelően jegyzőkönyvezetten kérjük meg. Ekkor kapunk teljes képet az adott kurzusban lezajlott tanítási–tanulási folyamat eredményeiről. Végül, a hallgatók kérdőívekre adott válaszai és a matematika tárgyakon elért eredményei összekapcsolásának statisztikai vizsgálataival igazolhatjuk vagy elvethetjük feltételezéseinket.

5. Egy kutatási terv az előzőekben meghatározott vizsgálati eljárások alkalmazására

A képzések eleje, első félévei kritikus időszakot jelentenek a hallgatói sikeresség elérése avagy a lemorzsolódás elkerülése szempontjából. Ugyanakkor „a reál jellegű informatikai, műszaki és természettudományi képzések vezetnek a lemorzsolódásban" (Demcsákné & Huszárik, 2020, 54. o.). Ezeken a képzéseken a matematika tanulmányterülete az alapozó tárgyak között jelenik meg, így az első féléves matematika tantárgyon az összes belépő hallgató megtalálható. A matematika tárgyakat ezenfelül a különösen nehezek közé soroljuk. Ha egy hallgató tudja teljesíteni ezeket a tantárgyakat, akkor nagyobb valószínűséggel túljut a további tanulmányi akadályokon is. Ellenben, ha már az első félévben elmaradása lesz, nemcsak mintatantervi haladása veszélyeztetett, de ez akár a képzés elhagyásához is vezethet. Minél előbb látjuk, hogy a felvett és beiratkozott hallgatók közül kik azok, akik valamilyen oknál fogva lemorzsolódhatnak, annál előbb tudunk közbelépni. Ez legalább annyira fontos egyéni hallgatói érdek, mint intézményi szintű és összességében kollektív társadalmi és gazdasági érdekeltség. Ezt nyilvánvalóvá teszik az Európai Unió stratégiai célkitűzései is. A hallgatói lemorzsolódás tényezői azonban sokrétűek Quinn (2013) jelentésében hat alapvető okot jelöl meg: társadalmi-kulturális, strukturális, politikai, intézményi, személyes és tanulmányi tényezőt. Legfőbb kiváltó tényezőként a bizonytalan társadalmi-gazdasági hátteret azonosítja.

Jelen kutatás terepéül a Dunaújvárosi Egyetem (DUE) szolgál, mely 2012 óta alkalmazott tudományok egyetemeként működik. A képzési profil nagy része az informatikai, műszaki- és gazdaságtudományi képzési területekhez tartozik. Ezek a képzések egyrészt nappali és levelező munkarendben, valamint magyar és külföldi hallgatók számára is elérhetőek. 2014–2018. között lezajlott a Hallgatói Sikerességet Támogató program, melynek fő célja a hallgatói lemorzsolódás csökkentése volt. A sokrétű intézkedéssorozat eredményeként a kurzust elhagyók száma egyes szakoknál 20%-kal csökkent 2018-ra (Rajcsányi-Molnár, 2018). Mindazonáltal a hallgatók benntartása, a tantárgy-, illetve kurzusteljesítések javítása az intézményfejlesztési stratégiának is egy meg nem szűnő eleme (Polónyi, 2021). Ezenkívül nem mehetünk el amellett sem, hogy a 2020 tavaszán berobbant, majd újabb évekre velünk maradt pandémia milyen rendkívüli hatással volt az oktatásra, szereplőire, viselkedésükre, módszereikre.

A matematika tantárgyak az 1. táblázatban felsorolt szakok mintatanterveiben az első három félévben szerepelnek mind a magyar, mind az angol nyelvű képzéseken. A hat magyar nyelvű

1. táblázat DUE matematika tantárgyak a képzéseken.

Őszi félévek	Tavaszi félévek
Matematika 1. – Mathematics 1. Matematika 3. – Mathematics 3.	Matematika 2. – Mathematics 2.
Mérnök informatikus (N + L) – Computer Science Engineering (N) Gazdaságinformatikus (N + L) – ------- Gépészmérnök (N + L) – Mechanical Engineering (N) Anyagmérnök (N + L) – Materials Engineering (N) Gazdálkodási és menedzsment (N + L) – Business Administration and Management (N) Műszaki menedzser – Engineering Management (N)	

ábraképzés nappali és levelező munkarendben is zajlik, az öt angol nyelvű képzés csak nappali munkarendben.

Az alábbiakban megfogalmazzuk azokat a kutatási kérdéseket, melyre a jelen dolgozatban vázolt módszerrel választ keresünk.

