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Hands-on Science

Science Education.
Resilience in challenging times

Edited by:

Manuel Filipe P. C. Martins Costa
Iryna Berezovska

Hands on Science

The Hand-on Science Network

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Foreword

Science Education. Resilience in challenging times

For several decades the today so-called artificial intelligence, AI, was used in scientific and technology research helping scientists in their painstaking work of unveiling and explaining the "mysteries" of our world, contributing to the development of our society and to a better life. Science technology and engineering greatly benefited from tools like neural networks or fuzzy logic for instance. Recently AI appears in front of our eyes with an extraordinary somewhat unexpected impact. However, now not only, or specially, for research and development purposes, but in a wide range of aspects of our everyday life. Often not to help investigators researchers and scholars to establish new knowledge, but simply to summate or reproduce, in a variety of ways, already published knowledge (certified or assessed and accepted, or not, unfortunately, being just published without filter or validation as it happens with the overwhelming amount of fake news or facts that are created everyday at alarming rates to serve dubious or twisted interests or purposes). The amount of information, reproduced or created, that is readily available effortlessly to everybody is amazing. That looks good and probably is, most of the time. However, is that information or knowledge curated or validated? if it is validated… by whom… or what? and specially, is the "reader"/user ready to critically analyze the information, data or knowledge received and either accept and consider it or else doubt it discuss it or even refuse it trying different sources and a sound validation?

There is no problem, on the contrary…, on having huge amounts of information, or to have "all" answers, readily available whenever needed, even if behind this profusion of AI providers there is "only" (or mostly…) greed and economic interest. The problem is to be trained to cope with it. And that's one of the major challenges the school and educators are having today. That's a huge task on these days of war conflict and utter disrespect of human' and peoples' rights, with raising self-centered autocracies undermining the role of dialog and disrespecting the concert of nations. Resilience is needed to all of us. The school already proved to be able to have it and raise to today' challenging circumstances.

The learning of science demands and induces critical spirit and reasoning, as well as hands-on methodic commitment of the students themselves, at the center of the learning process. Once more Science Education should be at the core of the school curriculum and practice not only by the knowledge but specially for the critical competencies it helps developing.

This book reunites a variety of diverse works in this line of thought presented at the 23rd International Conference on Hands-on Science, HSCI2026.

Braga, Portugal, June 19, 2026.

Manuel Filipe Pereira da Cunha Martins Costa
Editor in chief

FOREWORD

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Chapter 1: The Invisible Chemistry: The World of Smells

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Abstract. The main objective of this activity is to bring the chemistry of odors and volatile molecules closer to the general public, from young students to adults, by demonstrating that natural aromas are chemical compounds with specific structures, properties, and functions. The activity seeks to make accessible a fascinating invisible world that plays a fundamental role in biological and ecological interactions. Through this approach, participants discover that nature itself is chemistry in action. The activity consists of explaining and preparing a simple and safe cologne as a laboratory exercise suitable for primary school students. This hands-on experience introduces participants to the world of chemistry and odors, helping them understand how chemical compounds contribute to life and the natural environment. In addition to promoting scientific curiosity and experimentation, a key goal of the activity is to challenge the false opposition between "natural" and "chemical".

Keywords. Aerial chemical, molecules, nature, olfactory activities.

1. Introduction

Introducing the chemical science behind smells and olfactory perception through hands-on experiments is the central objective of this activity. By exploring the relationship between chemistry and the sense of smell, participants gain a better understanding of how volatile molecules interact with living organisms and influence our perception of the world.

The sense of smell, or olfaction, is the sensory system that enables humans and other animals to detect and identify odors. Olfaction occurs when airborne chemical molecules enter the nasal cavity and bind to specialized receptors located on olfactory sensory neurons. These receptors convert chemical information into electrical signals that are transmitted directly to the brain, where odors are identified and associated with emotions, memories, and behaviors.

According to the *Merriam-Webster Dictionary*, an odor is "a quality of something that stimulates the olfactory organ" and also "the sensation resulting from adequate stimulation of the olfactory organ" [1].

In scientific terms, odors arise from volatile chemical compounds that can be perceived by the olfactory system. The characteristic smell of a substance depends on the molecular structure of its volatile components and their interaction with olfactory receptors [2].

1.1. The Sense of Smell

The sense of smell performs several essential biological functions:

1.1.1. Flavor Perception

A large part of what we commonly describe as "taste" actually depends on smell [3]. Olfactory information combines with signals from the taste buds to create the perception of flavor. Without the contribution of olfaction, foods such as oranges, coffee, or chocolate would taste much less distinctive.

1.1.2. Safety and Survival

Smell serves as an important warning system by helping us detect potential hazards, including smoke from fires, gas leaks, spoiled food, and harmful environmental substances.

1.1.3. Connection to the Brain

Olfaction, the sense of smell or the act of smelling, is unique among the senses because it has direct neural connections to brain regions involved in emotion and memory, such as the limbic system.

This close relationship explains why certain smells can evoke vivid memories and strong emotional responses.

Understanding how odors are generated, detected, and interpreted provides an excellent opportunity to introduce students to chemistry, biology, and the scientific study of the natural world. Figure 1 shows the sense of smell.

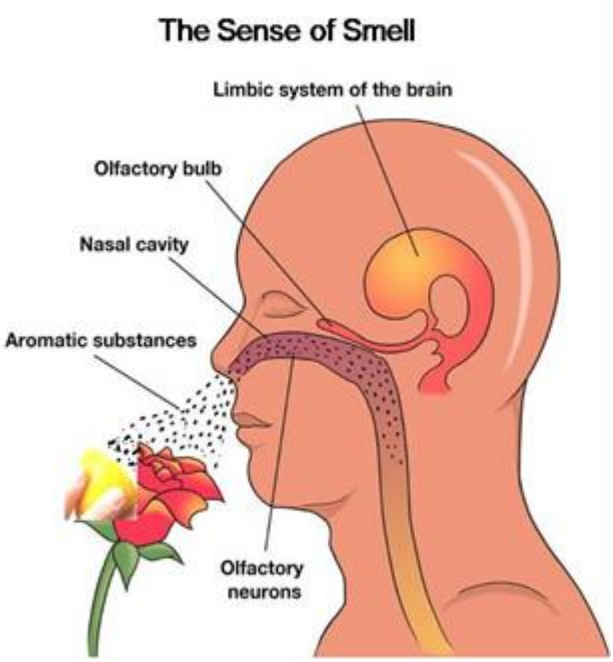

Figure 1. The sense of smell, modified from © 2026 Jodi Baglien Aromatherapy LLC

1.2. How the Sense of Smell Workst

The process of smelling begins when odor molecules travel through the air and enter the nose. These molecules may also reach the nasal cavity through the back of the throat while eating and drinking, contributing significantly to flavor perception.

1.2.1. Entry

Volatile molecules released from substances in the environment enter the nasal passages during breathing.

1.2.2. Detection

The molecules reach the olfactory epithelium, a specialized tissue located in the upper part of the nasal cavity. There, they bind to specific olfactory receptors found on sensory neurons. Each receptor responds to particular molecular features, allowing the detection of thousands of different odors.

1.2.3. Brain Processing

Once activated, the olfactory neurons generate electrical signals that travel to the olfactory bulb, where the information is organized and processed before being transmitted to other regions of the brain.

1.2.4. Reaction and Interpretation

The brain interprets these signals as recognizable smells and sends the information to areas associated with memory and emotion, particularly the limbic system. This direct connection explains why certain scents can instantly evoke vivid memories, emotions, or sensations.

The process can be summarized as follows:

Odor molecules → Olfactory receptors → Olfactory bulb → Brain interpretation → Sensations, memories, and emotions

The study of smell also includes topics such as olfactory memory, individual differences in odor perception, loss of smell (anosmia), the relationship between olfaction and health, and the influence of culture on how people perceive and interpret aromatic landscapes.

Scientific Basis of Odor Perception

For a substance to be smelled, some of its molecules must enter the air. However, aromatic molecules do not always evaporate with the same ease. Their ability to reach the nose depends on several factors, including their volatility, solubility, and affinity for the medium in which they are found.

An aromatic compound may be dissolved in water, oil, or alcohol, but only the fraction that escapes into the air can be detected by the olfactory system. For this reason, substances with highly volatile molecules generally produce stronger and more easily perceived aromas.

1.3. Every Odor Is Produced by Molecules

Participants will explore the fascinating world of volatile molecules: chemical substances that travel through the air and enable plants, animals, fungi, bacteria, and entire ecosystems to communicate, defend themselves, orient themselves, and interact.

This activity seeks to make visible an invisible reality, the vast aerial chemical network that sustains many of the interactions occurring in nature.

The scent of a forest, the fragrance of a flower, or the odor released by an alarmed animal are often experienced simply as smells. In reality, each of these odors is a chemical message produced by molecules with specific structures, physical properties, and biological functions.

These natural chemical signals are involved in: pollination and plant reproduction, defense against herbivores and pathogens, tracking and navigation, communication between organisms, decomposition processes, learning and memory, and even human health and well-being.

Through a combination of olfactory experiences, simple experiments, and scientific explanations, this activity transforms the molecular world into a tangible, engaging, and memorable learning experience.

Smell has a unique relationship with memory and emotions, making it a powerful educational tool. Participants leave with a deeper understanding of a fundamental scientific concept: the air around us is filled with chemical messages, and chemistry provides the key to understanding them.

1.4. A New Educational Experience

One of the major challenges in science education is increasing students' interest in chemistry and the natural sciences from an early age.

Most children have, at some point during their school years or while participating in workshops and holiday camps, created perfumes or colognes using flowers, plants, or citrus fruits such as lemons. This type of activity is both enriching and educational, providing valuable insights into chemistry, botany, and the life sciences. For this reason, the Official College of Chemists of Catalonia (COQC) [4] has developed this activity primarily for younger children, while ensuring that it can be adapted and expanded for students at higher educational levels.

This activity represents an innovative pedagogical approach that combines experimentation, sensory perception, and scientific inquiry to introduce young learners to the invisible world of odors.

The central objective is to explain and prepare a simple cologne through a safe and accessible laboratory activity designed for primary school students. By creating their own fragrance, participants are introduced to fundamental concepts of chemistry, including molecules, volatility, solutions, and natural aromatic compounds.

This educational experience was implemented in Catalan primary schools [5, 6] with students between 6 and 10 years of age. At this educational level, the activity encourages children to discover that odors are produced by molecules and that the air around them contains countless invisible chemical signals.

This activity combines chemistry, sensory perception, and environmental awareness, making scientific concepts accessible, engaging, and directly connected to everyday life. Through observation, experimentation, and discussion, students learn that chemistry is not limited to the laboratory but is present in every aspect of the natural world.

The same methodology has also been adapted for adult audiences, demonstrating that the chemistry of odors can serve as an effective and attractive gateway to science education for people of all ages. The outcomes of these experiences will be discussed in future work.

2. Nature is chemistry in action

The first stage of the activity introduces young students and adults to an immersive exploration of the invisible molecular world. Through simple explanations and experiments, particles, air currents, and molecules in constant motion are presented as fundamental components of our environment.

The objective is to understand that air is not empty space but rather a medium filled with chemical signals. Participants learn what volatile substances are, why certain molecules readily evaporate into the atmosphere, and how these molecules can reach the olfactory receptors of humans and other organisms.

The key message is that air serves as a medium for chemical communication, allowing organisms to exchange information without direct contact.

2.1. Plants communicate

Plants are often perceived as silent and passive organisms, yet they continuously produce and release a wide variety of chemical signals into the environment. The aromas emitted by flowers, leaves, fruits, and even wounded tissues are composed of volatile molecules that play important ecological roles. These chemical messages can:

- Attract pollinators such as bees and butterflies.
- Repel herbivores and harmful insects.
- Alert neighboring plants to environmental threats.

As part of the activity, participants prepare a simple cologne using aromatic plants such as lavender or thyme. Through this experience, they discover that plant odors are not merely pleasant fragrances but sophisticated chemical strategies related to defense, attraction, communication, and survival.

The workshop also introduces participants to the hidden chemical activity occurring beneath their feet. Soil is a living laboratory where roots, fungi, mycelial networks, and microorganisms constantly exchange chemical signals, creating complex interactions that sustain ecosystems.

A flower attracting a pollinator, a plant releasing alarm signals, or an insect following an aromatic trail are all examples of the same invisible communication system. By understanding these interactions, participants begin to appreciate that nature operates through an intricate network of chemical messages and that chemistry is an essential tool for understanding life on Earth.

2.2. Chemic animals

Animals also inhabit a world rich in chemical information. Many species rely on odors and volatile compounds to communicate, navigate, reproduce, and survive. Through pheromones, scent trails, territorial markings, and body odors, animals exchange information that is often invisible to human perception.

Chemical signals allow animals to: Find and recognize potential mates. Identify members of their own group or species. Mark territories and establish social hierarchies. Warn others of danger. Locate food sources and navigate their environment.

Examples range from the pheromones released by moths to attract partners over long distances to the extraordinary olfactory abilities of dogs, which can detect odors at concentrations far below human sensory limits.

This activity also connects these concepts to human biology. Although humans rely heavily on vision and hearing, body odors remain important indicators of identity, health, emotional state, and social interaction. Understanding the chemistry of body odors helps participants recognize that chemical communication is a fundamental aspect of life shared by many organisms.

Together, plants, animals, microorganisms, and humans participate in a vast network of chemical exchanges that shape ecological relationships and biological processes.

2.3. Applications of the Chemistry of Odors

The study of odors and volatile molecules has numerous practical applications that directly benefit society and the environment. Understanding how chemical signals are produced, transported, and detected allows scientists to develop innovative solutions in fields ranging from agriculture to medicine. Examples include:

- Improving food quality through the analysis of aroma compounds.
- Biological pest control using natural chemical signals.
- Early detection of diseases through volatile biomarkers present in breath, skin emissions, or other biological samples.
- Design of healthier indoor and outdoor environments.

- Development of chemical sensors and electronic noses.
- Monitoring and restoration of natural ecosystems.

These applications demonstrate how chemistry contributes to improving human well-being and environmental sustainability. The central message is that understanding the molecules that travel through the air can help us better understand, protect, and care for the world we inhabit.

Finally, participants discover how volatile molecules can be captured, separated, identified, and used. This stage of the workshop provides a highly interactive and experimental learning experience through simple, safe, and engaging laboratory demonstrations adapted to the general public.

By observing how scientists study odors and aromatic compounds, participants gain insight into the methods and tools used in modern chemistry. In this context, the College of Chemists plays a particularly important role by providing scientific guidance, professional expertise, and institutional support for educational outreach activities.

3. How to make cologne with aromatic plants

This educational activity combines chemistry, sensory perception, and environmental awareness, making scientific concepts accessible, engaging, and relevant to everyday life. The experiments were carried out in the classroom with primary school students aged 6–10 years.

During the activity, students are introduced to the concepts of volatility, evaporation, solubility, polarity, and affinity for different media. The following ideas are explained:

Water is a polar medium. It can dissolve substances such as salt and sugar. Its behavior can also be demonstrated through simple experiments, such as observing how a stream of tap water is deflected by a balloon charged with static electricity. Figure 2 shows that electrostatic attraction.

Oil is a non-polar medium and therefore dissolves different types of substances than water.

Alcohol has intermediate properties. It can dissolve many aromatic compounds found in plants and evaporates easily, making it an excellent solvent for preparing colognes and perfumes.

Figure 2. Photo provided by Zoe Fernández

Oil is a non-polar medium and alcohol has an intermediate behavior that allows it to dissolve many aromatic compounds and evaporate easily.

3.1. Thyme

Thymus vulgaris, commonly known as thyme, is a perennial Mediterranean shrub belonging to the mint family (Lamiaceae). It has small leaves that are dark green on the upper surface and whitish on the underside due to the presence of fine hairs. Its stems become woody as the plant matures.

Figure 3. Obtained from [7]

The flowers are pink to purple and grow in small clusters (Fig. 3). Under suitable conditions, thyme can flower for much of the year and typically reaches a height of 30–40 cm.

Uses: Medicinal: it has antiseptic, healing and expectorant properties, among others. It is one of the traditional condiments of Mediterranean cuisine (for meats, stews, soups, for marinating olives, etc.). In the field of perfumery it can be used to make cologne and soaps.

3.2. Lavender

Lavandula angustifolia, commonly known as lavender, is a perennial Mediterranean shrub belonging to the mint family (Lamiaceae), figure 4 and [8]. It has narrow, lance-shaped leaves and flowering stems bearing numerous bluish-violet flowers grouped together in spike-like inflorescences. The stems are characteristically square in cross-section, a typical feature of plants in this family. Lavender usually blooms in early summer and can reach a height of 0.30–1.0 m.

Figure 4. Obtained from [8]

Uses: Medicinal: Lavender has traditionally been valued for a variety of medicinal properties. It is commonly described as having:

- Tranquilizing and relaxing effects that may help promote sleep.
- Antispasmodic properties that can help relieve muscle tension.
- Mild antiseptic and disinfectant effects.
- Digestive benefits that may help alleviate minor digestive discomfort.

Lavender cologne has traditionally been used in massages and body rubs to help relieve fatigue and improve the sensation of poor circulation.

3.3. Thyme and lavender aromatic compounds

Thyme contains essential oils rich in aromatic compounds such as thymol. These compounds are more soluble in alcohol than in water. During maceration, the alcohol extracts the aromatic molecules from the plant tissues.

When the cologne is sprayed, the alcohol evaporates rapidly because of its high volatility, carrying the fragrance molecules into the air where they can be detected by our sense of smell.

Lavender is particularly suitable for classroom perfume-making activities because its flowers contain volatile aromatic compounds that are easily extracted by alcohol.

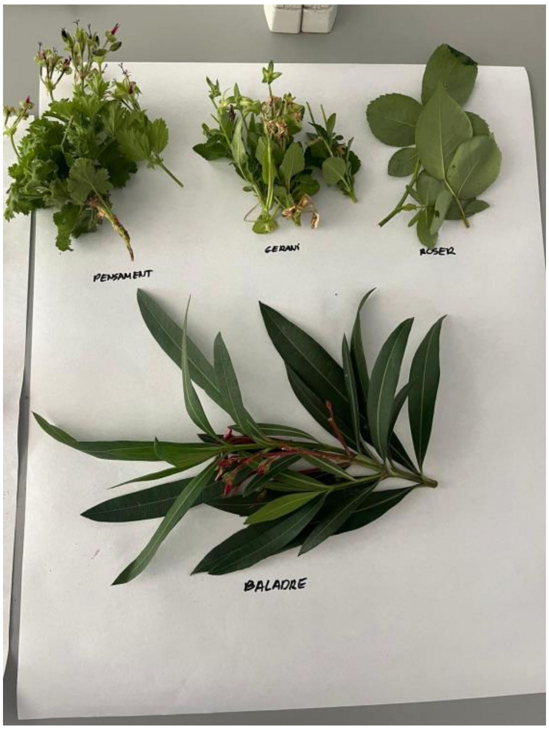

Figure 5. Plants and leaves of elm, geranium, rose and pansy

This activity helps students connect plant biology with chemistry concepts such as extraction, solubility, volatility, and evaporation, while also exploring the traditional and modern uses of aromatic plants. Figure 5 shows other plants used by students and adults to make perfumes and colognes, such as geranium, elderberry, rose and pansy.

4. Experiment making colognes

During the preparation of different colognes, students can observe how:

- Alcohol dissolves many fragrant substances present in the flowers.
- Aromatic molecules diffuse from the plant material into the solvent.
- The fragrance becomes noticeable when the alcohol evaporates and carries the scent molecules into the air.
- Different plants produce different aromas because they contain different chemical compounds.

4.1. Thyme and lavender colognes

To make cologne, we will macerate the plant in alcohol (thyme or lavender), figure 6 shows young students, aged nine to ten years old from a school in Barcelona, macerating the plants.

Through this process, the active principles of the plant that are soluble in alcohol are extracted, without using a heat source, as would be the case with distillation.

4.1.1. Materials

- Fresh thyme or lavender leaves and flowering stems
- Ethyl alcohol (70–96%, depending on availability and safety regulations)
- Small glass jar with lid
- Filter paper or coffee filter
- Funnel
- Small spray bottle or perfume bottle

Figure 6. Preparing a cologne in classroom

4.1.2. Procedure

1. Collect several fresh sprigs of thyme or lavender and gently crush the leaves to release their aromatic compounds.
2. Place the plant material in a glass jar.
3. Add enough ethyj alcohol (96%) to completely cover the thyme.
4. Close the jar and leave it in a cool, dark place for several days, shaking it gently once a day.
5. After 5–7 days, filter the mixture to remove the plant material.
6. Transfer the filtered liquid into a small spray bottle (Fig. 7).

During maceration, the plants are left to rest in alcohol that we have diluted with water (for each liter of water we put half a liter of alcohol). Normally, about 50 grams of plants are put per liter of diluted alcohol.

Figure 7. The students' cologne is now finished and ready to be used

For about 15 days, the bottle must be kept in a dark and dry place and the mixture must be stirred well to achieve maximum extraction of the active principles of the plants.

4.2. Create Your Own Floral Perfume

This simple activity allows students to discover where the scent of flowers is found and how different substances such as water, oil, alcohol, and air interact with aromatic molecules.

4.2.1. Material

- 1 cup of fresh flower petals with their centers (rose, jasmine, violet, lily, or...)
- ½ cup of water
- A microwave-safe container
- A bottle or jar for storing the fragrance
- Lemon cologne or 70% rubbing alcohol

4.2.2. Instructions

a. Prepare the Flowers

Remove the petals from the flowers and place them in a mortar. Gently crush them with a pestle to release their aromatic compounds and essential oils.

Figure 8, Different flower petals to obtain perfumes and colognes

b. Make the Infusion

Pour the water over the petals and heat the mixture in the microwave for about 20 seconds, or until the water begins to take on the color of the flowers.

c. Filter the Mixture

Strain the liquid through a fine sieve or filter paper to remove the petals and obtain the scented infusion.

d. Fix the Fragrance

Add a few drops of lemon cologne or a small amount of 70% alcohol. The alcohol helps preserve the perfume and improves the release of aromatic molecules.

e. Store the Perfume

Pour the liquid into a clean, airtight bottle. Leave it in a cool place for at least 24 hours before use. During this time, the different aromatic compounds blend and the fragrance becomes more balanced. Figure 8 shows some examples of flowers that were used by students to obtain smells.