6. Kutatási kérdések és hipotézisek

a) A DUE hallgatóinak milyen demográfiai, szocioökonómiai, szociokulturális jellemzői azok, melyek alapján nagy valószínűséggel be tudjuk őket sorolni a matematika tantárgyak szempontjából várhatóan „magas”, „közepes” vagy „alacsony” szinten teljesítő státuszba?

b) A DUE online tanulástámogató rendszerében rögzített hallgatói aktivitások közül melyek segítik elő a matematika tantárgyak teljesítését a legjobban? Rá tudunk-e mutatni olyan tevékenységekre, amik elősegítik a matematika tantárgyak teljesítését?

c) Vannak-e különbségek a DUE nappali és a levelező munkarendű, illetve a magyar és a külföldi hallgatók tanulási preferenciái között a tanítási–tanulási folyamat, a képzési tartalmak, tevékenységek, valamint az oktatási formák és módszerek tekintetében?

H1. Az előzetes elemzésekre és a hallgatói kérdőívekre (tesztre) adott válaszokra építve kapunk egy olyan mutatószámot a hallgatókhoz, ami alapján maximum 20%-os hibaaránnyal be tudjuk sorolni a matematika tantárgyak teljesítése szempontjából várhatóan „magas”, „közepes” vagy „alacsony” szintű státuszba.

H2. A tanulástámogató rendszerben rögzített hallgatói aktivitások elemzésével, illetve az azokat felhasználó predikciókkal tovább tudjuk növelni a matematika tantárgyak teljesítése szempontjából várhatóan „magas”, „közepes” vagy „alacsony” szinten teljesítő státuszba sorolás valószínűségi mutatóit.

H3. A tanulástámogató rendszerben rögzített hallgatói aktivitások elemzésével rálátunk arra, hogy a hallgatói aktivitások közül melyek vezetnek a legjobb hallgatói eredményekhez.

H4. Várhatóan különbségek vannak a nappali és a levelező munkarendű, illetve a magyar és külföldi hallgatók preferenciái között a tanítási–tanulási folyamat és módszerek tekintetében.

H5. A hallgatók várható teljesítési szintjének feltérképezésével és az azon keresztül történő támogatásával emelkednek a matematika tantárgyak teljesítési mutatói.

Egy tanítási-tanulási folyamatot annál jobban lehet támogatni, minél előbb és minél jobban megismerjük a tanulóinkat. A diagnosztikus értékelési módszerek egyik legfőbb célja, hogy olyan információkhoz juthasson a pedagógus, amik hagyományos mérésekkel nehezen elérhetőek (Csapó, 2018). A személyre szabott, differenciált oktatási stratégiák kialakításával nagyban fokozhatjuk a folyamat hatékonyságát, mellyel hozzájárulhatunk az intézményi teljesítménymutatók javításához.

7. Összegzés

Jelen dolgozatban bemutattuk, hogy a hipotézisekben megfogalmazott összefüggések beigazolásával avagy elvetésével hogyan juthatunk olyan stratégiai megfontolásokhoz, melyekkel feltérképezhetjük a hallgatók egyéni tanulási útját, és támogathatjuk őket a sikerhez vezető egyéni vagy közösségi tanulói aktivitásaikban.

Az eredmények segítségünkre lesznek a tananyagok olyan formátumú és struktúrájú kialakításában – akár munkarend vagy életkor, akár magyar-külföldi hovatartozás szerinti megkülönböztetésben –, melyet a hallgatók eredményesen használhatnak. A tanuláselemzési adatokból olyan előrejelzéseket tudunk kidolgozni, melyek segítségével ki tudjuk szűrni a hallgatói sikeresség, azaz a tantárgy teljesítésének szempontjából veszélyben lévő hallgatókat, és megfelelő támogatási módszerekkel jobb hallgatói eredményekhez juthatunk. Ezen felül az oktatókkal együttműködve optimalizálhatjuk az oktatási módszereket és a tanulási tevékenységeket a hallgatói létszámok mentén is, mellyel fokozzuk a tanulási élményt és motivációt. A hallgatói kérdőív és annak tanuláselemzéssel összekapcsolt használati metódusa olyan precedenst kíván megalkotni, mely segíthet a hallgatói lemorzsolódás csökkentésében, megelőzésében elsősorban hasonló képzési területeken.

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Rövid szakmai életrajz

Kocsó Edina a Dunaújvárosi Egyetem Tanárképző Központjában egyetemi tanársegédként dolgozik. A Tanárképző Központban feladata elsődlegesen a szakmai pedagógusok alap- és mesterképzésében a hallgatók pedagógiai digitális kompetenciáinak fejlesztése, digitális pedagógiával foglalkozó tantárgyak oktatása, valamint a több mint 200 szakoktató alapszakos hallgató mentorálása, tanulmányi előrehaladásának követése. Kutatásaiban oktatásmódszertani kérdéseket és a hallgatók sikerességének komponenseit, a lemorzsolódási kockázat összetevőit vizsgálja. Tanulmányainak gyökere ugyancsak a Dunaújvárosi Egyetem: főiskolai és mesterszakos tanulmányait is itt végezte. Jelenleg a Pécsi Tudományegyetem Oktatás és Társadalom Neveléstudományi Doktori Iskolájának doktorandusz hallgatója.