4.2.3. Tips for a Stronger and Longer-Lasting Perfume

- Choose fresh, high-quality flowers. Fresh petals contain more aromatic compounds.
- Add a natural fixative. A few drops of glycerin or vanilla essence can help slow down evaporation and retain the fragrance longer.
- Combine different flowers. Mixing floral scents can create more complex and pleasant perfumes.
- Allow the perfume to mature. Storing it in a cool, dark place for at least 24 hours helps the aromas develop.
- Use a dark glass bottle. Amber or blue glass protects the perfume from light, which can degrade some aromatic compounds.

5. Conclusions

This activity demonstrates that a smell does not depend solely on the aromatic molecule itself, but also on the medium in which it is found. For a fragrance to be perceived, aromatic molecules must be able to escape from the liquid or material that contains them, enter the air, and reach the nose.

Different media influence this process in different ways. Alcohol releases many aromatic molecules quickly and intensely because it evaporates easily. Oil can retain many fat-soluble compounds, often producing a fragrance that is less intense initially but more persistent over time. Water behaves differently depending on the solubility of each aromatic compound. Therefore, the medium does not simply “carry” the aroma; it regulates its intensity, the speed at which it is released, and its duration.

Students from Primary Education (6–10 years) can compare the same scent mixed with water, alcohol, and oil. They smell the fraction of that molecule that succeeds in escaping from its environment and reaching the air. The perception of a scent depends not only on the molecule itself but also on where it is found and how it is released.

As in [9, 10] to promoting scientific curiosity, observation, and experimentation, this activity helps students understand the relationship between chemistry and everyday life. The Official College of Chemists of Catalonia (COQC) has developed this activity primarily for younger children, while ensuring that it can be adapted and expanded for students at higher educational levels.

Nature is not the opposite of chemistry; rather, chemistry helps explain how nature works.

Through these activities, students learn that:

- Plants contain aromatic substances that can be extracted.
- Different substances dissolve better in different solvents.
- Alcohol acts as a solvent and facilitates the extraction of fragrances.
- Evaporation allows scent molecules to disperse through the air.
- The perception of a smell depends on both the aromatic molecule and the medium in which it is found.
- Many perfumes and colognes are produced using principles similar to those explored in these experiments.
- Scientific concepts such as solubility, polarity, volatility, and diffusion can be observed through familiar materials and everyday experiences.

A central objective is to challenge the widespread misconception that “natural” and “chemical” are opposed concepts. Through direct experimentation, participants discover that natural substances are themselves composed of chemical compounds and that chemistry is one of the most powerful tools for understanding living organisms and the natural world.

6. Acknowledgements

We thank the teaching staff and children from Catalan Primary schools who have participated in these adventures. This activity was supported by the Professional College of Catalan Chemists (COQC).

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Chapter 2: Chemistry of Cleaning

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Abstract. Cleaning is a fundamental activity in human societies. Beyond aesthetic considerations, the removal of dirt and contaminants is essential for preventing the growth and spread of pathogenic microorganisms, thereby contributing significantly to public health and well-being. Cleaning also plays a crucial role in technological and industrial development, as virtually all manufacturing and production processes require some form of cleaning to ensure product quality, safety, and efficiency. The diversity of materials, surfaces, and contaminants encountered in everyday life has led to the development of a wide range of cleaning products, each designed for specific applications. Different types of dirt, including grease, mineral deposits, organic residues, and microbial contamination, require different cleaning strategies and chemical formulations. The activity consists of explaining and preparing one kind of soap as a laboratory exercise suitable for school students and adults. This hands-on experience introduces participants to the world of chemistry and clean, helping them understand how chemical compounds contribute to life and the natural environment. As a result, cleaning represents a broad and important field of application of chemistry.

Keywords. Cleaning, environmental, health, soap, technology.

1. Introduction

Cleaning constitutes a fundamental aspect of human societies. Beyond mere aesthetic considerations, the removal of dirt and contaminants is essential for preventing the proliferation and transmission of pathogens, thereby safeguarding public health. Effective cleaning practices play a decisive role in reducing the incidence of infectious diseases and in maintaining hygienic conditions in both private and public settings. Furthermore, cleaning is indispensable to technological and industrial increase; quality-control processes require the systematic elimination of impurities from surfaces and materials.

Throughout history, cleaning practices have undergone profound transformations. Whereas early methods relied primarily on natural substances such as water, ash, and plant-derived compounds, contemporary cleaning largely depends on synthetic agents specifically formulated to maximize efficiency and safety.

Figure 1. Authors' photo of medieval washhouse in Cefalú

Modern cleaning products typically contain chemically engineered substances developed through extensive research and innovation. In recent decades, increasing environmental awareness has prompted the industry to prioritize the development of formulations that are not only highly effective but also less detrimental to ecosystems and human health.

The diversity of surfaces requiring cleaning ranging from domestic environments to complex industrial systems together with the wide array of contaminants, including organic matter, grease, mineral deposits, and microorganisms, underscores the breadth and complexity of this field. Consequently, cleaning represents a significant domain of application for chemistry.

The efficacy of cleaning agents is determined by their physical and chemical properties, such as solubility, polarity, and reactivity, as well as their capacity to interact with and remove specific types of substances. A thorough understanding of these properties enables the design of targeted and optimized cleaning solutions.

Soap is something we use every day, but have you ever wondered how it is made? Many children and adults enjoy playing with soap bubbles and observing the beautiful colors that appear when light shines on them. Fig. 2 The figure shows a photo obtained from the website of the Hands on Science network. Soap also plays an important role in keeping our hands and bodies clean.

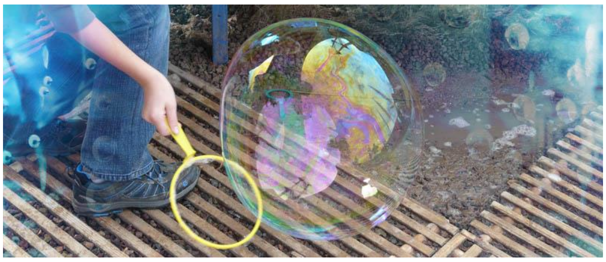

Figure 2 Playing with soap bubbles

Before commercial soaps were widely available, many families made their own soap at home using leftover cooking oil and other fats. This process allowed them to recycle materials while creating a useful product. Making soap is an excellent way to explore chemistry, sustainability, and traditional household practices.

In addition to its scientific and technological relevance, the chemistry of cleaning provides an excellent context for science education.

At the Official College of Chemists of Catalonia (COQC) [1], we have designed this activity to help secondary school students investigate the science behind soap making through hands-on learning. By making soap in the classroom and at home, students can discover how everyday materials are transformed through a chemical reaction and learn about the importance of reducing waste and reusing resources.

Making homemade soap was initially implemented in Catalan secondary schools with students aged 14–18 years working in small groups [2, 3]. Students participated in activities to obtained soap and some related to the chemistry of cleaning, including the analysis of cleaning products, the investigation of their chemical components, and the communication of scientific information through collaborative projects. Finally, the same approach was implemented with adult learners, highlighting its adaptability to different educational contexts and age groups.

The results obtained suggest that learning chemistry through everyday cleaning processes increases student engagement and facilitates the understanding of fundamental chemical concepts. Finally, the chemistry of cleaning can be used as an effective tool for science education and communication.

2. Cleaning Chemical compounds

Cleaning chemical compounds are formulated to break down dirt, disinfect surfaces, and dissolve stains.

2.1. Surfactants

Water is a highly polar solvent and is therefore particularly effective at dissolving polar compounds. However, it is ineffective at dissolving hydrophobic (non-polar) substances such as oils and greases. In these cases, the presence of surfactants is essential.

Surfactants are organic amphiphilic molecules, meaning that they contain both hydrophilic (water-attracting) and hydrophobic (water-repelling) regions within the same structure (Fig. 3). When dissolved in water, surfactants preferentially adsorb at interfaces, such as the liquid–air interface, where they reduce the surface tension of water.

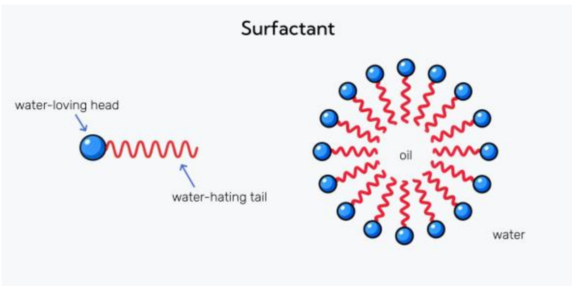

Figure 3. Surfactant

Surfactant hydrophobic regions interact with non-polar substances, such as oils and greases, while their hydrophilic regions remain in contact with the aqueous phase. As a result, hydrophobic contaminants become incorporated into the core of micelles and can be dispersed in water, allowing their efficient removal during rinsing.

Surfactants are generally classified according to the nature of their hydrophilic group, whereas their hydrophobic portion typically consists of long hydrocarbon chains or aromatic groups.

Anionic surfactants are characterized by the presence of a negatively charged hydrophilic group and they are the most widely used class of surfactants in household and industrial cleaning products. Cationic surfactants possess a positively charged hydrophilic group. They are employed in disinfectants and antiseptics.

2.2. pH based reactions

2.2.1. Acidity

Acids play a significant role in cleaning processes and are widely employed for the removal of a variety of unwanted substances, (review acid and alkali chemistry in any chemistry textbook [4, 5]). One of their most important applications is the dissolution of metal oxides, commonly known as rust. These oxides often form adherent and poorly soluble layers on metal surfaces, making their mechanical removal difficult. When treated with acids, metal oxides react with hydronium ions to form soluble metal ions, which can subsequently be removed by rinsing.

A general reaction for the dissolution of a metal oxide of a monovalent metal may be represented as:

$$M_2O(s) + 2\ H_3O^+(aq) \rightarrow 3\ H_2O(l) + 2\ M^+(aq)$$

Some specific examples include:

$$FeO(s) + 2\ H_3O^+(aq) \rightarrow 3\ H_2O(l) + Fe^{2+}(aq)$$

$$Ag_2O(s) + 2\ H_3O^+(aq) \rightarrow 3\ H_2O(l) + 2\ Ag+(aq)$$

The concentration of the acid and the duration of exposure must be carefully controlled, as acids may also react directly with certain metals, leading to corrosion and material degradation. For this reason, weak organic acids are often preferred in commercial cleaning formulations because they provide an appropriate balance between cleaning efficiency and material preservation.

Acids are also extensively used for the removal of limescale deposits from pipes, household appliances, and hard surfaces. Limescale consists primarily of calcium carbonate formed through the precipitation of dissolved minerals present in hard water. Upon treatment with an acid, carbonate ions are converted into carbon dioxide gas, while calcium ions remain dissolved in solution:

$$CaCO_3(s) + 2\ H_3O^+(aq) \rightarrow$$

$$Ca^{2+}(aq) + CO_2(g) + 3\ H_2O(l)$$

The release of carbon dioxide (CO2) is often observed as effervescence during the cleaning process.

Common acids used in cleaning products include hydrochloric acid, acetic acid, and organic acids such as citric or propanoic acid.

2.2.2. Alkalinity

A large proportion of cleaning products are formulated to exhibit an alkaline pH. However, this does not necessarily imply that their cleaning action is directly attributable to their basicity. For example, soaps are alkaline substances, yet their cleaning effectiveness primarily arises from their amphiphilic molecular structure rather than from their pH.

The direct cleaning action of alkaline substances (bases) is particularly important in the removal of fats and oils. These substances are largely composed of triglycerides and fatty acids, which can react with strong bases under sufficiently alkaline conditions. At high pH values, fatty acids are converted into their corresponding carboxylate salts, which are considerably more soluble in water.

A particularly important process is the alkaline hydrolysis of triglycerides, known as saponification [5]. During this reaction, ester bonds are cleaved by hydroxide ions, producing glycerol and the salts of fatty acids, commonly known as soaps:

$$\text{Triglyceride} + 3\ OH^- \rightarrow$$

$$\text{Glycerol} + 3\ \text{Fatty Acid salts}$$

The resulting fatty acid salts are amphiphilic molecules capable of forming micelles and emulsifying hydrophobic substances so, greasy residues become dispersed in water and can be removed during rinsing.

Saponification represents one of the most important chemical processes underlying the effectiveness of alkaline cleaning agents.

2.3. Oxidizing Agents: Bleaches

Oxidizing agents are highly effective at degrading complex organic molecules found in dirt, stains, and biological residues. Through oxidation, these substances are transformed into smaller, more polar, and more water-soluble compounds, facilitating their removal during rinsing.

Bleaching agents also possess significant antimicrobial properties. Their strong oxidizing capacity enables them to damage essential cellular components, including proteins, lipids, and nucleic acids, thereby inhibiting microbial growth and survival. Consequently, bleaches are widely used for the disinfection of surfaces, particularly in healthcare facilities, food-processing environments, and water treatment systems.

Commercial bleaching products are available in both liquid and solid formulations and are frequently incorporated into multi-component cleaning products. According to their active oxidizing species, bleaches are generally classified into two major categories: chlorine-based and oxygen-based systems.

Chlorine-based bleaches derive their oxidizing power from chlorine-containing species capable of undergoing changes in oxidation state. The most common chlorine-based bleach is sodium hypochlorite ($NaClO$), the active ingredient in household bleach solutions. To maintain chemical stability, sodium hypochlorite must be stored under strongly alkaline conditions, typically at a pH close to 11. Under acidic conditions, hypochlorite ions become protonated to form hypochlorous acid:

$$ClO^{-}(aq) + H_3O^{+}(aq) \rightarrow HClO(aq) + H_2O(l)$$

DANGER Hypochlorous acid may subsequently react with chloride ions in acidic media to generate chlorine gas, a highly toxic and corrosive substance: For this reason, bleach must never be mixed with acidic cleaning products.

Oxygen-based bleaches are extensively used in laundry detergents, dishwasher formulations, and environmentally friendly cleaning products. The simplest example is hydrogen peroxide (H_2O_2), which exhibits enhanced oxidizing activity under alkaline conditions. In basic media, hydrogen peroxide behaves as a weak acid and forms the perhydroxide ion, which is largely responsible for its bleaching activity.

Overall, oxidizing agents represent one of the most important classes of cleaning chemicals. Their ability to remove stains, destroy microorganisms, and degrade organic contaminants makes them indispensable in domestic, industrial, and healthcare applications. Understanding the chemistry underlying bleaching processes provides valuable insight into both their effectiveness and their safe use.

2.4. Enzymes

Enzymes are biological macromolecules, primarily proteins, that function as catalysts by accelerating chemical reactions without being consumed in the process. In cleaning applications, enzymes are employed to degrade complex organic substances present in dirt and stains. Many of these substances consist of large macromolecules that exhibit limited solubility in water. Through enzymatic hydrolysis, these compounds are converted into smaller, more hydrophilic molecules, thereby increasing their solubility and facilitating their removal during washing and rinsing.

Although enzymes are generally highly specific catalysts, detergent formulations often contain mixtures of enzymes with complementary substrate specificities. This approach enables the efficient removal of a broad spectrum of stains originating from fats, proteins, carbohydrates, and other biological materials. Accordingly, enzymes used in cleaning products are commonly classified according to the type of substrate they degrade.

Lipases catalyze the hydrolysis of triglycerides, the principal constituents of fats and oils, yielding glycerol and free fatty acids:

$$\text{Triglyceride} + 3\ H_2O \rightarrow \text{Glycerol} + 3\ \text{Fatty Acids}$$

Proteases catalyze the hydrolysis of peptide bonds, breaking proteins into smaller peptides and individual amino acids.

Cellulases and amylases catalyze the hydrolysis of polysaccharides, although they act on different substrates. Cellulases degrade cellulose, the structural polysaccharide present in plant cell walls, whereas amylases hydrolyze starch, a major storage carbohydrate found in many foods.

The use of enzymatic technology not only improves cleaning performance but also contributes to sustainability objectives by reducing the need for high washing temperatures and aggressive chemical treatments.

3. Homemade Soap: Step-by-Step Preparation

Soap is chemically defined as a water-soluble salt of a long-chain fatty acid. Soap making is based on one of the oldest known chemical reactions: saponification, in which fats react with a strong base to produce soap and glycerol.

Triglyceride + 3 OH^- →

Glycerol + 3 Fatty Acid salts

Fat + NaOH → Glycerol + Soap

Glycerol remains partially dissolved in the aqueous phase and may be recovered in industrial processes for use in cosmetics and pharmaceuticals.

Historically, soap production dates back to ancient civilizations such as the Greeks and Romans, and it has evolved from artisanal methods using natural ashes and fats to modern industrial processes. Today, soap remains one of the most effective agents for removing grease and dirt due to its amphiphilic molecular structure.

In this activity, we make soap using a method similar to the one our grandmothers and great-grandmothers used at home. This traditional practice allows us to connect science with everyday life and to explore how people reused household materials long before modern recycling programs existed. Figure 4 shows the diagram of the entire process in drawings [6].

Figure 4 Homemade Soap [6]

3.1. Materials

- 600 g of oil (used or fresh cooking oil, or mixtures with coconut, almond, or other vegetable oils)
- 80 g of sodium hydroxide (NaOH, caustic soda)
- 200 mL of water
- Optional additives: essential oils, natural colorants, coffee, herbs, coconut, etc.

(Authors' note: These are only indicative values for the amounts of reagents; you can also obtain soap with other quantities as long as the relationship between oil, caustic soda and water is maintained 15/2/5)

3.2. Procedure

1. Pour 200 mL of water into a heat-resistant glass jar.
2. Ensure the workspace is well ventilated. If possible, use an extraction hood, as the reaction may release heat and vapours.

3. Gradually add 80 g of sodium hydroxide to the water (**never add water to NaOH**). Stir continuously with a wooden spoon until fully dissolved (Fig. 5). *This step is highly exothermic, and the solution will heat up significantly.*

Figure 5. NaOH on H_2O

4. Allow the solution to cool to approximately 40 °C.
5. In a separate container, gently heat 600 g of oil.
6. Once both mixtures are at suitable temperatures (around 35–40 °C), slowly pour the sodium hydroxide solution into the oil.
7. Mix thoroughly using a spoon for a few seconds, then blend with a hand mixer until the mixture reaches a thick, pudding-like consistency (Fig. 6).

Figure 6. Mix with the mixer

8. Add optional ingredients such as fragrances, colorants or additives.
9. Pour the mixture into molds. Handle with care and use protective materials, as the mixture remains caustic at this stage (Fig. 7).

Figure 7. Soap molds

10. Allow the soap to rest in a dry place for approximately 24 hours until it solidifies.

After 24 hours, the soap can be removed from the mold and cut into pieces if necessary. It should then be left to cure in a dry, ventilated environment for 3–4 weeks. During this time, residual sodium hydroxide (NaOH) is fully consumed, and the pH stabilizes, making the soap safe for use (Fig. 8).

Figure 8. Pieces of soap made by high school students in different workshops

3.3. Safety Considerations

Sodium hydroxide is a highly corrosive substance. It can cause severe chemical burns and releases heat when dissolved in water. For this reason, strict safety precautions must be followed:

- Always wear gloves and protective goggles
- Use long sleeves and avoid skin exposure
- Add sodium hydroxide slowly to water (never the reverse)
- Work in a well-ventilated area
- Avoid inhaling vapours or aerosols

Proper handling ensures that homemade soap production is a safe and educational chemical experiment.

3.4. Environmental and Educational Value

Homemade soap production offers several advantages:

- Reduction of waste through reuse of cooking oils
- Decreased reliance on industrial packaging
- Hands-on understanding of a fundamental chemical reaction
- Promotion of sustainable and conscious consumption practices

When working with students, we adapt the scientific explanations to each educational level, helping them understand the chemical processes involved in soap making and the properties that make soap an effective cleaning agent. Through hands-on experimentation, students can observe how raw materials are transformed into a useful product.

The same methodology has also been adapted for adult audiences, demonstrating that the soap chemistry can serve as an effective and attractive gateway to science education for people of all ages.

6. Conclusion

Cleaning is a complex and multifaceted field due to its broad scope and the diversity of materials and contaminants involved. At its core, however, it consists of the removal of unwanted substances through processes that promote their detachment from surfaces, most commonly by enhancing their solubility or dispersibility in a liquid medium.

The mechanisms underlying cleaning processes allow for the classification of cleaning agents according to their mode of action.

Some agents rely primarily on physical and physicochemical interactions, such as solubilization, emulsification, and dispersion, as is the case with surfactants and certain organic solvents.

Other agents act through chemical transformations, in which the structure, polarity, or composition of the contaminant is altered, often leading to its degradation into smaller and more water-soluble species.

Current research efforts increasingly focus on the development of more sustainable, biodegradable, and low-toxicity alternatives, as well as on improving energy efficiency and reducing chemical waste throughout the cleaning cycle.

Although numerous substances are employed in cleaning processes, their effectiveness is ultimately determined by their physical and chemical properties.

During the preparation of different soaps, students can understand concepts such as solubility, polarity, surface tension, acid–base behavior, oxidation–reduction reactions, and intermolecular interactions.

These concepts play a central role in the design and performance of cleaning agents. Understanding these principles provides valuable insight into how cleaning products function and highlights the essential contribution of chemistry to everyday life.

By using cleaning as a central theme, students can better understand the practical applications of chemistry and appreciate its importance in daily life.

In workshops held at civic and community centers, many adult participants remember themselves making soap with their families. These memories provide an excellent opportunity to compare traditional knowledge with modern scientific understanding.

Together, we can discuss how chemistry has advanced over time, improving our understanding of chemical reactions, materials, safety, and environmental sustainability while still relying on the same fundamental principles used generations ago.

As in [7, 8] to promoting scientific curiosity, observation, and experimentation, this activity helps students understand the relationship between chemistry and everyday life.

Activities such as soap making also help challenge common misconceptions and highlight the positive role that chemistry plays in solving everyday problems and improving our quality of life.

By connecting chemistry to familiar activities such as soap making, we aim to help participants appreciate its value and to challenge the negative image that chemistry is sometimes perceived to have. Rather than being something distant or artificial, chemistry is a science that is present in many aspects of our daily lives.

7. Acknowledgements

We thank Mateu Montserrat, university student, for his important contributions to this work. We thank the teaching staff and children from Catalan Secondary schools and participants in community centers who have participated in these adventures. This activity was supported by the Professional College of Catalan Chemists (COQC).

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Chapter 3: The Power of STEM Learning in Play

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Abstract. The development of basic STEM is instinctively achieved if a child has access to objects, often toys made for them, sometimes reflecting cultural items. The use of objects in play is an important but neglected area of study but the Power of Play in developing emotional and social skills is recognized. We now urge practitioners of STEM to recognise the skills' development that occur in a child's free choice play form their earliest years.

Keywords. Play, toys, objects, skills, free choice, integrate.

1. Introduction

Play has a powerful role in the social and emotional development of young children (Ang et al., 2025). The first 1,000 days from conception are now recognised as a critical period in development, including cognitive learning (Abbott and Langston, 2005). A foundation for the future is laid, including, we believe, the basic skills of STEM and foundational understanding and experiences. However, some educators have resisted the idea of teaching science and recognising engineering in preschool, although basic mathematics has traditionally been advocated during that period (Areljung, 2019).

The increasing use of the term STEM (Science, Technology, Engineering and Mathematics) has become more common in pedagogy in the first quarter of the 21st century, as the need for a skilled workforce to address challenges such as climate change, emerging technologies, and economic pressures has grown.

The children observed were from birth to three years of age. Gelman and Brenneman (2004) acknowledged children's construction of understanding as they interacted with objects. Hands-on experiences enabled children to build on existing knowledge and share skills across learning. Everyday science in action with pre-pre-schoolers, described as "small science," was identified by Sikder and Fleer (2015). Areljung et al. (2023) viewed children's physics learning as emerging from everyday movements such as climbing. Preschool children's learning and thinking are comparable to the mental deliberations of scientists (Gopnik, 2012) and involve discovering fundamental mathematics and engineering concepts through their own experiences and progressive understanding, including free-choice interactions with three-dimensional objects, often toys.

Krapp's (1999) theory of situational interest applies to children's free-choice play, as they construct understanding from what interests them. However, there is an observable sequence in children's interactions in spontaneous play of their own choice, as observed in school settings (Milford and Tippett, 2015) and in inquiry-based science learning sequences (Constantiou et al., 2018).

In these earliest years, the ability to recognise small numbers of objects is instinctive, as is the recognition of collections of up to four items (Butterworth, 2000). Everyday observations of physics in action have been referred to as folk physics (Falk, 2025, p. 6).

2. A *Power of Play* Experiment in England

The author was asked by the priest of the local Church of England to help at the regular Mother and Toddler Group. This was a church-run playgroup for parents, particularly homebound mothers, children, and local carers attending during term time. Observations were made over six years at weekly term-time sessions. An enhanced DBS check (a certification of no criminal record in the UK) was required, and the Church of England safeguarding principles were followed. Parents completed consent forms and indicated whether recognisable photographs of their child could be taken.

No direct scaffolding interactions with the children were made; only anonymous observations were conducted, although parents or carers did periodically interact, most often to instruct the child on what to do and to repeat aloud numbers or letters relevant to the play interaction.

None of the children were alone; all were with their responsible adult. After play items were set up according to the age of the children, all participants were under three after the first two years, as older children moved on to formal preschool.

Observations of the children involved free-choice play. Field notes were kept, and observations were written up afterwards. Using grounded theory, STEM actions, such as pushing, and stages of engagement similar to those of IBSE were identified. However, play is not a uniform activity. It is progressive and incremental in both understanding and the ability to actively inquire. Hence, the play-STEM sequence identified is not completed at once by the youngest learners but develops incrementally over time through hands-on, free-choice interaction.

3. Conclusion

Our observations in South England show that free-choice play have a crucial role in the development of STEM understanding, as well as in the development of fundamental language awareness and recognition of culture in everyday life.

We identified a pattern in children's free-choice toy play. The STEM actions followed a sequence of identifiable stages formulated in the Play Cycle (Tunnicliffe, 2022). Moreover, the first stage in achieving STEM actions and understanding through playing with toys is called STEM-E, where "E" stands for experiences (Tunnicliffe, 2022). Once this is achieved, free-choice play in which the child's interest is engaged allows the learner to develop STEM competence, and the interaction sequence resembles that of inquiry-based science education (IBSE).

There are implications for training and development in early STEM practice. This highlights the **power of play** in STEM learning.

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Chapter 4: Value Orientations as a Predictor of Interest in STEM Careers Among Students at Technical Universities

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Abstract. The article investigates value orientations as a predictor of interest in STEM careers among students of technical universities. The relevance of the increasing need for highly qualified specialists for the digital transformation and restoration of Ukraine. The aim is to substantiate the role of values in the formation of professional motivation and resilience of future engineers. The empirical study covered 245 students, using standardized methods and statistical analysis. The results showed that a balanced profile (“Benevolence”, “Security”, “Independence”, “Achievement”) explains up to 38% of the variation in motivation and self-actualization. Practical significance is created in the implementation of value diagnostics for career guidance and adaptive educational programs.

Keywords. value orientations, STEM careers, predictors of interest in a profession, self-actualisation, career guidance.

1. Introduction

In the current context of global digital transformation, innovative economic development and Ukraine’s post-war recovery, the issue of training highly qualified specialists in STEM fields is taking on strategic national importance. Interest in STEM careers and the resilience of future engineers, programmers and technologists in their professional development are largely determined not only by the level of knowledge and cognitive abilities, but also by deep-seated personal value orientations, which form the motivational basis for the choice, duration and quality of professional fulfilment. Despite numerous studies on the professional self-determination of young people, the question of the predictive role of value orientations specifically regarding interest in technical specialisations at domestic technical universities remains insufficiently theoretically grounded and empirically verified.

The theoretical and methodological analysis of the problem draws on classical and contemporary psychological approaches. Humanistic psychology (A. Maslow, V. Frankl) regards the value sphere as the core of self-actualisation and the search for meaning in life. The structural models of M. Rokich and S. Schwartz allow values to be differentiated according to motivational types and their hierarchical organisation. Domestic researchers (I. Bekh, S. Maksymenko, A. Kurbatova, L. Romanyuk, Y. Shaygorodskyi, A. Kaplienko) focus on the sociocultural determination of value orientations and their role in professional self-determination, particularly in crisis situations. At the same time, the vast majority of empirical studies focus on general patterns or students of humanities disciplines, whereas the specifics of value profile formation at technical universities and their link to interest in STEM careers require a separate, comprehensive study.

2. Summary of the main content

The issue of value orientations as a predictor of interest in STEM careers among students at technical universities requires a comprehensive theoretical and methodological foundation, taking into account both classical and contemporary psychological approaches. Humanistic psychology regards the value sphere as the core of personal development and professional formation. A. Maslow [10], in his theory of motivation, emphasises that self-actualisation, as the highest ‘value of being’, is realised through the pursuit of truth, beauty, perfection and justice. In the context of STEM careers, this is directly linked to the need for engineers and technologists to engage in constant creative exploration, develop innovative solutions and refine technologies. Students of technical disciplines who are highly oriented towards self-actualisation are more likely to show a sustained interest in complex projects in aviation, mechanical engineering, information technology and energy.

In logotherapy, V. Frankl interprets values as an objective phenomenon that gives life meaning through three main pathways: creative activity, experience, and attitude towards inevitable suffering. For future engineers, this means the ability to find deep meaning in creating technologies that improve the quality of life in society, particularly in the context of Ukraine's post-war reconstruction. M. Rokich [11] classifies values as terminal (ultimate life goals) and instrumental (means of achieving goals). In technical education, terminal values such as 'interesting work', 'freedom' and 'independence' often become the driving force behind the choice of a STEM specialism, whilst instrumental values such as 'responsibility', 'honesty' and 'perseverance' determine academic success and subsequent professional activity.

S. Schwartz [12] developed a universal model of values comprising ten motivational types, organised into a circular structure with two main dimensions: 'openness to change – conservatism' and 'self-enhancement – self-transcendence'. For students at technical universities, the values most predictive of an interest in a STEM career are 'autonomy' (independent thinking and choice of actions), 'stimulation' (a desire for novelty, challenges and change), 'achievement' (success in accordance with social standards) and 'security' (stability, harmony and protection). These values form a solid motivational foundation for sustained work in conditions of high uncertainty, characteristic of modern technological projects. At the same time, the values of 'friendliness' and 'universalism' ensure the ability to work effectively in teams within interdisciplinary engineering groups.

Domestic psychological science significantly enriches our understanding of this issue. I. Bekh [1] views spiritual values as idealised benchmarks that shape the 'spiritual self' of the individual and influence professional self-determination. S. Maksymenko [3], in a genetic-psychological concept, emphasises that the value sphere is a dynamic structure that is formed and transformed under the influence of internal and external factors throughout ontogenesis. A. Kurbatova [2] focuses on value-semantic regulation as a mechanism of professional self-determination, particularly in crisis situations. L. Romanyuk [7] and Y. Shaygorodskyi [8] emphasise the social nature of the value sphere, which is formed through the individual's interaction with educational institutions, professional communities and society at large. A. Kaplienko [9] directly analyses the interconnection between the professional and value orientations of higher education students in contemporary conditions.

The factors shaping the value orientations of students at technical universities are multifaceted. Social factors include the influence of family, peers, societal expectations and the context of the war. Psychological factors encompass intrinsic motivation, emotional state, self-esteem and prior experience. Cultural factors are linked to Ukrainian traditions, globalisation and digitalisation. Educational factors play a leading role in technical universities: lectures, laboratory work, coursework and dissertation projects, as well as participation in research societies and start-ups, actively shape the values of achievement, motivation and independence. Individual factors (personality traits, cognitive styles, interests) determine the individual variability of profiles. Taken together, these factors form the basis for certain value orientations to become reliable predictors of interest in STEM careers and career persistence.

An empirical study was conducted on a representative sample of 245 students aged 18–23, with stratified selection by gender and specialisation (psychology — Group 1, socio-economic specialisations — Group 2, technical specialisations — Group 3). Standardised psychodiagnostic methods were used, followed by statistical data analysis in SPSS (descriptive statistics, correlation, factor and regression analysis, Student's t-test, ANOVA).

Students in technical disciplines (Group 3) are characterised by a clearly defined, balanced value profile, which distinguishes them from other groups and makes their orientations a reliable predictor of sustained interest in a STEM career.

Table 1. Descriptive statistics on the value orientations of students in technical disciplines (Group 3) based on the Schwartz Questionnaire

Value	Medium (M)	Standard deviation (SD)	Median	Mode	Min	Max
Power	4.12	1.71	4.0	4	1	7
Achievements	5.56	1.87	6.0	6	2	7
Hedonism	5.23	1.78	5.0	5	1	7
Stimulation	5.34	1.85	5.0	5	1	7
Independence	5.98	1.99	6.0	6	2	7
Universalism	5.78	1.92	6.0	6	1	7
Friendliness	6.34	2.02	6.0	6	2	7
Tradition	4.67	1.76	5.0	5	1	7
Conformism	4.89	1.73	5.0	5	1	7
Safety	6.12	2.05	6.0	6	2	7

An analysis of the data in Table 1 shows that students in technical disciplines score highest on the ‘Friendliness’ (M=6.34) and ‘Security’ (M=6. 12), indicating a combination of concern for others and a desire for stability — important qualities for working in engineering teams. At the same time, fairly high scores for ‘Autonomy’ (M=5.98) and ‘Achievement’ (M=5.56) provide internal motivation for independent and productive work. Relatively low scores for ‘Power’ (M=4.12) and ‘Tradition’ (M=4.67) indicate a preference for equality and flexibility over hierarchy, which aligns with modern flexible approaches in technical projects.

According to Mehrabian’s achievement motivation scale, engineering students demonstrated an average score of M=14.32 (SD=12.10, median 14.5, mode 15). This indicates moderately pronounced motivation with a certain preference for the drive to succeed. According to Shostrom’s Self-Actualisation Test (SAT), high scores were recorded for self-acceptance (M=13.48), support (M=42.14), behavioural flexibility (M=15.61) and sociability (M=12.36). According to Rabinovich’s Four-Mode Emotional Questionnaire, the positive emotion of joy (M=8.50) dominates, with relatively low scores for anger (M=6.98), fear (M=5.84) and sadness (M=5.09). The correlation between joy and sadness is -0.45, indicating a good emotional balance.

In particular, the ‘Achievement’ and ‘Stimulation’ scales showed positive correlations with the overall achievement motivation score according to Mehrabian’s methodology. This means that students of technical disciplines, for whom personal success and a desire for new experiences are important, simultaneously have a higher level of intrinsic motivation to overcome difficulties and achieve academic results. This correlation has significant predictive value, as it is precisely these values that can serve as markers of potential interest in innovative technical activities, where not only executive discipline is required, but also the ability to generate new ideas and take responsibility for the outcome.

‘Autonomy’ correlated positively with indicators of self-esteem and creativity on Shostrom’s Self-Actualisation Test ($r \approx 0.35$). This suggests that students who value autonomy in decision-making and independent thinking simultaneously possess a higher level of self-acceptance and the ability to solve problems in unconventional ways. In the context of technical education, this link is particularly significant, as most engineering tasks require precisely this kind of independent problem analysis and the search for original technical solutions.

Conversely, the ‘Security’ value correlated negatively with levels of fear and anxiety. In other words, students who prioritise stability, predictability and security demonstrate lower levels of anxiety. This has a positive effect on long-term professional resilience, as technical disciplines often involve working in conditions of uncertainty (new technologies, tight deadlines, responsibility for system safety).

The values of ‘Agreeableness’ and ‘Universalism’ correlated positively with the ‘Interpersonal’ and ‘Synergy’ dimensions of the CAT. This means that students with a strong orientation towards caring for others and universal human values are better at establishing relationships and are capable of effective teamwork. In modern STEM projects, where work is almost always carried out in interdisciplinary teams, this connection is of great practical significance.

Regression analysis showed that value orientations account for up to 38% of the variation in self-actualisation and motivation scores ($R^2 \approx 0.38$). This is a fairly high figure for socio-psychological research, indicating a significant contribution of the value sphere to the formation of the motivational and personality profile of engineering students. In particular, the regression model demonstrated that a combination of high scores on the ‘Autonomy’, ‘Achievement’ and ‘Stimulation’ scales is a statistically significant predictor of increased levels of proactivity and creativity. Students with such value priorities are less likely to postpone complex tasks (lower procrastination) and demonstrate greater psychological resilience when faced with difficulties in the learning process.

At the same time, factor analysis identified two stable factors that explain a significant proportion of the total variance in the data. The first factor — ‘Proactivity and Openness to Change’ — combined high loadings on the ‘Achievement’, ‘Stimulation’ and ‘Autonomy’ scales. The second factor, ‘Social Harmony and Stability’, was formed around the values of

'Friendliness', 'Security' and 'Universalism'. The presence of these two factors specifically confirms the hypothesis regarding the balance of the value profile of engineering students: they possess both individually active and socially oriented values simultaneously. This structure is optimal for a STEM career, as modern technical work requires a combination of personal initiative with the ability to work in a team and adhere to safety standards.

A comparative analysis using all methodologies revealed statistically significant differences between the groups ($p<0.05$ according to the results of ANOVA and the t-test). Students of technical disciplines are characterised by the most balanced value profile among all the groups studied. High scores on the 'Agreeableness' (M=6.34) and 'Safety' (M=6.12) scales are combined with fairly high scores for 'Autonomy' (M=5.98) and 'Achievement' (M=5.56). This combination is particularly well-suited to modern STEM professions, where specialists must simultaneously demonstrate creativity and initiative in developing new technical solutions whilst adhering to strict safety requirements, working as part of a team and taking responsibility for the outcome.

Unlike engineering students, psychology students score highest on humanistic values: 'Friendliness' (M=6.45), 'Security' (M=6.23) and 'Autonomy' (M=6.12). However, this group is characterised by significantly greater variability in scores (SD up to 2.09). This means that within the group of psychology students, there are both very strong and quite weak students in terms of these parameters. Such heterogeneity may require additional psychological support and remedial work, particularly during the stage of professional development.

Social and economic students are characterised by the lowest overall scores both on the value scales (in particular 'Friendliness' M=6.23) and on achievement motivation (M=12.65). This indicates a more pronounced external motivation and an orientation towards the material and status aspects of activity. Such a profile is less conducive to the development of a deep and sustained interest in complex technical work, which often requires prolonged concentration, resilience in the face of setbacks, and an intrinsic interest in the process.

Cluster analysis confirmed that, even at the stage of the baseline study, technical students exhibit less pronounced heterogeneity in their psychological profiles compared to psychology students. This means that the group of technical students is more homogeneous in terms of their value and motivational characteristics. Such homogeneity is a positive prognostic factor; it indicates a higher likelihood of maintaining interest in the chosen technical specialism throughout the entire period of study and at the start of their professional career without the need for intensive corrective work.

Thus, the comparative analysis clearly demonstrates that it is the balanced value profile of engineering students that is the most adaptive and predictive of sustained interest in STEM careers in today's environment.

The mechanisms through which value orientations influence interest in STEM careers and professional persistence are complex and encompass motivational, cognitive, emotional and behavioural levels. At the motivational level, high scores for 'achievement' and 'stimulation' activate intrinsic motivation (according to Mehrabian), encouraging the setting of ambitious goals, overcoming learning difficulties and participation in research work. The cognitive mechanism operates through the influence of values on the perception of professional tasks; students with high 'autonomy' cope better with uncertainty, independently seek solutions to complex engineering problems and demonstrate creativity.

The emotional mechanism is linked to the balance of positive and negative emotions: a predominance of joy and low levels of fear/sadness among engineering students reduces the risk of anxiety, burnout and loss of interest in the profession. The behavioural mechanism manifests itself in the choice of educational pathways, participation in project work, conferences, start-ups and voluntary technical initiatives. In the wartime and post-war context of Ukraine, the value of 'security' helps maintain psychological resilience, whilst 'stimulation' helps find new meaning in restorative technological projects. Together, these mechanisms ensure both an initial interest in STEM disciplines and long-term professional resilience.

3. Conclusions

The analysis confirmed that value orientations are a significant predictor of interest in STEM careers among students at technical universities. A balanced profile among technical students, combining high scores for agreeableness, security and autonomy with moderate scores for achievement and stimulation, contributes to the development of sustainable professional motivation, emotional balance and readiness for innovative activity. This complements the theoretical propositions of S. Schwartz and M. Rokich regarding the role of values in professional development and is consistent with empirical data on the specific nature of technical disciplines.

The practical significance of the results lies in the advisability of implementing value-based diagnostics to optimise career guidance, develop adaptive educational programmes and prevent maladjustment among future engineers and technologists. Further research should focus on longitudinal monitoring of the dynamics of value orientations throughout the entire period of study, their impact on career success in STEM fields, and the adaptation of the tools to the conditions of the modern Ukrainian educational environment.

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Chapter 5: Innovative Communication Strategies in Science Education: Storytelling, Internal Influencer and Digital Etiquette

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Abstract. Modern science education faces growing challenges related to the quality of communication between educators and students. This paper examines three complementary and practically applicable communication strategies: storytelling as a pedagogical tool, the internal influencer model as a means of engaging youth, and digital etiquette as a foundation for respectful academic interaction. The study draws on observational data from Ukrainian educational settings and relevant scholarly literature. Findings suggest that the integration of these strategies fosters trust, sustains student motivation, and supports a resilient educational environment, particularly in contexts of social uncertainty.

Keywords. digital etiquette, internal influencer, science education, storytelling, trust-based communication.

1. Introduction

Science education extends beyond the transmission of content knowledge. It is deeply shaped by the communicative practices that govern the relationship between educators and learners. In Ukraine, as in many other countries experiencing social instability, educational communication is under additional stress: teachers may inadvertently transfer personal anxieties onto students, suppressing the intrinsic curiosity and motivation that are essential to scientific learning. Education must nurture, not inhibit, the desire to explore and understand the world.

At the same time, the rapid expansion of digital communication in educational settings has introduced new challenges. The absence of shared norms for electronic correspondence between students, teachers, and administrators frequently produces misunderstandings and undermines the quality of academic interaction. This paper proposes three interrelated strategies to address these challenges: storytelling, the internal influencer model, and the cultivation of digital etiquette.

2. Storytelling as a Pedagogical Tool

Storytelling has emerged as a widely adopted complement to classical instructional methods, particularly in higher education. Rather than presenting theoretical content in abstract terms, educators use contextualised narratives to illustrate concepts, enabling students to form mental images and integrate new knowledge more effectively [1, 2]. This approach aligns with established findings in cognitive psychology: a substantial proportion of learners are primarily visual processors who benefit from narrative-based visualisation rather than purely logical-sequential exposition.

A related practice the educator’s introductory self-presentation at the beginning of a first semester functions as an applied form of storytelling. By sharing relevant elements of their professional and personal trajectory, educators reduce the psychological distance between themselves and their students, establish a foundation of trust, and create the conditions for open academic dialogue [3]. This technique, when applied with appropriate boundaries, has been shown to increase student engagement and lower communicative anxiety.

3. Internal Influencer as a Strategy for Youth Engagement

The concept of the internal influencer refers to a student, pupil, or young staff member who, by virtue of their credibility within a peer community, shapes the informational practices and attitudes of that community from within. Unlike top-down institutional messaging, peer-mediated communication carries an inherent authenticity that resonates more readily with young audiences [4]. In educational institutions, the systematic use of internal influencers enables organisations to deliver educational and social messages in a language and register familiar to their target audience.

This strategy also supports the integration of digital and social tools into the learning process through peer modelling, stimulates active participation in science and educational projects, and contributes to building interpersonal trust between students and teaching staff [3]. Crucially, the internal influencer does not replace the educator but serves as a bridge between institutional values and youth culture a mediating function that is particularly valuable in environments where traditional authority structures face reduced legitimacy.

4. Digital Etiquette in Academic Communication

Digital etiquette the set of norms governing respectful and effective behaviour in electronic communication constitutes an underexplored dimension of educational communication quality. In Ukrainian academic contexts, electronic correspondence between students, educators, and administrators frequently violates basic norms of professional interaction [5]. Common infractions include the use of all-capital text (universally interpreted as shouting), excessive exclamation or question marks (conveying aggression or impatience), the use of red font colour (associated with hostility or rebuke), and sending messages outside working hours.

In asynchronous text-based communication, where vocal tone, facial expression, and gesture are absent, such formal-stylistic markers become the primary carriers of emotional meaning. Their misuse therefore generates unintended interpersonal friction. The incorporation of netiquette training into initial teacher education programmes, as well as into university induction curricula for incoming students, is proposed as a low-cost systemic intervention with significant potential to improve the quality of academic communication.

5. Conclusions

The three communication strategies examined in this paper storytelling, the internal influencer model, and digital etiquette are mutually reinforcing and readily implementable across both school and higher education contexts without requiring substantial financial or infrastructural resources. Their integrated application promotes trust, sustains motivation for scientific inquiry, and reduces communicative tension within educational communities. In contexts of protracted social uncertainty, the capacity to build and maintain respectful, human-centred communication becomes not merely a pedagogical virtue but a prerequisite for educational resilience.

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Chapter 6: STEAM Learning Ecosystem and Inclusion in a TEIP Context: A UDL Approach to Developing a Technological Solution for Color Blindness

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Abstract. This paper presents a pedagogical and research proposal for a STEAM learning ecosystem grounded in Universal Design for Learning, designed for implementation in a Priority Intervention Educational Territories school context in Portugal. The proposal involves middle school students in the collaborative development of an assistive technological prototype for colour blindness. The intervention integrates scientific inquiry into colour perception, block-based programming, 3D modelling, tangible artificial intelligence, and collaborative prototyping. Rather than treating technology as an end in itself, the proposal frames digital tools as mediating resources for inclusive problem-solving, computational thinking, accessibility awareness, and student agency. Methodologically, the study is planned as an evaluative case study with descriptive pre- and post-intervention indicators, supported by classroom observation, student questionnaires, focus groups, teacher logs, and artefact analysis. The article outlines the conceptual rationale, pedagogical design, prototype structure, data collection strategy, and expected educational contributions of the intervention. It argues that UDL-grounded STEAM ecosystems may offer a promising approach for connecting science learning, digital literacy, and inclusion in socially vulnerable school contexts, provided that implementation constraints, teacher mediation, accessibility, and ethical use of AI are explicitly addressed.

Keywords. Color Blindness, Inclusion, STEAM, UDL, TEIP, AI.

1. Introduction

Contemporary education faces the challenge of responding to rapid technological transformations, an increasing diversity of student profiles, and persistent social inequalities. In vulnerable contexts, such as schools within Priority Intervention Educational Territories (TEIP), traditional teaching practices frequently reveal limitations in promoting participation, motivation, and school success. The school is then summoned to adopt pedagogical approaches that are not limited to the transmission of content but rather favor the active involvement of students in knowledge construction, problem solving, and the development of citizenship skills [1].

This proposal is based on the conviction that integrating the STEAM approach with Universal Design for Learning (UDL) can offer a robust pedagogical response. STEAM promotes interdisciplinary, contextualized, and meaningful learning through the integration of science, technology, engineering, arts, and mathematics [2]. UDL offers a pedagogical design framework that anticipates student variability, guaranteeing multiple means of engagement, representation, and action/expression [3]. The combination of these perspectives allows for the design of more flexible, accessible, and inclusion-oriented learning experiences.

The selected problem is colour blindness, or dyschromatopsia, a visual condition that is often unnoticed in school contexts but may affect tasks that rely exclusively on chromatic coding [4]. Difficulties in distinguishing colours may compromise the interpretation of graphs, maps, diagrams, signage, and digital interfaces when colour is used as the sole channel of information. They may also affect everyday activities, such as the autonomous selection and coordination of clothing. Despite its prevalence, color blindness is rarely treated as a relevant pedagogical problem in school practices. This absence of a systematic response constitutes an opportunity to develop an inclusive technological solution with educational and social value [5].

This paper is guided by the following research-oriented question: how can a UDL-grounded STEAM learning ecosystem be designed to engage middle school students in the conception and prototyping of an assistive technological solution for colour blindness in a TEIP context? The article describes the project's rationale, the conceptual framework, the structure of the intervention, and the planned methodology, assuming its character as a proposal under development.

The paper is organized in six sections. Section 2 presents the Theoretical Framework, addressing the STEAM approach, Universal Design for Learning (UDL), color blindness accessibility, and the integration of artificial intelligence. Section 3 outlines the Pedagogical Proposal, including the project's purpose and general intervention structure. Section 4 describes the Planned Methodology, detailing the research design, participants, and data collection instruments. Section 5 presents the expected educational contributions, preliminary discussion, and anticipated limitations of the study. Finally, Section 6 provides the Conclusion and outlines Future Work.

2. Theoretical Framework

2.1. STEAM as a Learning Ecosystem

The STEAM approach has been affirming itself as a pedagogical paradigm capable of overcoming traditional disciplinary fragmentation, promoting learning experiences based on the resolution of authentic problems [2]. By integrating science, technology, engineering, arts, and mathematics, this perspective favors active, collaborative, and situated knowledge construction, allowing students to mobilize diverse knowledge to respond to concrete challenges. Instead of presenting isolated content, STEAM activities are frequently organized around projects, prototypes, and investigations, creating opportunities for the development of critical thinking, creativity, and collaboration skills [6].

In this paper, STEAM is understood as a learning ecosystem, that is, as a dynamic set of relationships among students, teachers, content, tools, and context [1]. This perspective positions the school as an environment for experimentation and co-creation, in which students are invited to act as investigators, designers, programmers, testers, and communicators, rather than as passive recipients of information [1]. The value of this approach becomes even more evident in TEIP contexts, where motivation and engagement can be enhanced by practical, challenging, and socially meaningful experiences [7].

Literature has shown that well-designed STEAM projects can contribute to the development of cognitive and socio-emotional skills, including perseverance, communication, empathy, and a sense of social responsibility [6]. When associated with real community problems, these projects favor the perception of the utility of learning and reinforce the students' commitment to the school [3]. In the present case, the choice of color blindness as a starting problem fits precisely within this logic of social relevance and meaningful learning [5].

2.2. Universal Design for Learning and Inclusion

Universal Design for Learning constitutes the inclusive framework of the proposal. This reference baseline starts from the principle that student diversity must be considered from the moment of pedagogical planning, and not merely as a posterior response to identified difficulties [3]. Thus, UDL promotes the creation of learning environments that offer multiple means of engagement, representation, and action/expression, allowing for the reduction of barriers and the expansion of participation opportunities [8].

In operational terms, UDL will be embedded in the intervention through multimodal resources, differentiated task complexity, flexible group roles, visual and auditory feedback, scaffolded programming tasks, alternative forms of documentation, and varied modes of presentation. Students will be able to contribute through scientific explanation, coding, modelling, oral communication, drawing, prototype testing, or reflective writing. This design choice is intended to reduce participation barriers and to prevent technical proficiency from becoming the sole criterion for success.

In the context of this project, UDL will play a central role in the organization of activities, the selection of resources, and the form of assessment. Student diversity will be welcomed through the provision of different formats for accessing information, the creation of tasks with varied levels of complexity, and the appreciation of multiple ways of expressing knowledge [8]. This logic is particularly important in TEIP contexts, where class heterogeneity is high and where many students benefit from more flexible and contextualized pedagogical proposals [9].

The articulation between UDL and STEAM is especially promising because both frameworks value active participation, experimentation, and differentiation [9]. While STEAM organizes learning around concrete challenges, UDL ensures that those challenges are accessible to all students [3]. This convergence allows for the design of fairer educational experiences, preventing technological innovation from producing new exclusions [10].

2.3. Colour Blindness and Accessibility in the School Context

Color blindness is a visual condition associated with alterations in chromatic perception, resulting from dysfunctions in the cones of the retina. Although it varies in severity and typology, the most frequent form affects discrimination between tones of red and green [4]. In the school context, this limitation can pass unnoticed for years, especially when explicit mechanisms for detection or adaptation do not exist. However, the consequences are real: the use of color codes as the sole channel of information can compromise task comprehension and student autonomy [4].

The educational relevance of the topic is easy to grasp when considering that many school and digital materials use color as the main organizing element. Maps, graphs, legends, tables, diagrams, and digital platforms can represent barriers for students with dyschromatopsia, especially when they are not accompanied by other visual or textual supports [11]. Furthermore, daily school and personal life tasks, such as organizing materials or choosing clothing independently, can generate difficulties and social constraints [5].

The proposal to develop an assistive technological solution for colour blindness responds to this gap through a pedagogical and functional approach. The aim is not merely to build a device, but to involve students in understanding the condition, identifying user needs, analysing accessibility barriers, and designing a response that combines usability, simplicity, multimodal feedback, and inclusive design principles.

2.4. Artificial Intelligence, Programming and Computing

The integration of Artificial Intelligence and physical computing in the project has a dual function: pedagogical and technological. On one hand, it allows for the introduction of students to emerging concepts of contemporary digital literacy; on the other, it offers concrete tools for building the proposed solution [12]. The use of devices such as the Micro:bit and an intelligent color recognition camera, HuskyLens, (Figure 1, Figure 2) enable the exploration of block-based programming principles, automation, signal reading, and interactive response [13].

Figure 1. HuskyLens AI module connected to BBC micro:bit V2.

Figure 2. HuskyLens module illustrating the face-detection function

In this context, Artificial Intelligence will not be presented as an abstract or distant technology, but as a system that depends on data, training, validation, and ethical limits [12]. AI literacy will be addressed at an introductory level, helping students understand that AI-based recognition systems depend on data, training examples, classification processes, and validation, and that their outputs require human interpretation and critical supervision [2]. This dimension is particularly relevant for promoting an informed and responsible relationship with technology.

Block-based programming will allow students to structure logical sequences, test hypotheses, correct errors, and understand the basic operation of a computer system. 3D modelling, in turn, will support the transformation of design ideas into a tangible artefact through Tinkercad, reinforcing the link between imagination, engineering, and materialization [14]. Thus, technology is used as a means of learning and inclusion, and not as an end in itself.

3. Pedagogical Proposal

3.1. Problem and Goal of the Project

The proposal is based on the need to create educational responses that are simultaneously scientifically rigorous, pedagogically meaningful, and socially useful [5]. The chosen problem (color blindness) has an accessible and concrete dimension, which facilitates its exploration with middle school students. By working on this theme, students can understand a real visual limitation, reflect on the importance of inclusion, and conceive a technological solution oriented toward the autonomy of potential users [4].

The educational purpose of the project is twofold. On one hand, it is intended to promote learning in science and technology through research on vision, color, sensors, and digital systems [12]. On the other hand, it aims to develop empathy, social responsibility, and collaboration skills by involving students in a challenge with human and practical meaning [5]. This combination is coherent with the STEAM philosophy and with the assumptions of UDL [15].

3.2. General Structure of the Intervention

The intervention will be organized into five main moments. The first moment corresponds to awareness-raising and exploration of the problem, with research activities on color blindness (Figure 3), human vision, and the obstacles faced by people with dyschromatopsia [4]. The second moment is dedicated to scientific foundation, addressing topics of optics, colors, light, and the functioning of the visual system [11]. The third moment introduces the technological component, with an initiation into block-based programming, the operation of sensors, and the basic principles of Artificial Intelligence [13]. The fourth moment focuses on the conception and construction of the prototype, including 3D modeling, functional testing, and the integration of electronic components [14]. The fifth moment corresponds to reflection and evaluation, with the collection of students' perceptions about the experience, the learning process, and the utility of the developed solution [1].

Figure 3. Color-blindness simulation glasses for deuteranopia

This progressive organization allows students to advance from understanding the problem to creating the response, passing from scientific curiosity to technical action. At the same time, it facilitates teacher mediation and task differentiation, in accordance with the principles of UDL [3].

3.3. Planned Technological Prototype

The planned prototype will be a portable device to support color identification, designed to assist people with color blindness in daily tasks, such as the coordination and autonomous choice of clothing. The system will integrate a HuskyLens smart camera for color recognition via *edge computing*, a BBC Micro: bit V2 microcontroller (Figure 4) for processing and response, and an ergonomic physical structure designed by the students in Tinkercad modeling software [13].

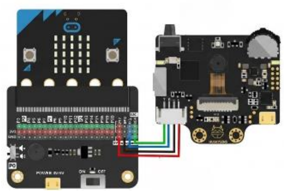

Figure 4. I2C connection between HuskyLens, Shield and BBC micro:bit V2

The detected information will be returned to the user through multiple channels, displaying the name of the color on the LED matrix and providing a synchronous sound response, guaranteeing the multissensorial feedback recommended by UDL. The construction of the device will also be an opportunity to work on sustainability, mechanical tolerances of 3D printing, and creativity [5].

4. Planned Methodology

4.1. Research Design and Operationalization of Variables

The research will be developed in the form of an evaluative case study, with a quasi-experimental component of non-randomized groups. [1]. This methodological option results from the real school context and the applied nature of the intervention. The study aims to empirically map the impact of the ecosystem on the following structured variables:

i) Computational Thinking and AI Literacy: Logical decomposition, block-based automation, and critical understanding of model training.

ii) Social Awareness: Rates of inclusive attitudes face to chromatic barriers and empathy among peers.

iii) Motivation: Practical engagement and persistence in the iterative debugging process.

4.2. Participants

The sample will consist of two 6th-grade classes (2nd cycle of basic education) from a TEIP School Cluster in the Northern region of Portugal [10]. The experimental group will participate in the integrated STEAM activities, while the comparison group will not be exposed to the specific intervention. The collaboration of the Class Advisor (Diretor de Turma) will also be considered as a key informant, in order to enrich the understanding of the context, behavior, and motivation of the students throughout the school year.

The convenience selection is coherent with the school reality and with the exploratory nature of the project [1]. Nevertheless, biographical comparability and grade level between the classes will be ensured, seeking to minimize confounding variables and guarantee the robustness of the comparative data.

4.3. Data Collection Techniques and Instruments

Data will be collected through multiple instruments to ensure triangulation [10]. Questionnaires will be applied in digital format before and after the intervention (pre and post-test) [1]. Participant observation will be conducted and rigorously recorded in a logbook by the researcher, documenting interactions and difficulties in real time [1].

Additionally, focus groups will be organized with sub-sets of the experimental group to gather their subjective perceptions regarding the social value of the activity [10]. A documentary analysis of the constructed artifact will be performed, guided by a rubric matrix that will evaluate the algorithmic functionality of the code, the ergonomics of the 3D-printed enclosure, the effectiveness of the UDL multissensorial feedback, and the sustainability of the design [10].

4.4. Treatment and Data Analysis

Quantitative data will be treated with descriptive and inferential statistics (paired-samples t-test procedure) to compare progress between the groups [1]. Qualitative data (logbook, focus groups, and interviews) will be submitted to structured categorical content analysis [10]. The articulation of these dimensions will allow for a holistic interpretation, evaluating the prototype not only by its technical success but by the educational value generated during its co-creation [9].

5. Expected Results and Preliminary Discussion

The presentation of this proposal assumes that pedagogical innovation gains greater strength when linked to concrete and socially relevant problems [5]. Color blindness constitutes one of these problems, precisely because it is poorly visible, yet has real implications for participation and autonomy [4]. By transforming this issue into a technological creation challenge, the project seeks to mobilize students' curiosity and promote learning with a purpose.

Preliminary qualitative observations recorded during the initial immersion phase suggest that using visual simulations of dyschromatopsia immediately raises the intrinsic interest of classes in rehabilitation engineering. It is expected that the multisensory approach of STEAM-UDL will function as an equalizer in a TEIP environment, mitigating the digital divide through the introduction of tangible artificial intelligence [15].

5.1. Limitations of the Study

Ensuring the scientific rigor of the proposal, preliminary limitations are identified:

i) the geographic nature and restricted size of the convenience sample collected in a single TEIP school cluster;

ii) the novelty effect associated with the use of the HuskyLens sensor, which can generate fluctuating motivational peaks;

iii) the technical susceptibility intrinsic to the HuskyLens camera which, as a low-cost tool designed for students to carry out prototyping in a school context, presents natural limitations regarding its effectiveness and precision in complex or large-scale operational scenarios.

6. Conclusion and Future Work

This paper presented a research and pedagogical intervention proposal that articulates STEAM, UDL, inclusion, and Artificial Intelligence in a TEIP context. The central idea consists of actively involving middle school students in the design of a technological solution for color blindness, simultaneously promoting scientific, technical, and socio-emotional learning. The proposal values experimentation, problem solving, and co-creation, in perfect consonance with the principles of Hands-on Science. By integrating science, technology, and inclusion around a real accessibility problem, the proposal argues that digital transition in schools should be understood not merely as technological modernisation, but as an opportunity to promote citizenship, participation, and ethical responsibility.

Future work will involve implementing the intervention, analysing the collected data, refining the prototype according to student and teacher feedback, and examining whether the proposed ecosystem can be adapted to other accessibility challenges. Particular attention will be given to the sustainability of the approach across cohorts, the transfer of learning to new assistive design problems, and the ethical use of AI-based tools in inclusive school contexts.

7. Acknowledgements

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Chapter 7: Developing Sustainability Competencies through Project-Oriented Management of Eco-Innovations in Maritime Education

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Abstract. Sustainable maritime development requires professionals capable of managing eco-innovation projects under environmental, technological, and regulatory uncertainty [1,2]. This paper proposes a competency-oriented framework based on project-oriented management of eco-innovations in maritime education. The model integrates project life-cycle approaches, sustainability principles, and ballast water treatment technologies as a practical case [3,4]. The results demonstrate that structured project-based learning enhances systems thinking, risk awareness, and decision-making competencies in future maritime specialists. Practical implementation is supported by real-world ballast water treatment technologies developed within international scientific cooperation [5].

Keywords. eco-innovation, maritime education, project management, sustainability competencies, water transport.

1. Introduction

The maritime industry is undergoing a rapid transformation driven by environmental regulations, decarbonisation targets, and technological innovation [1]. In this context, the training of maritime professionals must go beyond traditional technical knowledge and include competencies related to sustainability and innovation management [2].

Eco-innovations in shipping, particularly ballast water management systems, require complex decision-making that integrates engineering, environmental, economic, and regulatory dimensions [4]. Therefore, maritime education faces the challenge of embedding project-oriented approaches that reflect real operational conditions at sea and in shipping companies.

The purpose of this study is to present a structured educational framework for developing sustainability competencies through project-oriented management of eco-innovation projects in maritime transport.

2. Methodological Framework

The proposed approach is based on the integration of three methodological components.

First, project management principles based on the project life cycle (initiation, planning, execution, monitoring, and closure) are applied to eco-innovation implementation scenarios in maritime systems [3].

Second, sustainability education principles are integrated, including systems thinking, environmental responsibility, and alignment with international maritime environmental regulations [1,2].

Third, case-based learning is used, with ballast water treatment systems (BWTS) serving as a representative example of complex eco-innovation implementation on vessels [4].

The methodological structure allows analysis of technical constraints, regulatory compliance, and economic feasibility of environmental technologies in maritime operations.

2.1. Evaluation Methodology

To assess the effectiveness of the proposed competency-oriented model, a mixed-method evaluation approach was applied. The assessment combined quantitative and qualitative indicators of competency development among students participating in eco-innovation project scenarios.

The evaluation was structured in three stages:

Baseline assessment (pre-test): measurement of initial knowledge in sustainability, project management, and maritime environmental regulation.

Formative assessment: continuous evaluation during project execution using structured rubrics focused on analytical thinking, teamwork, and decision-making.

Final assessment (post-test): comparison of competency improvement through scenario-based tasks and reflective analysis.

In addition, expert evaluation was conducted by academic staff and maritime industry specialists to validate the practical relevance of student solutions. A Likert-scale survey was also used to assess perceived improvements in systems thinking, risk awareness, and sustainability-oriented decision-making.

The results confirmed a measurable increase in interdisciplinary competencies, particularly in the areas of environmental compliance understanding and project lifecycle management skills.

3. Competency-Oriented Model of Eco-Innovation Management

The proposed model defines four key groups of competencies:

Environmental and regulatory competencies include understanding international maritime environmental conventions and compliance procedures [1,4].

Project management competencies involve planning, resource allocation, stakeholder coordination, and monitoring of implementation processes [3].

Risk management competencies include identification of operational, technical, and environmental risks, as well as mitigation strategies.

Economic and communication competencies focus on cost evaluation, investment justification, and professional interaction with maritime stakeholders.

These competencies are developed through structured eco-innovation project scenarios that replicate real maritime operational environments.

4. Case Study: Ballast Water Treatment System as an Eco-Innovation Model

The ballast water treatment system (BWTS) is used as a representative complex eco-innovation case for competency development in maritime education. The case is based on real-world technological configurations, including filtration combined with ultraviolet (UV) disinfection and electrochemical oxidation processes, which are widely applied in modern shipboard systems.

During the initiation phase, students analyze compliance requirements under the IMO Ballast Water Management Convention, particularly the D-2 standard, which defines permissible biological content in discharged ballast water.

In the planning phase, alternative technological solutions are compared using multi-criteria analysis, including treatment efficiency, energy consumption, operational cost, and system integration complexity.

The execution phase involves simulation of BWTS integration into shipboard systems, including spatial constraints, energy supply limitations, and crew operational procedures.

Risk assessment includes identification of technical and environmental risks such as membrane fouling, electrode degradation, formation of disinfection by-products, and system failure under variable salinity conditions.

The monitoring phase introduces performance evaluation indicators such as treatment efficiency, operational stability, and regulatory compliance consistency.

Finally, the closure phase includes certification procedures, environmental impact assessment, and reflection on system performance within the context of sustainable shipping operations.

This structured case enables learners to engage with real engineering constraints while simultaneously developing sustainability-oriented decision-making competencies.

5. Discussion

The findings demonstrate that project-oriented eco-innovation learning significantly enhances the development of integrated sustainability competencies in maritime education.

Compared with traditional lecture-based approaches, the proposed model promotes active cognitive engagement and problem-solving under realistic operational constraints, which is consistent with the principles of Education for Sustainable Development [2].

Students are required to operate within regulatory, environmental, and technical limitations reflecting real maritime industry conditions, particularly those defined by international environmental governance frameworks [1,4].

A key advantage of the model is its ability to bridge engineering decision-making with environmental compliance requirements. This integration is essential in modern shipping, where operational decisions must align with strict international regulations such as the IMO Ballast Water Management Convention [4]. The competency-based structure of the model also aligns with contemporary project management standards emphasizing lifecycle thinking, stakeholder coordination, and risk-informed decision-making [3].

The inclusion of ballast water treatment systems (BWTS) as a real industrial eco-innovation case increases authenticity and improves learner engagement. It also strengthens systems thinking by exposing students to multi-layered interactions between technological performance, environmental impact, and regulatory compliance [5]. In particular, students develop the ability to evaluate trade-offs between treatment efficiency, energy consumption, and operational feasibility, which is critical for sustainable maritime operations.

However, the model has certain limitations. Its effectiveness depends on access to realistic industrial case studies and may require adaptation in institutions without direct cooperation with maritime technology providers. Additionally, further empirical validation is required across larger cohorts and different maritime education contexts to generalize the findings [2,3].

6. Conclusions

Project-oriented management of eco-innovation provides an effective methodological basis for developing sustainability competencies in maritime education.

The integration of ballast water treatment systems as a case study enables practical understanding of environmental technologies in operational contexts [4,5].

The proposed framework can be extended to other maritime eco-innovations, including exhaust gas cleaning systems and alternative fuels.

Overall, competency-based and project-oriented approaches are essential for preparing future maritime professionals for sustainable industry transformation.

7. Acknowledgements

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Chapter 8: STEM Solution for Clean Water

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Abstract. This STEM project aims to raise awareness about clean water preservation and purification. Selected as one of the 11 delegates to represent Turkey at the European Science on Stage festival in Lithuania (2026), the project empowers students as 'Water Ambassadors'.

Using a biomimicry approach inspired by mangrove trees, students designed purification systems via Tinkercad and conducted experiments.

Results were evaluated using artificial intelligence, while learning was reinforced through Scratch and Canva games.

This interdisciplinary study aligns Grade 3 Science outcomes with Sustainable Development Goals fostering environmental responsibility and scientific inquiry.

Keywords. Artificial intelligence, Biomimicry, STEM education, Water purification.

1. Introduction

Access to clean water is a critical global challenge [1]. This project was developed to transform primary school students into "Water Ambassadors" by fostering environmental awareness through scientific methodology.

The project gained international recognition by being selected as one of the 11 projects representing Turkey at the European Science on Stage festival in Klaipėda, Lithuania [3].

This recognition underscores the effectiveness of the integrated STEM model in addressing real-world environmental problems [1,6].

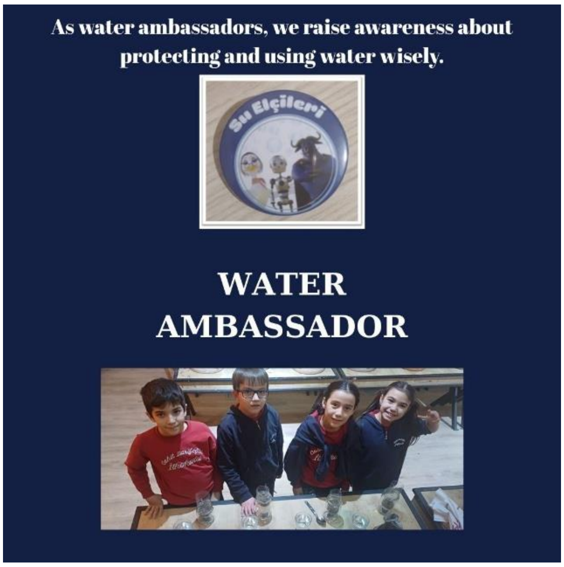

Figure 1. The "Hidro Kids" team and project overview

2. Theoretical Framework and Inspiration

The project began with the literature-based inquiry of the book "The Water Princess"[1].

Students analyzed Princess Lily's struggle to access clean water, linking the narrative to the United Nations Sustainable Development Goals (SDG 6: Clean Water and Sanitation) [7].

This empathetic start motivated students to research the harms of dirty water and the necessity of sustainable water management [1,7].

Figure 2. Princess Lily's story and its connection to the Sustainable Development Goals

3. Methodology and Application

The study was structured around the Grade 3 Science curriculum outcome: "Explains water purification methods" [6].

In collaboration with the TEMA Water Brotherhood Project [2], students explored the journey of water to their homes and understood the importance of conservation.

Figure 3. TEMA Water Brotherhood project, biomimicry research on mangroves, and the water purification experiment

3.1. Biomimicry and 3D Design

Students utilized a biomimicry approach by researching how mangrove trees naturally filter salt and impurities from water.

Based on these biological models, students created 3D designs for their own purification systems using Tinkercad [4].

Figure 4. 3D designs for clean water purification using Tinkercad and the transition to experiments

Figure 5. Implementation of the water purification experiment and testing of different material proportions

3.2. Technology Integration and AI

The transition from design to physical experiment involved testing various material proportions.

The efficiency of the filtered water was evaluated using AI-based tools.

To solidify the learning process, students designed interactive educational games using Canva and Scratch [5].

Figure 6. Evaluation of water purification results using artificial intelligence

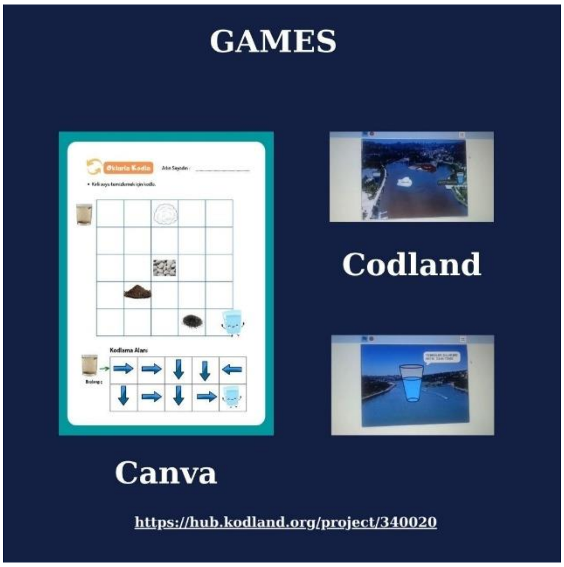

Figure 7. Reinforcing learning through educational games designed with Canva and Scratch platforms

4. Conclusion

Through the motto "We are the water ambassadors, the guardians of this water," students developed significant problem-solving and research skills.

The project's representation at the Science on Stage festival [3] demonstrates that early childhood STEM education can effectively address complex global issues by combining nature-inspired engineering with modern technology [1,4].

5. Acknowledgements

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Special thanks are also extended to the Science on Stage National Steering Committee for the opportunity to represent Turkey as a delegate [1,3].

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Chapter 9: Ponds, urban ecology and Aedes albopictus control: conservation, biological regulation and pedagogical value

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Abstract. The expansion of the Asian tiger mosquito, Aedes albopictus, in Portugal represents a significant challenge for public health and environmental management in urban and peri-urban contexts. The response to this problem must be based on scientific evidence and principles of applied ecology. The species' reproduction is linked to water, particularly stagnant water, with its eggs being deposited on the walls of containers above and near the water's surface. However, it is necessary to clearly distinguish between artificial water containers, which constitute preferred breeding grounds for the species, and natural or constructed ponds, due to their ecological and educational value. Although some stagnant water bodies may favor the presence of mosquitoes, biodiverse and ecologically structured ponds play a role in biological regulation, supporting communities of natural predators and associated organisms that integrate complex trophic networks, ensuring controlled breeding conditions for these species. At the same time, these habitats constitute high-potential educational resources and can be used as living laboratories in school settings. Its preservation allows for the integration of biodiversity conservation, environmental education, and ecological monitoring, while its destruction can compromise important ecological and educational functions.

Keywords. *Aedes albopictus*, ponds, urban ecology, living laboratory, environmental education, biodiversity, vector control.

1. Introduction

The presence and expansion of Aedes albopictus in Portuguese territory have reinforced the need for entomological surveillance, appropriate management of stagnant water, and environmental literacy. This species, frequently referred to as the tiger mosquito, constitutes a relevant public health vector, and its expansion is strongly associated with the occupation of environments altered by human activity, especially in urban and peri-urban areas. However, combating this species requires conceptual rigor. Not all accumulated water has the same ecological meaning or the same management value. An abandoned container, a tire, an obstructed gutter, or an urban tank have very different functions and dynamics from a naturalized pond with vegetation, predators, macroinvertebrates, and stable aquatic communities. Therefore, the mosquito control approach cannot be reduced to the indiscriminate elimination of any water body, risking the confusion of sanitary problems with valuable ecological habitats [1][2][3][4][5][6][7].

This chapter builds on the above distinction to defend a central idea: ponds should not be viewed as spaces to destroy, but as ecosystems to understand, conserve, and use pedagogically. In the school context, this function becomes even more relevant, as ponds can be transformed into living laboratories where real ecological processes are observed, scientific skills are developed, and a closer relationship between students and nature is fostered [2][3][7][8].

2. *Aedes albopictus* and its preferred habitat

Aedes albopictus and its preferred habitat *Aedes albopictus* is a species with a strong association to small volumes of water accumulated in artificial containers. Used tires, plant saucers, domestic containers, cans, bottles, tanks, drains, and other urban micro-habitats offer particularly favorable conditions for larval development, especially when the water is relatively stable and predation pressure is reduced [1][9][10].

Its ecological strategy is deeply linked to human proximity. It is a species adapted to modified environments, exploring fragmented spaces, temporary containers, and places with water accumulation where monitoring is low. Females deposit their eggs on suitable surfaces above the water line, and these eggs can resist desiccation, which facilitates the species' survival during unfavorable periods [9][10].

This biological pattern explains why the most effective control measures must focus on artificial breeding sites and not on ponds with ecological value. The elimination of accumulated water in urban containers, waste management, and public education regarding the removal of domestic hotspots constitute priority measures in this context. What cannot be done is transferring this logic to all aquatic systems, as if any pond were automatically a sanitary problem [2][3][7][9][10].

3. Ponds as complex ecological habitats

Ponds are small water bodies, either permanent or temporary, that hold high ecological relevance despite their reduced size. They are dynamic habitats whose biological composition depends on the hydroperiod, water quality, depth, vegetation, sun exposure, and the presence of predatory organisms [3][4][5][6][7].

Unlike simple artificial containers, naturalized ponds can host a wide diversity of organisms, including algae, aquatic plants, macroinvertebrates, amphibians, reptiles, birds, and, in some cases, mammals. Many of these living beings depend entirely or partially on these habitats to survive, reproduce, or complete part of their life cycle. Their importance is, therefore, much greater than the physical space they occupy [3][6][7][11].

Ponds can also act as biodiversity refuges in fragmented landscapes and as ecological connection points between different habitats. In urban environments, they assume particular importance because they provide ecological continuity, promote biological diversity, and help maintain natural processes that might otherwise disappear [2][3][7][12].

4. Ecological functions and biological regulation

Beyond the biodiversity they support, ponds perform significant ecological functions. They contribute to water retention, hydrological regulation, aquifer recharge, natural purification, and flood mitigation. In many cases, they act as small natural water management infrastructures, with positive effects at local and regional scales [3][7][12].

From a biological perspective, biodiverse ponds can also help in the regulation of insect populations, including species with vectorial potential. The presence of natural predators, such as odonate larvae, aquatic coleopterans, and amphibians, can reduce the probability of opportunistic organisms' proliferation. This does not mean that every pond eliminates mosquitoes, but rather that its ecological complexity tends to make the system less favorable to uncontrolled population explosions [1][4][6].

Figure 1. Predatory insect (*Odonata*) in the vegetation of a school pond. They act as biological barriers through the active predation of culicid larvae.

It is precisely here that it becomes important not to oversimplify the relationship between stagnant water and mosquitoes. A balanced pond, with a functional biological community, is not the same as an artificial container without predators. Environmental management must recognize this difference and avoid interventions that destroy habitats with ecological value merely because they wrongly associate any stagnant water with a sanitary risk [2][3][6][7].

5. Ponds as living laboratories

One of the most valuable aspects of ponds is their pedagogical potential. Their size, accessibility, and biological diversity make them ideal resources to be used as living laboratories in a school context. Unlike overly extensive or inaccessible environments, ponds allow for direct observation, simple sampling, systematic recording, and monitoring over time.

At school, a pond can serve to study various themes: life cycles, adaptation of living beings, food chains, biodiversity, water quality, relationships between abiotic factors and biota, ecological succession, and the impact of human action. Students can collect data, compare observations across different seasons, identify species, measure physicochemical parameters, and interpret results based on evidence [2][3][8].

Figure 2. Aquatic biodiversity monitoring activity functioning as a living laboratory.

his type of learning is particularly powerful because it shifts the focus from abstract science to lived science. Instead of learning only from textbooks or images, students come into contact with real organisms, observe behaviors, formulate hypotheses, and participate in research processes. The pond thus becomes a space for knowledge construction, where theory and practice meet naturally [2][3][8].

6. The pond in the school and in the community

The creation or maintenance of ponds in schools, gardens, educational centers, or community spaces is a strategy with multiple benefits. First, it allows the school to have a permanent ecological resource, available throughout the school year and capable of being integrated into different subjects. Second, it fosters students' regular contact with nature, something increasingly important in a context of growing urbanization and detachment from natural environments [3][2][8].

School ponds can be integrated into citizen science projects, biodiversity inventorying, ecological monitoring, and education for sustainability. Furthermore, they can involve teachers, students, municipal technicians, researchers, families, and local associations, creating a participation network around nature conservation [3][13].

At the same time, these spaces help change the social perception of ponds. Instead of being viewed as dirty, abandoned, or useless places, they are understood as living, useful, and educational habitats. This change in perspective is essential to promote a more mature and informed conservation culture. The school plays a decisive role here, because it can transform a small pond into a symbol of learning, science, and environmental citizenship [2][3][8].

Figure 3. Field class on aquatic ecosystems and awareness in the school grounds.

7. Mosquito management and pond conservation

The expansion of Aedes albopictus should not be used as an argument to eliminate ecologically relevant ponds. Effective vector control must focus on the true preferred breeding grounds of the species: artificial containers, small urban hotspots, water accumulated in bins, and poorly managed human structures. That is where intervention produces the greatest impact and the lowest ecological cost [1][9][10].

When there are ponds with clear biodiversity and ecological function, the response must be cautious and based on a diagnosis. The actual presence of larvae, the biological composition of the system, its environmental function, and its educational value must be evaluated before any intervention. Drainage or landfilling is only justified in very specific, properly substantiated situations [3][7].

Whenever necessary, selective measures should be prioritized, such as cleaning, monitoring, vegetation management, correcting stagnant water in artificial containers, and, when applicable, using specific biological solutions. The guiding principle should be simple: combat the mosquito without destroying the valuable habitat, and protect the pond without ignoring public health [3][9][10][14].

8. Pedagogical application in the school context

The use of ponds at school allows for the achievement of learning objectives that go far beyond the simple observation of living beings. These spaces enable the execution of field activities, research projects, laboratory experiments, and environmental awareness actions. They are, therefore, particularly effective instruments for developing scientific and social skills [2][3][8].

For example, a school pond can be used to:

i) observe biodiversity at different times of the year [2][3]

ii) compare ponds with different characteristics [3][4][5]

iii) study the relationship between light, temperature, vegetation, and biological diversity [4][5][6]

iv) analyze water quality [2][3]

v) discuss the presence or absence of specific groups of organisms [3][6][11]

vi) understand conservation and sustainable management strategies [3][7][13].

These activities favor the development of skills in observation, recording, comparison, interpretation, and scientific communication. At the same time, they stimulate critical thinking and a sense of environmental responsibility. The student ceases to be merely a receiver of content and becomes an active researcher of a living system [2][3][8].

Figure 4. Workshop for teachers at the Eco-Schools Seminar in Guimarães

9. Ponds, science, and citizenship

Ponds can also be used as a starting point for citizen science projects and for involving the school community in ecological inventory and monitoring initiatives. By recording species, tracking habitat evolution, and sharing data with the scientific or educational community, the school begins to produce useful knowledge beyond the classroom [3][13].

Figure 5. Citizen Science Action, guided by the Braga Ciência Viva Center, at the Sete Fontes park in Braga

This dimension is particularly important because it connects learning to the territory and to collective responsibility. Pond monitoring helps to understand changes over time, identify threats, promote good practices, and develop a culture of informed participation. It is not just about teaching content, but about shaping citizens capable of reading the environment, interpreting ecological signs, and acting consciously [2][3][8][13].

In this sense, the pond is not just a pedagogical setting: it is a space of relationship between school, nature, and society. It is a place where one learns science, but also where one learns to care for the common world [2][3][7].

10. Conclusion

Ponds are habitats of high ecological, functional, and pedagogical value. Their importance lies not only in the biodiversity they support but also in their capacity to promote learning, observation, and active participation in a school context. When viewed as living laboratories, they become powerful instruments for environmental education and for bringing students closer to nature.

In the case of *Aedes albopictus* control, it is essential to distinguish between artificial containers and biodiverse ponds. The fight against the mosquito must focus on opportunistic breeding grounds and poorly managed urban spaces, without resorting to the indiscriminate destruction of aquatic habitats with ecological and educational functions. Pond conservation is not an obstacle to vector control; it is part of an intelligent, balanced, and sustainable environmental strategy.

Preserving ponds is, therefore, preserving biodiversity knowledge and educational opportunities. At school, these habitats can function as engines of learning and scientific citizenship, contributing to the formation of generations that are more aware of the importance of ecosystems and better prepared to protect them.

11. Acknowledgements

This work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UID/04650/2025”.

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Chapter 10: Science on Screen: The Role of Weekly Video Journalism in Advancing Indian Science

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Abstract. There is need to strengthen the science content in Indian Television channels. At present the science content is very less in the private and government owned Indian television channel. There is very less numbers of weekly/daily science news emphasizing the Indian Science are available in Indian Television. The technical programmes like Tech Guru and others are focused majorly on latest technology of gadgets. To increase the general awareness about science happenings in daily life, the Vigyan Prasar, an autonomous institution under Department of Science and Technology, Government of India, started production of weekly science news in Hindi and English Languages since 2011. The news programmes are titled as "Science Monitor"-in English and "Gyan Vigyan"-in Hindi languages.[1]

The news was telecasted through the Indian government owned Loksabha Television Channel (LSTV) - channel of national repute from February 2011. After two years of successful telecast the news telecast was shifted to the Indian government owned Rajyasabha Television (RSTV) -channel of national repute. Since last 3 years the news was successful telecasting through the Rajyasabha Television (RSTV). The news in addition to the telecast through RSTV also repackaged for telecast through the Doordarshan-India for the viewers residing in countries other than India. In view of the treatment of the news have components of the television media angle of writing and voice over of the news. The news has main components includes the main news and happenings, in-depth stories, science express, meet the scientist, technology and innovations in various areas of science and technology.[2]

The production agency after collecting news and happenings from various source feeds produces original scripts in both Hindi and English languages, the scripts were cross checked by the scientists at Vigyan Prasar for accuracy of content. The pre-telecast rough cut of the program is checked by the nominated experts in the field of science communication for accuracy of content going on air through news.[3] The Rajyasabha Television (RSTV) in addition to telecast of the program also created youtube page and upload the news on the page for the viewers who missed the news while on air. In depth analysis of the news topics by classification into various areas of science, viewer's response analysis received by emails and letters, youtube analytical responses, comparative study of other science news/content on other channels is the part of the current study. In the past 5 years the news proved beneficial for the students, general public and various section of the society.[4] The news program also used to produce a CD entitled as "India Innovate"- which cover all major stories covered during a year. In the year 2015 which was celebrated by United Nations on Light-and Light-based Technologies, a 13 episodes series was produced on "Light-and Light-based Technology" (Prakash Kirno ka Rahasy) in Hindi language from the stories covered in the news program.[5] The production of 13 episodes on Cutting Edge Technology from the stories covered in the news program was produced and telecast through Doordarshan-national. These approaches widen the reach to audience and make more usefulness of the covered stories. The shelf life of the news stories by making episodes from it increases to great extent, as the news stories now can be repeat telecast in mode of popular science program after extracting episodes from it.

Keywords. Loksabha Television Channel (LSTV), Rajyasabha Television (RSTV), Vigyan Prasar, Science Monitor, Gyan Vigyan.

1. Introduction

The news as per definition is a new information about recent events, happenings took place in the society. There are many channels which telecast news in Hindi, English and various regional languages. The major news channels include Aaj Tak, Zee news, NDTV news, Sahara news, CNBC-TV18, Times now, LSTV, RSTV. The regional language in which the news is being telecasting in India are Tamil, Telugu, Malayalam, Kannada, Marathi, Gujarati, Bengali, Oriya and Urdu. The basic objectives of television are providing information, entertainment and education. The two new words infotainment and edutainment have evolved. These two words have common term entertainment. Hence the program is appreciable when it has basic thing of entertainment.[6] The viewer generally watches the channels depending on the mood, interests and other requirements. The viewer developed the emotional involvements with the television channels in regular watching it. The desire to obtain more and more information from television may be fulfilled by watching the informative programmes. The various information like news and current affairs, sports programmes, cookery and food related programmes, programmes based on environmental issues, science and technological innovations, discoveries, economic policies.

The entertainment is the most important factor for which large number of people watches the television. The programmes include serials, soap opera, dramas and plays, comedy shows, musical programmes, game shows, chat shows, cartoons, fairy tales, horror shows, reality television shows.[7]

The educational programmes play an important role in education. The education channel like Gyandarshan of Doordarshan, channels of Open University like Indira Gandhi Open University IGNOU, University Grant Commission UGC channel, kisan channel of Doordarshan are some important names in area of educational information. The social and health development programmes are getting more viewers since last 2-3 decades. Cultural and gender study programmes also have their own place among all these channels. There are two broad formats of the television programmes i.e fiction and non-fiction programmes. The fiction programmes include the imagination and dramatization of the stories. The non-fiction programmes on television generally depend on the information regarding various events that take place in our surroundings along with the incorporation of education on contemporary issues. The news bulletin essentially based on the summary of the news stories in order of importance and interests.[8]

The Vigyan Prasar, an autonomous institution under Department of Science and Technology, Government of India, started production of weekly science news in Hindi and English Languages since 2011. The news programms are titled as “Science Monitor”-in English and “Gyan Vigyan”-in Hindi languages on RSTV (Rajya Sabha Television). The news is also being telecast on DD-India as “Science this week”.

Some basic rules for the news for television are followed while production of the news program. These basic rules include clarity, Brevity, Conversational, Time Reference and Active Voice.

Clarity: The first rule of TV news is that the story must be clear at once. Unlike the reader the viewer have no second chance to go over the material. A person who writes the science articles for the popular magazines must able to translate the complicated scientific jargon into the general reader’s language, the writer of TV news must be able to make complicated stories simple. In short the understanding of TV news must be immediate. Hence it is well said that “never underestimate the viewer’s intelligence or over estimates their knowledge.” The average acceptable words per sentence in TV copy are 13 to 14.[9]

Brevity: Sentence need to be not only simple but short also. As the news reader can easily read short sentence in comparison to longer ones. Viewer also can follow short sentence more easily as compared to longer ones.

Conversational: TV newswriters use words of daily uses, the language of conversation.

Time reference: The element of immediacy is biggest assets of the TV medium in reporting news. Every effort should be made to include up-to-date reports and to write copy in a manner that sounds fresh and timely.

Active Voice: The passive voice is avoided in TV news. It is important to keep action in the verb.

2. Methodology

All papers should be written in English and must have **between three and twelve pages long** and arranged in the following order: The sources of the main sources of news used include the satellite/microwave video feed services and syndicated video coverage. The primary sources of news on TV are the news wire services such as Press Trust of India (PTI) and United News of India (UNI) among other agencies. Still photographs transmitted by the facsimile wire services are also used on the television, especially for the late breaking stories for which moving pictures are not available. The satellite/microwave video feed is television's own unique version of wire service. It is electronic transmission of the news stories originally recorded on film or video and sent by closed circuit microwave or through satellite to subscriber who record it on their own tape and then decide which stories to use for inclusion in the Science Monitor and science this week news. The advance planning for news production enables the producer for shooting location selection, research on news topic, communications regarding shooting etc. After the final of news to be incorporated in the news script writing is done through the science communicator cum script writer. The scripts in both Hindi and English languages are checked by the Scientist and Media personnel for the accuracy of science content and television language respectively. The finalization of script will be followed by the professional voice over artist voice over. The shooting of the anchor take place in the studio. Now at the editing table the whole story builds up by the video editor which includes shooting at news places, voice over of artists, stock shots, related visuals, anchor shots in between, important tag line in news, byte inclusion. The stories then compiled to get the news package of 24-27 minutes duration with one break. At the end of news, the anchor announces the Vigyan Prasar address, email id for the feedback of the viewer. After actual telecast the RSTV upload the news on its YouTube page. Analysis of numbers of viewer on YouTube, Email received is performed as impact study.

The news is being telecasted through the Indian government owned Loksabha Television Channel (LSTV) - channel of national repute from February 2011. After two years of successful telecast the news telecast was shifted to the Indian government owned Rajyasabha Television (RSTV) - channel of national repute. Since last 3 years the news was successful telecasting through the Rajyasabha Television (RSTV).[10] In view of the treatment of the news have components of the television media angle of writing and voice over of the news. The news was produced through hired production agency M/S Credence Media Solutions Pvt Ltd, New Delhi as per Government of India (GOI) norms and currently news is being produced by it for Vigyan Prasar. The news has main components includes the main news and happenings, in-depth stories, science express, meet the scientist, technology and innovations in various areas of science and technology. The production agency after collecting news and happenings from various source feeds produces original scripts in both Hindi and English languages, the scripts were cross checked by the scientists at Vigyan Prasar for accuracy of content. The pre-telecast rough cut of the program is checked by the nominated experts in the field of science communication for accuracy of content going on air through news. The Rajyasabha Television (RSTV) in addition to telecast of the program also created youtube page and upload the news on these pages for the viewers who missed the news while on air.[11]

3. Results

Table 1. The news coverage percent analysis study in 5 years

News Subject	Number of news	% analysis
wild life	57	6.27
space research	120	13.2
Health	141	15.51
Astronomy	51	5.61
current news	56	6.16
Biography	53	5.83
Eco tour	9	0.99
climate Change	33	3.63
Themed	74	8.14
Science communication	111	12.21
Career	32	3.52
Nuclear Energy	9	0.99
Disaster	20	2.20
Application of Science and Technology	70	7.70
Conservation	33	3.63
Renewable energy	28	3.08
Weather	12	1.32

	909	100

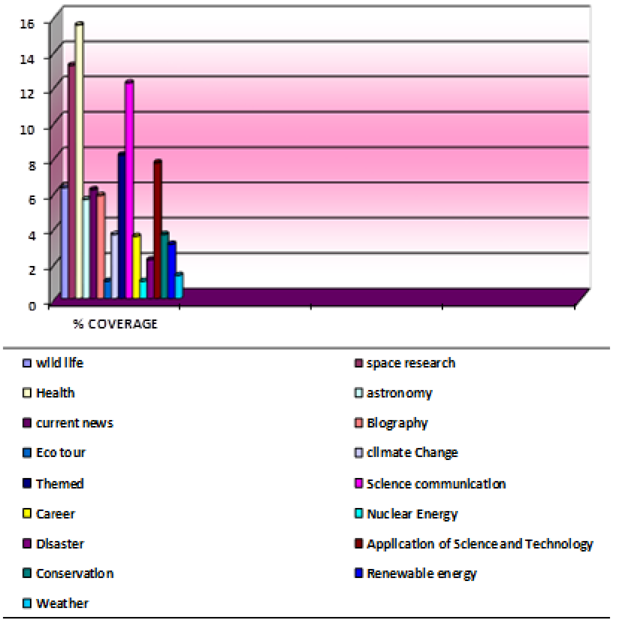

Figure 1. Different subject area covered in news

Table 2. Showing details of In-Depth stories covered from 24th February 2012 to 16th July 2016

Subject Title	Numbers	Subject wise % of In-depth
Biology	12	11.88
Chemistry	2	1.95
Space	16	15.94
Physics	10	9.96
Mathematics	1	0.99
Health	26	25.74
General Science	15	14.86
Environment	17	16.83
Information Technology	1	0.95
Biography	1	0.9

	101	100

4. YouTube analytical report

The news program in Gyan Vigyan in Hindi and Science Monitor in English is uploaded on RSTV YouTube page for post telecast viewers. The viewers gave good response on YouTube. The engagement of social platform like YouTube proven additional impact along with the television due to availability all time, ease of surfing news, can be seen by any device even mobile phones too, can be seen in one's own language as translated version.[12]

The You Tube analytical report revealed the watch time (minutes), Views, Average Percent views, Average View Duration, Geographical locations, translation views, device used by the viewers, view with subtitles for both Gyan Vigyan and Science Monitor.

Here the comparative analysis is performed for both programs Gyan Vigyan and Science Monitor. As the programs in two different languages the comparison study reveals many facts and results about the news programs, their national and international impacts, viewers using various devices to watch the programs.[13]

Table 3. (after the References)

5. Key Editorial Shifts and Trends (Last 3 Years)

The "Shorts" Explosion: Traditional 30-minute weekly science news roundups on digital platforms have largely migrated toward a hybrid format. Creators now split weekly news into daily 60-second vertical shorts, backed up by one detailed weekend long-form breakdown.

Nationalism in Science: Since major milestones like Chandrayaan-3 and the Aditya-L1 solar mission, audience demand for news concerning ISRO, indigenous defense tech (DRDO), and Indian deep-tech startups has surged dramatically over global science news.

Language Dominance: Hindi and regional language science communication vastly outperforms English-only channels in India, driving the democratization of science news in Tier-2 and Tier-3 cities.14.

Comparison of Various laboratories of CSIR, ICMR, Space science and others for highlighting science contents:

The following comparison table evaluates how different government entities highlight science content across digital, broadcast, and print media.15

Table 4 – (after the References)

For Written & Institutional Content: CSIR-NIScPR highlights the largest volume of diverse science topics. Because CSIR covers everything from aerospace and oceanography to genomics and metallurgy, NIScPR processes and highlights a massive stream of multi-disciplinary Indian research.

For Video Content & Mass Reach: ISRO leads exponentially in audience engagement and visual storytelling, while **DST's India Science** platform produces the highest volume of strictly scheduled weekly and daily science video programming.16

Science video content acts as a cognitive bridge, translating raw data and complex, abstract theories into dynamic visual narratives. Its importance varies fundamentally depending on who is watching.

Here is how science video content serves three distinct audiences:

5.1. 1. For Students: The Classroom Catalyst

For students, abstract textbook formulas can feel completely detached from reality. Video content makes the invisible visible.

Visualizing Abstract Concepts: Videos can animate things that cannot be seen with the naked eye—such as a strand of DNA replicating, chemical bonds breaking, or the curvature of spacetime.

Enhancing Retention and Motivation: According to educational research, multimedia learning activates both visual and auditory processing channels simultaneously (Dual-coding theory), which significantly improves memory retention compared to reading text alone.

Democratic Access to High-Quality Education: A student in a remote Indian village with an internet connection can watch the same high-level breakdown of astrophysics or biotechnology as a student in an elite urban school, leveling the educational playing field.

5.1. 2. For the Common Man: The Shield Against Misinformation

For the general public, science video content is not about passing an exam—it is about navigating daily life and building a scientific temper (critical thinking).

Democratizing Complex Knowledge: Good science videos bypass heavy academic jargon, translating breakthroughs into clear, everyday language that connects to daily life (e.g., how vaccines work, the impact of climate change on local weather, or how AI affects job security).

Combating Fake News and "WhatsApp University": In an era where pseudoscientific health myths and conspiracy theories spread rapidly, engaging, evidence-based video content acts as a factual antidote. Humans are visually driven; a debunking video with visual proof is vastly more convincing to a layperson than a text-heavy fact-checking article.

Empowering Personal Decision-Making: Whether evaluating dietary choices, understanding public health guidelines, or making smart consumer tech purchases, video content equips citizens to make data-driven personal choices.17

5.1. 3. For Policy Makers: The Evidence-Based Guide

Policy makers rarely have the time to read 50-page academic peer-reviewed papers. They require concise, high-impact, actionable insights to draft legislation.

Bridging the Science-Policy Gap: Short, highly structured briefings or video explainers allow scientists to deliver evidence-based data directly to lawmakers, ensuring that public policy (on environment, healthcare, or technology) is grounded in reality.

Gauging Public Sentiment: High-engagement public science videos help policy makers understand what scientific issues the public cares about, where public anxieties lie (e.g., fears surrounding GMOs or nuclear energy), and where public education campaigns are needed.

Justifying Public Funding: When government laboratories (like ISRO or CSIR) visually broadcast their breakthroughs, it builds public trust and national pride. This visual accountability makes it easier for policy makers to justify allocating taxpayer money to long-term scientific research.

Table 5. (after the References)

For Written & Institutional Content: CSIR-NIScPR highlights the largest volume of diverse science topics. Beca

6. Summary and Conclusion

An analysis of the 909 stories (100%) disseminated during the study period reveals that the highest proportion of coverage was devoted to Health, accounting for 141 stories (15.51%), followed by Space Research with 120 stories (13.20%), and Science Communication with 111 stories (12.21%). The remaining stories were distributed across various other scientific and technological domains, reflecting the diverse spectrum of science communication activities undertaken during the period.

The predominance of health-related stories underscores the growing importance of public health issues in India. Increasing environmental pollution, recurring natural disasters and hazards, emerging and re-emerging infectious diseases, as well as recent epidemic and pandemic experiences, have heightened public interest in health and healthcare-related information. Consequently, health emerged as the most frequently reported subject area, highlighting its relevance to both policymakers and the general public.

The substantial coverage of space research reflects India's remarkable achievements in the field of space science and technology. Major milestones, missions, and technological advancements by the Indian space sector attracted significant media attention and public engagement during the study period. These achievements not only enhanced national pride but also stimulated wider interest in science and innovation among citizens.

The strong representation of science communication stories indicates sustained efforts to promote scientific awareness, disseminate research outcomes, and foster a scientific temper among the public. Overall, the distribution of stories suggests that topics with direct societal impact, national significance, and public relevance received the greatest attention. The findings demonstrate the crucial role of science communication in connecting scientific developments with society and in enhancing public understanding of contemporary scientific issues.

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Table 3. India Weekly Science News & Science

Channel / Program	Sector / Type	Avg. Weekly Content Format	Primary Focus Area	Est. Avg. Weekly Views / Reach (Last 3 Years)	Subscriber / Audience Base (As of 2026)
India Science (DST / Vigyan Prasar)	Government (OTT & Internet TV)	Daily & Weekly video bulletins, expert interviews	Indian lab breakthroughs, space missions (ISRO), national S&T policies	300K - 500K digital views weekly	Multichannel OTT apps & web platform
DD Science (Doordarshan National)	Government (Public TV Broadcast)	1-hour daily slot (Mon-Sat), weekly news roundups	Documentaries, institutional walkthroughs, rural science outreach	2M - 5M linear TV viewers	Pan-India terrestrial & DTH network (92% population reach)
Antariksh TV (by Kaushik Bhattacharjee)	Independent (YouTube)	1-2 videos per week, regular shorts	Astronomy, space exploration news, ISRO/NASA updates	1.5M - 3M views weekly	~5.3 Million subscribers
Gaurav Thakur (GetsetflySCIENCE)	Independent (YouTube)	2-3 highly produced weekly videos	Theoretical physics, futuristic tech, space anomalies, general science	2.5M - 4M views weekly	~6.5 Million subscribers
Indian Scientist	Independent (YouTube)	Multi-weekly uploads and shorts	Emerging technology, deep-space news, daily science facts	1M - 1.8M views weekly	~2.2 Million subscribers
Khan GS Research Centre *(Science/Geopolitics segments)*	Independent (YouTube)	Weekly deep-dives on defense tech, space, and core science	Geopolitical technology, space missions, weapon systems physics	5M - 10M views per science-focused video	~26.5 Million subscribers

Table 4. Indian Government Entities Highlighting Science Content

Government Entity / Lab	Primary Medium	Target Audience	How Content is Highlighted	Key Strengths & Content Focus
CSIR-NIScPR *(National Institute of Science Communication and Policy Research)*	Print, Digital Journals, & Popular Magazines	Academics, Students, and the General Public	Publishes iconic monthly magazines like *Science Reporter* (English) and *Vigyan Pragati* (Hindi), alongside open-access research journals.	**The Policy & Print Champion:** Excellent at converting complex lab research across all 37+ CSIR laboratories into structured, readable articles and newsletters.
ISRO *(Indian Space Research Organisation)*	Live Streaming, YouTube, & Social Media	Mass Global & National Public, Students	High-profile live broadcasts of rocket launches, space mission tracking animations, and deep-dive technical infographics.	**The Mass Engagement Leader:** Commands the highest digital traction. Captivates the public imagination through milestone events (e.g., Chandrayaan, Gaganyaan) and real-time mission updates.
India Science / DST *(Department of Science & Technology)*	OTT Platform, YouTube, & Web Video	Rural & Urban Students, Civil Services Aspirants	Dedicated 24/7 internet communication channel broadcasting weekly documentaries, lab walkthroughs, and interviews with Indian scientists.	**The Video Pioneer:** Created as India's primary web-TV platform for science. Covers grassroots innovations, government fellowships, and laboratory breakthroughs outside of space science.
ICMR *(Indian Council of Medical Research)*	Public Advisories, Digital Portals, & Press Briefings	Healthcare Professionals, General Public	Focuses on medical health graphics, disease prevention explainers, epidemic bulletins, and open-access healthcare data repositories.	**The Public Health Authority:** Translates clinical trial data, vaccine developments, and bio-medical research into highly critical, easily digestible public safety guidelines.

Table 5. Indian Government Entities Highlighting Science Content

Audience	Primary Barrier to Science	How Video Resolves It	Ultimate Outcome
Students	Boredom / Difficulty visualizing abstract theories	Animates concepts & engages multiple senses	Academic excellence & inspiration for STEM careers
Common Men	Academic jargon & overwhelming misinformation	Replaces jargon with storytelling & visual proof	Scientific literacy & rational daily decision-making
Policy Makers	Lack of time to digest massive research papers	Compresses data into high-impact, actionable summaries	Evidence-based laws & smarter budget allocation

Chapter 11: Personalized Education of Students in The Conditions of Digitalization and Implementation of Artificial Intelligence

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Abstract. The article examines the problem of personalized education of students in the conditions of digitization of education and introduction of artificial intelligence. The relevance is due to the transition from the traditional unified model of education to individualized and adaptive educational systems. A theoretical analysis of the personalization of learning, digitalization of education and the use of AI was carried out. It was determined that personalized learning is based on a combination of a person-oriented approach, digital technologies and educational analytics. The role of artificial intelligence in the analysis of educational data, prediction of results and formation of individual recommendations is revealed. The capabilities of digital platforms and LMS in providing a flexible educational process are considered. Pedagogical conditions for the effective implementation of personalization and the main challenges of AI implementation have been determined. A conclusion was made about the prospects of personalized training for improving the quality of education and developing students' competencies.

Keywords. personalized training, artificial intelligence, digitization of education, adaptive educational technologies.

1. Relevance of the research

The rapid development of digital technologies and the active implementation of artificial intelligence systems in all spheres of social life lead to significant transformations of the educational environment. The modern stage of education development is characterized by the transition from the traditional model of education to innovative approaches focused on the needs, opportunities, and individual characteristics of those seeking education. In these conditions, the problem of personalized education of students becomes especially relevant, which involves adapting the educational process to individual educational needs, level of training, pace of knowledge acquisition, learning style and professional interests of each student.

Digitization of education has become one of the key directions of modernization of educational systems in many countries of the world. The use of digital platforms, electronic educational resources, learning management systems, cloud services and means of remote interaction creates new opportunities for organizing the educational process. At the same time, a significant volume of information, a variety of educational resources and the need for an individual approach to students require the use of more effective learning management mechanisms, among which artificial intelligence technologies occupy an important place.Today, artificial intelligence is considered not only as a tool for automating certain processes, but also as a powerful means of supporting decision-making in educational activities. Thanks to the ability to analyze large data sets, identify patterns and predict learning outcomes, artificial intelligence systems can ensure the adaptation of educational content to the individual characteristics of students, form personalized recommendations regarding the educational trajectory, identify educational difficulties in a timely manner and offer ways to overcome them. As a result, prerequisites are created for increasing the effectiveness of learning, developing student independence, and improving the quality of educational results.

The problem of personalized training becomes especially relevant in the conditions of modern socio-economic challenges associated with rapid changes in the labor market and the growth of requirements for the professional competencies of future specialists. Employers increasingly need specialists who can quickly adapt to new conditions, master modern technologies, work with information and constantly update their knowledge. Traditional approaches to education do not always ensure the formation of such competencies in a sufficient amount, which actualizes the need to find new educational models based on the principles of individualization and flexibility.

An important factor in the relevance of research is also the growing role of mixed and distance learning. The events of recent years have demonstrated the need to ensure the continuity of the educational process regardless of external circumstances. The use of digital technologies made it possible to support education in the conditions of a pandemic, martial law and other crisis situations. However, the mass implementation of distance education revealed a number of problems related to insufficient motivation of students, the difficulty of monitoring their educational activities, and limited opportunities for individual support. That is why the use of artificial intelligence tools to create a personalized educational environment is becoming one of the promising areas of modern education development.

Personalization of learning with the help of artificial intelligence technologies opens up new opportunities for increasing the level of student involvement in the educational process. Adaptive educational systems are able to take into account the individual level of knowledge, the style of information perception and educational achievements of education seekers, offering the most effective forms of presentation of educational material. This contributes to increasing motivation to study, developing self-education skills, and forming responsibility for one's own educational trajectory.

At the same time, the wide implementation of artificial intelligence in educational practice gives rise to a number of new challenges and problems that require scientific understanding. Among them, the issues of ensuring academic integrity, protecting students' personal data, ethical use of artificial intelligence algorithms, preserving the role of the teacher in the educational process, and preventing excessive dependence on digital technologies attract special attention. Solving these issues is a necessary condition for the effective and safe use of intelligent systems in the field of education.

An equally important aspect is the need to prepare pedagogical workers to work in the conditions of digital transformation of education. The effective use of artificial intelligence tools requires new digital competencies from teachers, the ability to integrate modern technologies into the educational process and provide pedagogical support for personalized learning. Therefore, the study of the features of the application of artificial intelligence in educational activities is of important practical importance for improving the professional training of pedagogical personnel.

The topicality of the topic is also determined by the strategic directions of education development in Ukraine and the world, which provide for the digital transformation of the educational sphere, improving the quality of educational services, developing innovative learning technologies and creating conditions for the realization of the individual potential of each student. In the context of the integration of Ukrainian education into the European educational space, the implementation of modern approaches to the organization of education, which meet international standards and contribute to the formation of competitive specialists, is of particular importance.

2. The degree of scientific development of the problem

The problem of personalization of learning has been the subject of scientific research in pedagogy, psychology and educational technologies for a long time. The theoretical foundations of individualization and personally oriented education were developed in the works of such scientists as I. Beh, O. Savchenko, S. Sysoeva who substantiated the need to take into account the individual characteristics of education seekers, their needs, abilities and educational requests. The concept of person-oriented education, developed by I. Bech and I. Yakymanska, became an important foundation for the formation of modern approaches to personalized education.

Foreign researchers C. Bray, H. McCluskey, B. Patrick, M. Horn and K. Christensen made a significant contribution to the development of the theory of personalized learning. In their works, personalized learning is considered as an educational model that ensures adaptation of the content, pace and methods of learning to the individual needs of each student. Special attention is paid to the construction of individual educational trajectories and the creation of conditions for the development of the autonomy of education seekers.

Theoretical and practical aspects of digitalization of education were studied in the works of V. Bykova, .R. Gurevicha, M. Kademii and other scientists. Scientists considered the introduction of information and communication technologies into the educational process, the formation of digital competence of participants in the educational process, the development of electronic and distance learning, as well as the creation of a digital educational environment of educational institutions. In particular, V. Bykov paid considerable attention to the conceptual foundations of the digital transformation of education and the development of open educational systems.

A separate direction of modern research is related to the use of artificial intelligence technologies in education. A significant contribution to the study of this issue was made by R. Lucky, V. Holmes, U. Holmes, M. Tuominen, R. Baker, K. Dwedi and other researchers. Their works highlight the possibilities of using artificial intelligence to create adaptive learning systems, automated knowledge assessment, educational data analysis, and pedagogical decision-making support. Scientists pay special attention to the use of intelligent algorithms to personalize the educational process and increase the effectiveness of training.

The problems of introducing artificial intelligence into educational practice are being actively investigated by international organizations and scientific centers. The analytical reports of UNESCO, the Organization for Economic Cooperation and Development (OECD), as well as the European Commission, which defined the prospects for the use of artificial intelligence in education and outlined the key ethical, social and pedagogical challenges of its application, became important for the development of this issue.

At the same time, the analysis of scientific works shows that the majority of studies are devoted either to issues of digitization of education or to certain aspects of the use of artificial intelligence. Insufficient attention is paid to the comprehensive study of the mechanisms of personalization of education of students of higher education institutions based on intelligent digital technologies. Pedagogical conditions for the effective use of artificial intelligence for the formation of individual educational trajectories, the development of students' educational motivation, ensuring academic integrity and improving the digital competence of teachers require further research.

3. The purpose of the study

is the theoretical justification and analysis of the possibilities of personalized training of students in the conditions of digitalization of education and the introduction of artificial intelligence technologies, as well as the determination of its role in increasing the efficiency of the educational process, forming individual educational trajectories and developing the professional competences of students of higher education.

4. Presentation of the material

The current stage of the development of higher education is characterized by deep transformational processes caused by the digitalization of society, the rapid development of information and communication technologies, and the introduction of artificial intelligence systems into educational practice. In these conditions, the traditional model of education, based on a unified approach to all students, is gradually losing its effectiveness, giving way to more flexible and adaptive models of organizing the educational process. One of these models is personalized training, which involves taking into account the individual characteristics of the student, his educational needs, the rate of learning the material and professional interests.

As noted by I. Beh, a person-oriented approach in education involves the creation of conditions for the development of the unique personality of the student of education, which becomes the basis for the formation of modern models of individualized education [2]. In this context, personalization is considered not only as a methodical approach, but as a holistic pedagogical paradigm that changes the role of the teacher and student in the educational process. The teacher increasingly performs the function of a tutor, mentor and facilitator of educational activities, while the student becomes an active subject of his own educational trajectory.

The development of education in the conditions of globalization and digital transformation requires a transition to innovative learning models capable of ensuring the formation of 21st century competencies. These competencies include critical thinking, digital literacy, self-education, communication and teamwork. It is personalized learning that creates the prerequisites for the development of these competencies, as it allows the educational process to be adapted to the individual educational trajectory of each student.

Digitization of education significantly expands the possibilities of implementing personalized training. As V. Bykov notes, the formation of a digital educational environment involves the integration of various electronic resources, learning management platforms, cloud services and analytical systems that ensure the accumulation and processing of large arrays of educational data [3]. This creates the basis for the implementation of adaptive learning systems that can automatically adjust the learning content to the level of knowledge and needs of the student.

The use of digital technologies in the educational process makes it possible to implement the principles of flexibility, accessibility and continuity of education. In particular, learning management systems (LMS), such as Moodle, Google Classroom or other platforms, provide the possibility of individual choice of learning pace, access to materials at any time and from any place, as well as constant feedback between the teacher and the student. This creates conditions for the transition from a reproductive model of learning to a constructivist one, where the student independently forms knowledge.

A special role in the development of personalized learning is played by the concept of adaptive learning, which involves automatic adjustment of educational content in accordance with the results of the student's activity. In the works of B. Patrick, M. Horn and K. Christensen, it is noted that adaptive learning models allow to significantly increase

the efficiency of knowledge acquisition, as they take into account the individual characteristics of the cognitive development of students and ensure the optimal complexity of educational tasks [8].

Learning analytics is also an important component of personalized learning, which allows you to monitor the learning activity of students, analyze their results, and predict possible learning difficulties. As noted by R. Baker, the use of educational analytics makes it possible to timely identify problem areas in learning the material and offer individual recommendations to overcome them [1].

Thus, the theoretical principles of personalized learning are based on a combination of a person-oriented approach, digital technologies and educational data analytics. This makes it possible to create a new model of the organization of the educational process, which is focused on the student as the central figure of the educational system.

The development of artificial intelligence (AI) has significantly changed approaches to the organization of education, opening up new opportunities for the implementation of personalized educational trajectories. Unlike traditional digital technologies, which mostly provide access to educational materials, artificial intelligence systems are capable of analyzing students' learning behavior, predicting their results and forming individual recommendations for further learning.

As noted by V. Holmes, M. Bialik, and K. Feidel, artificial intelligence in education performs three key functions: automation of educational processes, adaptation of educational content, and support for pedagogical decision-making. It is the last function that is the most important from the point of view of personalization, as it allows the teacher to receive analytical information about each student and quickly adjust the educational trajectory [5].

One of the most widespread areas of application of AI in education is adaptive learning systems. Such systems are based on machine learning algorithms that analyze students' answers, the speed of task completion, the number of errors and other parameters of educational activity. Based on this, an individual model of the student is formed, which is used to select the optimal level of difficulty of the educational material.

In particular, research by R. Baker in the field of educational data mining shows that the use of forecasting algorithms makes it possible to determine the risk of academic failure of students with high accuracy. This enables teachers to intervene in the educational process in a timely manner and provide additional support to those students who need it [1].

An important element of personalized learning is recommender systems that function based on the principle of analyzing the student's previous learning behavior and offer him the most relevant learning content. Such systems are widely used in modern online platforms, in particular in Coursera, edX and other massive open online courses. They allow you to create individual study routes, which significantly increases the efficiency of learning the material.

As U. Holmes notes, artificial intelligence also contributes to the development of the concept of "intelligent learning environments" that are able to interact with the student in real time. Such systems can not only evaluate the correctness of tasks, but also explain errors, offer additional materials and adapt the difficulty of tasks according to the student's level of preparation [5].

The role of chatbots and virtual assistants, which are one of the most accessible tools of artificial intelligence in education, should be noted separately. They provide prompt support to students, answer questions, help navigate the educational material and perform the functions of a personal tutor. This is especially important in distance learning, when contact between the teacher and the student is limited.

In addition, artificial intelligence systems allow automated assessment of educational achievements. Natural language processing and machine learning algorithms are capable of analyzing student writing, test assignments, and even creative projects. This significantly reduces the teacher's workload and provides a more objective assessment of learning outcomes.

At the same time, the use of artificial intelligence in the educational process raises a number of debatable issues. As noted in the UNESCO reports, there are risks associated with excessive automation of learning, possible algorithmic biases and insufficient transparency of decision-making by AI systems. Therefore, it is important to ensure a balance between technological support of learning and maintaining the leading role of the teacher.

Digitization of education has created fundamentally new conditions for the organization of the educational process, in which digital educational tools play a key role platforms and learning management systems (Learning Management Systems, LMS). They provide the technical basis for the implementation of personalized learning, as they allow the integration of educational materials, means of communication, assessment and analytics into a single educational environment.

As V. Bykov notes, the digital educational environment is a complex system that combines technological, pedagogical and organizational components aimed at ensuring effective learning. In this environment, the student gets the opportunity to independently manage his own educational trajectory, choose the pace of learning, the level of difficulty of tasks and additional resources for studying the material [3].

The most common platform for organizing the educational process in institutions of higher education is Moodle, which allows you to implement elements of personalization through the setting of individual courses, testing, forums and a feedback system. Google Classroom, Microsoft Teams, and other digital environments that are actively used in blended and distance learning also provide similar opportunities.

Blended learning is one of the most effective models of modern education, as it combines traditional classroom classes with online learning. As noted by M. Horn and K. Christensen, blended learning creates conditions for a more flexible organization of the educational process, where a student can master part of the material independently in the digital environment, and part of it in interaction with the teacher. In the context of personalized learning, the mixed model is of particular importance, as it allows combining the individual work of the student with collective forms of learning [6]. This ensures a balance between the autonomy of the learner and pedagogical support from the teacher. In addition, digital tools allow the teacher to monitor the progress of each student and adjust the learning process in a timely manner.

An important component of personalization is the use of electronic educational resources that can be adapted to different levels of student training. These can be interactive textbooks, video lectures, simulation models, online tests and other digital materials. Their use allows taking into account individual learning styles - visual, auditory or kinesthetic.

As N. Morse notes, the effectiveness of the digital learning environment largely depends on the quality of the pedagogical design of the courses. It is the teacher who determines the structure of the educational material, the logic of information presentation and the level of interactivity of tasks, which directly affects the possibilities of personalization [7].

The practical implementation of personalized learning in institutions of higher education involves the use of individual study plans. Such plans allow students to choose disciplines, modules and tasks according to their own professional interests. This is especially relevant in the conditions of the competence approach, where the result of training is not only knowledge, but also formed skills and abilities.

Online courses and massive open online courses (MOOCs) play a special role in the implementation of personalization. The Coursera, edX and FutureLearn platforms allow students to shape their own educational trajectory by choosing courses according to their own needs. This contributes to the development of autonomy and responsibility for learning outcomes.

At the same time, the experience of implementing digital technologies shows that the effectiveness of personalized learning largely depends on the level of digital competence of both students and teachers. As O. Spirin points out, digital competence is a key condition for the successful integration of technologies into the educational process, as it provides the ability to effectively use digital resources for learning and teaching [9].

The effective implementation of personalized learning in the conditions of digitization and the use of artificial intelligence requires the definition of clear pedagogical conditions that ensure the effectiveness of the educational process. Such conditions include: the readiness of teachers to use digital technologies, the presence of a developed digital educational environment, methodical support for personalized learning, as well as the motivation of students for independent educational activities.

As S. Sysoeva notes, modern education should focus on the development of the individual as an active subject of learning, which implies a change in the traditional role of the teacher. In the context of personalized learning, the teacher ceases to be only a source of knowledge and gradually turns into a tutor, facilitator and mentor who accompanies the individual educational trajectory of the student [10].

The conditions of the digital transformation of education significantly change the nature of pedagogical interaction. The teacher gets access to a large array of data on students' educational activities, which allows for more accurate pedagogical forecasting. At the same time, it requires new competencies, in particular, the ability to work with analytical systems, interpret the results of educational analytics, and make informed pedagogical decisions.

An important role in this process is played by the formation of digital competence of pedagogical workers. As O. Spirin points out, digital competence includes not only technical skills in the use of information technologies, but also the ability to critically evaluate digital resources, ensure safe use of data, and integrate technology into pedagogical practice [9].

Along with the positive aspects of the implementation of artificial intelligence in education, a number of problems and challenges arise. One of the key problems is the risk of excessive automation of the educational process, when algorithmic systems begin to influence pedagogical decisions without sufficient consideration of the human factor. As noted in UNESCO research, it is important to ensure a balance between the use of technology and maintaining the leading role of the teacher.

Another important issue is the issue of algorithmic bias. Artificial intelligence systems can reproduce or even exacerbate existing social and educational inequalities if they are trained on poor-quality or unrepresentative data. This creates risks of unfair assessment of students or incorrect formation of recommendations regarding their studies.

No less important is the issue of protecting students' personal data. The use of analytical systems involves the collection of a large amount of information about educational activity, which requires clear protection mechanisms and compliance with ethical standards. In this context, compliance with the principles of confidentiality and information security is of particular importance.

The problem of academic integrity also remains relevant. The use of generative systems of artificial intelligence can contribute both to improving the quality of education and to the emergence of risks of plagiarism or uncontrolled use of automatically generated texts. Therefore, institutions of higher education should develop policies for the responsible use of AI in the educational process.

Psychological adaptation of students to new forms of education is also an important challenge. Not all learners are equally ready for the high level of autonomy and independence that personalized learning entails. This requires teachers to provide additional support to students in the process of adapting to the digital educational environment.

Thus, the effective implementation of personalized learning based on artificial intelligence requires a comprehensive approach that takes into account both technological capabilities and pedagogical, ethical and organizational aspects of the educational process.

The analysis of modern approaches to the organization of personalized training in the conditions of digitization and the introduction of artificial intelligence allows us to conclude that this model of the educational process is one of the most promising areas of higher education development. Its implementation ensures the transition from a unified education system to a flexible, adaptive and student-centered model that takes into account the individual characteristics of each student.

The effectiveness of personalized training is largely determined by the level of integration of digital technologies and artificial intelligence into the educational process. The use of adaptive learning systems, analytics of educational data and recommendation algorithms allows to improve the quality of study material, reduce the level of academic failure and increase the motivation of students to study.

Research by R. Baker and V. Holmes shows that the use of artificial intelligence technologies in education contributes to a more accurate determination of the educational needs of students and the timely identification of learning difficulties. This enables teachers to quickly adjust the educational process and provide individual support to students [1, 5, 6].

At the same time, the effectiveness of personalized learning depends not only on technological solutions, but also on the teacher's pedagogical skills. It is the teacher who provides a meaningful interpretation of the data provided by digital systems and makes the final decisions regarding the organization of the educational process. Thus, artificial intelligence acts as an auxiliary tool, not a substitute for pedagogical activity.

An important result of the implementation of personalized learning is an increase in the level of student autonomy. Education seekers get the opportunity to independently plan their own educational trajectory, choose the pace of learning and the formats of learning the material. This contributes to the development of self-organization skills, critical thinking and responsibility for learning outcomes.

In addition, personalized training has a positive effect on the formation of professional competences, as it allows more accurate consideration of the requirements of future professional activity. Students can choose individual educational routes focused on their specialization, which increases the practical value of the acquired knowledge.

At the same time, the implementation of personalized learning requires further improvement of the regulatory framework, development of the digital infrastructure of educational institutions, and an increase in the level of digital competence of teachers and students. It is also necessary to develop ethical standards for the use of artificial intelligence in education. In order to find out the possibilities of personalized training of students in the conditions of digitization and introduction of artificial intelligence, we conducted a survey of teachers of higher education institutions. We came to the conclusion that the majority of teachers use personalized learning technologies and believe that personalized learning with AI will become the norm in higher education in the future.

The table graphically illustrates the conclusions personalized training.

Table 1. Respondents' answers about the possibilities of using personalized training

	Yes %	No %	Answers to open questions
Are you familiar with the concept of personalized learning?	80	20	
Do you use artificial intelligence (AI) technologies in the learning process?	60	40	
How do you think artificial intelligence can improve the learning process?			Individual approach to each student Automatic assessment of knowledgeRecommendations of educational materials Assistance in training planning
To what extent do you think personalized learning increases student motivation?	50	35	
What do you think are the main challenges in implementing personalized learning using AI?			Lack of skills among teachers Insufficient technical equipment Students' resistance to new technologies Data privacy issues
What digital platforms or tools do you use for learning? (open question)			Google Search; Google Workspace; Google Classroom, Moodle, Coursera, Prometheus, EdEra та Kahoot!
Do you think personalized learning with AI will become the norm in higher education in the future?	67	33	

5. Conclusions

Personalized training in the conditions of digitalization and the introduction of artificial intelligence is an effective tool for the modernization of higher education, which ensures the improvement of the quality of the educational process, the individualization of educational trajectories and the development of the competencies of future specialists. Further research should be aimed at improving models of artificial intelligence integration into educational practice and developing pedagogical strategies for their effective use.

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Chapter 12: Where is the Line? Focus Group Insights into AI as an Assistant vs. AI as Cheating in STEM Education

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Abstract. he rapid integration of Generative AI (GenAI) into higher education has blurred the boundaries between legitimate academic assistance and plagiarism. This paper analyzes a part of data from a comprehensive, 6-hour focus group involving university students (N=8) exploring how learners delineate the line between AI-assisted learning and cheating. To capture unvarnished perspectives, this preliminary study focuses strictly on the quantitative and qualitative data gathered through anonymous surveys and written tasks which were included in the focus group, comparing them against non-anonymous demonstration of own opinions among peers. The findings reveal five distinct behavioral patterns, including a strong consensus that submitting raw AI output is unacceptable, and a highly nuanced spectrum of what constitutes "assistance" (e.g., grammar corrections, translation) versus "cheating" (e.g., idea generation, conclusion writing). Crucially, a comparative analysis reveals a socio-psychological paradox: students express significantly more conservative, strict ethical boundaries when answering anonymously than when defending their views openly among peers, highlighting the impact of social compliance in academic environments.

Keywords. Generative AI, academic Integrity, STEM education, focus group, social desirability, human-AI collaboration.

1. Introduction

The rapid rise of Large Language Models (LLMs) and Generative Artificial Intelligence (GenAI) has destabilized traditional assessment models in science, technology, engineering, and mathematics (STEM) education. Faculty members frequently struggle to design policies that accommodate AI as a pedagogical tool without compromising academic rigor. Concurrently, students find themselves in an ambiguous ethical landscape. While universities scramble to define institutional policies, the day-to-day choices of students are guided by internal, peer-influenced, and highly fluid definitions of where "assistance" ends, and "cheating" begins [1].

This paper addresses this conceptual boundary. Instead of evaluating institutional frameworks, we investigate the empirical reality of student perceptions. By utilizing data from an intensive focus group, this study captures how university students negotiate their relationship with AI tools. Understanding these internal boundaries is critical for STEM educators who wish to build trust-based, effective learning environments [2] rather than reactive, surveillance-driven classrooms.

2. Methodology

To explore these nuances, a comprehensive, 6-hour focus group was conducted with eight university students (N=8). Due to the longitudinal and exhaustive nature of the session, the data was segmented. This paper specifically analyzes the first phase of the focus group, which focused entirely on how students define the boundary between AI as an assistant and AI as a mechanism for plagiarism.

The methodology relied on a mixed-methods approach embedded within the focus group structure. Crucially, additionally to entering the open verbal debate, participants completed anonymous questionnaires (comprising both open-ended and closed questions) and individual written exercises. Students were tracked using codes from S1 to S8. A thematic analysis was applied to the qualitative responses to extract semantic codes.

This paper intentionally isolates the anonymous surveys and written tasks from the subsequent verbal transcripts. The rationale for this approach is methodological: anonymous feedback minimizes social desirability bias, allowing students to be significantly more candid, vulnerable, and honest about ethically sensitive behaviors than they might be in a transparent peer-to-peer discussion.

3. Results

The analysis of the quantitative data from the anonymous surveys revealed five highly repetitive, distinct behavioral and ethical patterns among the participants.

The thematic analysis of the empirical material revealed a multi-layered conceptual model used by students to navigate GenAI. While the boundaries are perceived as fluid, students possess a highly structured framework for evaluating the legitimacy of AI use, rooted in the concepts of authorship, utility, and educational value.

3.1. Five Patterns of Anonymity

1. Rejection of Pure AI Authorship: There was an absolute consensus regarding the refusal to submit any academic work written entirely by GenAI. Even when students fully comprehended the AI-generated text and its underlying mechanics, they viewed unedited submission as a violation of the student role.

2. The Editing Gray Area: A stark disagreement emerged regarding the permissibility of submitting AI-generated text after manual human editing. Students split on whether heavy stylistic rewriting legitimizes an AI baseline or if the underlying intellectual property remains fundamentally compromised.

3. Task Solutions as Direct Plagiarism: Submitting direct problem solutions or technical code generated by AI was universally categorized as cheating. In STEM fields, where answers are often binary or deterministic, outsourcing the core analytical execution was seen as bypassing the learning objective entirely.

4. Rejection of the "Fluid Boundary" Persona: In a scenario-based question, participants were presented with a fictional character who effortlessly and guiltlessly crossed the line between assistance and cheating based on convenience. Interestingly, not a single student selected this character as a model for their own behavior, signaling a universal desire to project ethical stability.

5. The Imperfection Obligation: Participants expressed a strong belief that a student must submit their own human work, even if they are fully aware that the AI could generate a technically superior, more polished, or optimized version of the assignment.

3.2. Authorship and the Mechanics of the "Gray Zone"

The primary theme emerged around the Boundary between assistance and cheating, specifically concentrated on the subtheme of Authorship. Students do not view AI assistance as a binary metric; instead, they anchor integrity in the origin of the core intellectual property:

- **The Primacy of Ideas (S7)**: Student S7 argued that the line remains safe if the human controls the conceptual framework: "... if it was written by AI based on my ideas and prompts, then it is actually assistance."
- **Output Ownership (S8)**: Conversely, S8 established that the final execution must belong to the student: "A solution (output) must be provided by you. Ways to solve can be provided by AI." For S8, integrity equals the generation of a "unique product.”
- **The Ethical Cost (S2)**: Ethical friction points were explicitly linked to intellectual theft. S2 noted that completely outsourcing work to GenAI means they would have "harmed the environment, stolen someone else's work, and allowed GenAI that does this and more morally bad things grow."

3.3. Acceptable Assistance vs. Signs of Cheating

When defining the Acceptable level of assistance, participants focused heavily on the distinction between process optimization and total cognitive replacement:

Linguistic and Structural Refinement (S1, S4): S1 accepted AI usage provided that "everything is clear to me," viewing it as a tool for comprehension. S4 added that using AI to express pre-existing human thoughts is entirely legitimate: "If you give an idea to AI and use generative tool, in order to express your thoughts, then it is good."

Pedagogical Scaffolding in STEM (S6): For quantitative tasks, S6 defined the boundaries through a pedagogical lens: "AI shouldn't generate a solution but rather explain it to you providing formulas and laws."

The Threshold of Cheating (S4, S5): Cheating is coded explicitly as Replacement. S4 noted that cheating occurs "when AI fully creates a text and idea." S5 expanded this, identifying that cheating is manifested when "people generate the idea with AI and create this idea with AI," leading to zero human cognitive investment.

3.4. Stability of Boundaries and Educational Value

A crucial finding relates to the Stability of boundary, which appears highly dependent on institutional contexts, alongside a deep internalization of *Educational value*:

Contextual and Course-Specific Rules (S8): S8 emphasized the situational nature of academic misconduct: "...Depends on a course. If the main aim is to write a text by yourself, it's cheating."

Personal Competence and Anxiety (S2, S3, S4): In individual responses, students linked assignments directly to self-assessment. S4 stated, "Assignment is way to understand your level of knowledge," while S2 remarked, "I better my own skills that way." However, as highlighted in individual reflections, when technical gaps occur—such as unresolved complexities in Excel or advanced data processing—students experience acute anxiety. For instance, S3 admitted to uploading confidential or redundant data to an LLM to resolve a complex Excel task, explicitly blaming a pedagogical gap: "the thing is we weren't taught how to use those tools on Excel during classes, that's why... I asked AI to help me with that missing part."

4. Discussion

4.1. The Spectrum of Assistance vs. Cheating

Beyond the fixed patterns, the data collected through open expression of opinions mapped out a highly fragmented spectrum of specific AI use-cases. When participants evaluated explicit actions, their consensus shifted dynamically based on the degree of AI intervention (Table 1).

Table 1. Assistance vs. Cheating

Action / Use-Case	Participant Classification
Correcting Grammar	Assistance (Universal Consensus)
Translating Text	Assistance (Universal Consensus)
Explaining Subject Matter	Assistance (Universal Consensus)
Generating Ideas / Brainstorming	Cheating
Writing a Conclusion Based on Own Text	Cheating
Paraphrasing Your Own Text	Something in Between / Gray Area
Generating Part of a Text	Something in Between / Gray Area
Generating a Full Assignment	Something in Between / Gray Area
Proposing the Outline/Structure of a Thesis	Divergent Opinions / No Consensus

As shown above, mechanical, linguistic, and informational operations (grammar, translation, conceptual explanation) are safely classified as Assistance. Conversely, tasks that outsource core synthesis or ideation (generating initial ideas, writing final conclusions) are labeled as **Cheating**.

The true tension lies in the structural and transformative tasks. Generating parts of a text, paraphrasing, or compiling full drafts sit in a volatile "**Something in Between**" category. Most notably, using AI to propose the structural outline of a thesis caused a complete fracture in opinions. Some students viewed structural modeling as a cognitive roadmap (assistance), while others considered structuring to be the primary intellectual labor of research (cheating).

4.2. The Paradox of Public vs. Private Opinion

When comparing the anonymous survey inputs with the open, non-anonymous movement phase of the focus group, an unexpected socio-psychological dynamic emerged. In both settings, the boundary between acceptable assistance and plagiarism became sharper as the perceived level of AI intervention increased.

However, the intensity of the stances differed dramatically. In the open movement expresiion, students expressed their ethical boundaries much less categorically than they did anonymously. When contacting face-to-face with peers, students loosened their restrictions, showing more leniency toward AI integration.

This suggests a powerful peer-pressure effect within the student community. Expressing a highly rigid, conservative ethical stance regarding AI can isolate a student from the contemporary peer norm. It appears that not every student possesses the social courage to maintain a strict ethical boundary when it risks placing them in a social minority or making them look overly compliant to traditional faculty rules.

5. Conclusion and Implications for STEM Education

The empirical material from this focus group highlights that students are not inherently malicious actors looking to bypass education; rather, they are navigating a highly complex, internal ethical matrix. While mechanical assistance is universally accepted, structural and generative assistance remains deeply polarizing.

For STEM educators, the key takeaway lies in the discrepancy between anonymous conviction and public compliance [3]. If students feel pressured to downplay their strict ethical stances in public to fit in, institutions must create safe, transparent spaces to discuss AI usage without judgment. Educational policies should move away from binary "use/don't use" rules and instead address the specific gray areas identified here—such as outlining, partial text generation, and the boundaries of editing—to help students maintain their intellectual autonomy without fearing social alienation. Rather than relying on punitive surveillance mechanisms, higher education must address the curriculum gaps that force students to use AI under desperate circumstances, ensuring that GenAI functions strictly as an assistive bridge rather than an intellectual replacement [4].

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Chapter 13: AI Tools in University Learning: Student Practices, Habits and Self-Reflection

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Abstract. The rapid integration of generative artificial intelligence tools into everyday academic life raises important questions about how university students actually use these technologies. This paper presents a student-centred perspective on the practices, habits, and critical awareness surrounding AI tool use in higher education. Drawing on a trilingual student survey and a focus-group discussion, it examines the purposes for which students employ AI, the patterns that emerge over time, and the degree to which students reflect on the limitations and ethical implications of these tools. The paper argues that fostering AI literacy is essential for resilient, future-ready science education.

Keywords. AI literacy, artificial intelligence, generative AI, higher education, student practices.

1. Introduction

Generative artificial intelligence tools such as ChatGPT and Claude have become widely accessible to university students worldwide. Their adoption in academic settings has been rapid and largely self-directed, outpacing formal guidance from educational institutions. While much research focuses on the risks of AI misuse, comparatively little attention has been paid to understanding how students themselves experience and reflect on their day-to-day use of these tools. This paper addresses that gap by combining a trilingual student survey with a focus-group discussion to offer a student-centred account of AI literacy in practice.

2. Methodology

Data were collected through two complementary instruments. A structured online questionnaire, available in English, Russian, and Kazakh, gathered responses from university students on the frequency, purposes, and self-perceived effects of their AI tool use, including Likert-scale items on trust, dependence, and academic integrity. In addition, a small focus group of senior students discussed open questions about the boundaries between assistance and academic dishonesty, the skills they may be losing, and the role universities should play. Together these methods combine quantitative patterns with qualitative reflection.

3. AI Use Patterns Among University Students

Students engage with AI tools for a wide variety of academic tasks, including summarising complex texts, generating drafts, clarifying concepts, translating materials, and checking code or calculations. Over time, patterns of reliance emerge: some students develop a habit of consulting AI as a first step rather than a last resort, while others use it primarily for verification and refinement. These habits raise questions about cognitive engagement and the development of independent problem-solving skills. AI tools are most valued when they act as an interactive tutor, offering explanations, alternative formulations, and immediate feedback; yet students also report frustration when AI produces plausible sounding but incorrect information, underlining the importance of verification skills.

4. Critical Awareness and Self-Reflection

A key dimension of AI literacy is the capacity to critically evaluate AI-generated content. Students who actively reflect on their AI use tend to develop a healthier relationship with these tools: they cross-check important claims, acknowledge uncertainty, and treat AI as a collaborator rather than an authority. By contrast, students with low AI literacy may uncritically accept outputs, leading to errors in academic work and a reduced ability to detect bias or hallucination. Self-reflection also encompasses ethical awareness, including academic integrity, data privacy, and the environmental cost of large language models. These dimensions are rarely taught explicitly, yet they are central to responsible AI use.

5. Implications for University Education

Universities are at a critical juncture: they must neither ignore AI tools nor allow unguided adoption to undermine learning outcomes.

Effective AI literacy education should be embedded across disciplines, not confined to computer science programmes. It should include practical experience with AI tools alongside structured reflection on their limitations, ethical dimensions, and appropriate use. Student voices and experiences, such as those captured in this study, are a valuable resource for designing such programmes.

6. Conclusions

AI literacy is not simply a technical skill but a composite of practical competence, critical thinking, and ethical awareness. As generative AI becomes a permanent feature of the academic landscape, universities must equip students not just with access to these tools but with the judgment to use them wisely. A student-centred approach to understanding AI practices can meaningfully inform curriculum design and support resilient science education in challenging times.

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Chapter 14: Ethical Challenges of Generative AI in Journalism: Shaping AI Literacy and Professional Responsibility in Future Media Professionals

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Abstract. The rapid adoption of generative artificial intelligence (AI) tools in newsrooms raises pressing ethical questions about accuracy, authorship, transparency, and accountability in journalism. This paper examines the main ethical challenges posed by generative AI for journalistic practice, including misinformation, algorithmic bias, and erosion of public trust, alongside its potential to enhance efficiency and creativity. Particular attention is given to the role of journalism education in developing AI literacy among future media professionals. Drawing on current curricula and emerging industry guidelines, the paper proposes a framework for embedding ethics-focused AI literacy into journalism education, aiming to prepare graduates capable of responsibly using generative AI while safeguarding journalistic integrity and the public's right to reliable information.

Keywords. AI literacy, generative AI, journalism education, media ethics.

1. Introduction

Generative artificial intelligence (AI) systems, capable of producing text, images, audio, and video from natural-language prompts, have moved from experimental newsroom pilots to everyday editorial tools within a remarkably short period [1]. Large language models are now used to draft headlines, summarise documents, transcribe interviews, generate social media posts, and even produce first drafts of routine news items such as financial reports or sports recaps. While these tools offer clear productivity benefits, their adoption also raises fundamental ethical questions that touch the core values of journalism: truthfulness, independence, fairness, and accountability to the public [3].

This paper argues that the ethical challenges of generative AI cannot be addressed solely through newsroom policies or technical safeguards. They must also be confronted at the level of journalism and media education, where future professionals form their understanding of what responsible practice looks like [2]. The paper therefore pursues two interrelated aims: first, to map the principal ethical risks associated with the use of generative AI in journalism; and second, to outline how AI literacy and professional responsibility can be deliberately cultivated in the curricula that prepare the next generation of media professionals [2, 4].

2. Generative AI tools and their use in journalism

Newsrooms currently use generative AI across the full editorial workflow [1]. In the research and gathering stage, AI assistants help journalists search archives, summarise lengthy documents, and identify patterns in large datasets. In production, tools generate draft text, suggest headlines, translate content, and create illustrative images or short video clips [4]. In distribution, AI personalises content recommendations, automates social media scheduling, and supports audience analytics [1].

These applications promise significant efficiency gains, particularly for smaller newsrooms with limited staff, and can free journalists from repetitive tasks so that they can focus on investigation, analysis, and storytelling [4]. At the same time, each application carries a distinct ethical profile [3]. A tool that summarises a press release poses different risks than one that generates a photorealistic image of an event that never took place. Understanding this diversity is a precondition for developing proportionate and meaningful ethical guidance [3, 4].

3. Ethical challenges of generative AI in journalism

3.1. Accuracy, hallucination, and misinformation

Generative language models are known to produce plausible-sounding but factually incorrect statements, commonly referred to as hallucinations [2]. When such outputs are inserted into news content without verification, they can introduce fabricated quotes, incorrect dates, or non-existent sources, directly undermining the accuracy that journalism promises its audiences. The risk is compounded by the fluency of AI-generated text, which can mask errors that a human reader, and sometimes even an editor, may fail to detect.

3.2. Authorship, transparency, and disclosure

The use of generative AI raises questions about who, or what, should be credited as the author of a piece of content, and whether audiences have a right to know that AI was involved in its production [3]. Failure to disclose AI assistance, particularly for synthetic images or audio, can mislead audiences about the nature of the content they are consuming and may blur the line between journalism and AI-generated entertainment or propaganda [3]. Establishing clear, consistent disclosure practices is therefore central to maintaining audience trust [4].

3.3. Bias, fairness, and representation

Generative models are trained on large corpora of existing text and images, which may embed historical biases related to gender, ethnicity, culture, or political perspective [3]. When journalists rely on such models without critical scrutiny, these biases can be reproduced or amplified in published content, affecting how groups and issues are represented [1]. Addressing this challenge requires journalists to understand, at least at a conceptual level, how training data and model design can shape outputs, and to apply editorial judgement accordingly.

3.4. Accountability and editorial oversight

Traditional journalistic ethics assign responsibility for published content to identifiable individuals and institutions. Generative AI complicates this chain of accountability: when an AI-assisted article contains an error or a biased framing, it may be unclear whether responsibility lies with the journalist, the editor, the news organisation, or the AI provider [1, 2]. Maintaining meaningful human oversight, sometimes referred to as a human-in-the-loop requirement, is therefore essential to preserve clear lines of editorial accountability [4].

4. AI literacy as a pillar of journalism education

4.1. Defining AI literacy for media professionals

AI literacy for journalists can be understood as the combination of technical, critical, and ethical competencies needed to use generative AI tools responsibly [2]. Technically, this includes a basic understanding of how generative models work, their typical failure modes, and their appropriate and inappropriate use cases. Critically, it involves the ability to evaluate AI-generated content for accuracy, bias, and appropriateness before publication [1]. Ethically, it requires familiarity with disclosure norms, copyright considerations, and the broader societal implications of AI-generated media [3].

4.2. Curricular approaches and pedagogical strategies

Journalism programmes can integrate AI literacy through several complementary strategies [2]. Dedicated modules can introduce students to the technical foundations of generative AI and to existing newsroom guidelines on its use [4]. Case-based learning, using real or simulated examples of AI-related editorial incidents, can help students recognise ethical dilemmas and practise applying verification procedures [2]. Hands-on exercises, in which students compare AI-generated drafts with their own reporting and critically annotate the differences, can build the habit of treating AI output as a starting point rather than a finished product. Finally, embedding discussions of AI ethics within existing courses on media law, ethics, and editorial practice ensures that AI literacy is not treated as a separate, optional add-on but as an integral part of professional formation [2, 3].

5. Toward a framework for professional responsibility

Building on the challenges identified above, the author proposes a three-tier framework for embedding professional responsibility regarding generative AI into journalism education, as shown in Fig. 1.

The first tier, awareness, ensures that students understand what generative AI can and cannot do, including its tendency to produce inaccurate or biased content. The second tier, verification practice, trains students to apply the same fact-checking and sourcing standards to AI-generated material as to any other unverified source, and to document when and how AI tools were used in producing a story. The third tier, ethical judgement, develops students' capacity to weigh the benefits of AI assistance against risks to accuracy, fairness, and audience trust, and to make transparent, defensible editorial decisions.

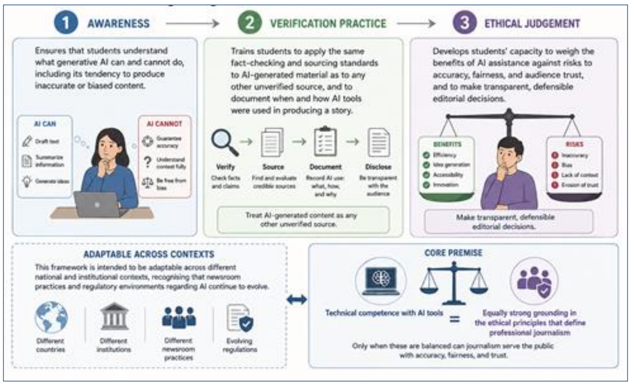

Figure 1. A Three-Tier Framework for Embedding Professional Responsibility Regarding Generative AI into Journalism Education

This framework is intended to be adaptable across different national and institutional contexts, recognising that newsroom practices and regulatory environments regarding AI continue to evolve [4]. Its core premise, however, is constant: technical competence with AI tools must be matched by an equally strong grounding in the ethical principles that define professional journalism [3].

6. Discussion and conclusion

Generative AI is unlikely to be a passing trend in journalism; rather, it represents a structural shift in how news content can be produced and distributed [1, 4]. The urgency of this shift is profoundly amplified within specific geopolitical realities, most notably the current wartime environment in Ukraine. In a landscape saturated with foreign state-sponsored disinformation, weaponised AI deepfakes, and synthetic media designed to destabilise society, the verification of AI outputs ceases to be a purely academic exercise. Instead, it becomes a vital shield for national information security. For Ukrainian journalism education, embedding these verification competencies into curricula is a critical necessity to ensure the survival of an objective, resilient, and quality information space. The ethical challenges it raises, concerning accuracy, transparency, bias, and accountability, are not merely technical problems to be solved by better tools, but professional and educational challenges that require deliberate attention [2, 3]. By integrating AI literacy and ethical reflection into journalism curricula, educational institutions can help ensure that future media professionals are equipped not only to use generative AI effectively, but to do so in ways that uphold the credibility of journalism and serve the public interest [2].

7. Acknowledgements

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Chapter 15: From Individual Use to Institutional Support: Generative AI in Ukrainian Higher Education during Wartime

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Abstract. As generative artificial intelligence becomes part of everyday university study, students are often expected to make responsible choices without receiving equally clear guidance from their institutions. This paper examines whether students' perceptions of institutional readiness are associated with the educational value they attribute to generative AI. The analysis uses survey data from 298 university students collected within a Visegrad+ project. Institutional readiness was positively associated with perceived pedagogical value ($r = 0.489$, $p < .001$) and explained 23.9% of its variance. In this sample, students reported greater educational value when they also experienced clearer guidance, access to training, and opportunities to discuss appropriate use.

Keywords. academic integrity, generative AI, higher education, institutional readiness.

1. Introduction

Generative artificial intelligence (GenAI) has become part of ordinary student work in a very short time. Students use it to clarify unfamiliar concepts, develop an outline, improve language, test an argument, or obtain a first explanation before returning to course materials. The educational effect depends largely on what the student does with the response. Asking for another explanation of a difficult topic may support understanding, whereas submitting an unverified answer may remove the very thinking that the assignment was designed to develop. The educational question is therefore not simply whether students use GenAI, but under what conditions that use becomes useful, transparent, and compatible with academic standards.

Universities have often responded by placing responsibility on the individual student: use the tool carefully, check the answer, do not plagiarise, and follow the rules. This advice is reasonable, but it assumes that the rules are clear and that students have been taught how to verify AI-generated material. In practice, expectations may differ between programmes, courses, and individual teachers. A student may be encouraged to use GenAI in one class and warned against it in another, without a clear explanation of the difference. For students, the difficulty is not always a lack of responsibility. In many cases, they are trying to interpret rules that have not been explained consistently.

Recent studies show that students generally recognise both the practical value and the risks of GenAI. They report benefits related to explanations, idea generation, language support, and efficiency, while also expressing concern about inaccurate content, privacy, dependency, and academic misconduct [1-5]. International guidance increasingly emphasises human agency, critical evaluation, transparency, and institutional capacity rather than a simple choice between prohibition and unrestricted use [1, 2].

The issue has additional importance in Ukraine. Higher education continues under air alerts, displacement, damaged infrastructure, unstable electricity, and considerable psychological pressure. Digital tools can help students continue learning when access to a teacher, library, or stable study environment is interrupted. At the same time, uneven access and unclear rules may deepen existing inequalities. Under these conditions, even simple institutional guidance may matter. A student who loses access to a lecture or teacher may use GenAI to continue working, but without clear expectations the same tool can add confusion, unreliable information, or anxiety about academic misconduct.

This paper presents a focused analysis of survey data collected within the Visegrad+ project “GAI V4: Inspiring Innovation, Upholding Ethics”. The broader study examined several dimensions of students' perceptions and practices. The present conference paper addresses a narrower question: is perceived institutional readiness associated with the pedagogical value that students attribute to GenAI? The aim is to understand whether students' assessment of GenAI as a learning tool is connected with what their university provides in practice: guidance, training, access, and space for discussion.

2. Study context and methods

The study was conducted as part of the Visegrad+ project "GAI V4: Inspiring Innovation, Upholding Ethics", supported by the International Visegrad Fund. An online questionnaire was administered to university students. Participation was voluntary and anonymous, informed consent was obtained electronically, and no personally identifiable information was collected.

The analytical sample included 298 respondents. Bachelor's students represented 65.1% of the sample, master's students 23.5%, and doctoral students 11.4%. Women accounted for 52.0% of respondents, men for 46.6%, and 1.4% selected another response or preferred not to state their gender. The sample included students from engineering and technology, science, social sciences, and other fields.

The questionnaire covered practical uses of GenAI, perceived learning benefits, ethical concerns, institutional conditions, barriers, and general preparedness. The internal consistency of the full scale was high (Cronbach's alpha = 0.889). Sampling adequacy was also satisfactory (KMO = 0.829), and Bartlett's test of sphericity was significant (chi-square = 7223.89, df = 1081, $p < .001$). The broader analysis showed that students did not view GenAI through a single attitude. Their responses reflected several different concerns, including learning value, practical usefulness, ethical risk, and institutional support.

For the paper, attention was limited to two dimensions. Institutional Readiness and Governance included perceptions of training, guidelines, access, and opportunities to discuss appropriate use. Pedagogical Value reflected the extent to which students associated GenAI with understanding, engagement, language support, preparation, and other learning-related benefits. Operational Usefulness was retained as a descriptive comparison because it captured time saving, brainstorming, and task support.

The analysis used descriptive statistics, Pearson correlation, and simple linear regression. Pedagogical Value was treated as the dependent variable and Institutional Readiness and Governance as the predictor. The data capture students' perceptions at one point in time. The regression therefore shows a statistical relationship, but it does not demonstrate that institutional readiness itself caused stronger pedagogical perceptions.

3. Results

The descriptive results show that students did not assess GenAI only in terms of speed or convenience. Pedagogical Value received the highest mean score (M = 3.98, SD = 0.86). Institutional Readiness and Governance was also rated relatively highly (M = 3.84, SD = 0.72), whereas Operational Usefulness had a lower mean (M = 3.58, SD = 0.70). This pattern suggests that respondents distinguished between using GenAI to complete a task more quickly and using it in a way that contributes to learning.

Table 1. Selected results of the focused analysis

Indicator	Result
Pedagogical Value	M = 3.98; SD = 0.86
Institutional readiness	M = 3.84; SD = 0.72
Operational Usefulness	M = 3.58; SD = 0.70
Correlation (IR-PV)	r = 0.489; p < .001
Regression	beta = 0.67; R2 = 0.239; p < .001

Institutional Readiness and Governance showed a moderate positive correlation with Pedagogical Value ($r = 0.489$, $p < .001$). Students who perceived clearer guidance, better access, more training, and more opportunities for institutional discussion were also more likely to report educational benefits from GenAI.

The regression model produced the same general conclusion. Institutional readiness was a positive predictor of Pedagogical Value (beta = 0.67, $p < .001$), and the model explained 23.9% of the variance in pedagogical perceptions ($R2 = 0.239$). This is not evidence that institutional support alone causes better learning. Although other factors clearly remain important, the size of the association indicates that students' institutional environment forms a meaningful part of how they evaluate GenAI.

4. Discussion

The most important result concerns the connection between institutional support and students' views of educational value. In our sample, students who reported clearer guidance, training, access, and opportunities for discussion also tended to evaluate GenAI more positively as a learning resource. This matters because discussions of GenAI in higher education often focus on individual motivation or technical competence. The present results point to a broader explanation. Students make judgements within an institutional setting, and that setting can either reduce or increase uncertainty.

This interpretation is consistent with technology acceptance research, which identifies facilitating conditions as an important part of technology use [6, 7]. It also fits an institutional perspective: formal rules, shared expectations, and organisational support shape what is considered legitimate and workable [8]. In practical terms, a student's willingness to use GenAI for learning may depend on whether the teacher explains permitted uses, whether disclosure is expected, whether suitable tools are available, and whether the student knows how an incorrect answer should be checked.

The difference between Pedagogical Value and Operational Usefulness is also relevant. Respondents gave a higher rating to learning-related value than to efficiency-oriented use. This does not mean that students reject time saving. It suggests that they recognise a distinction between receiving help and avoiding intellectual work. That distinction should be reflected in teaching. A prompt that asks a tool to produce a finished assignment offers little evidence of learning. A task that asks students to compare an AI response with scholarly sources, identify weaknesses, revise the answer, and explain their decisions can make the same technology part of a meaningful learning process.

Academic integrity rules are necessary, but students also need to understand how those rules apply to ordinary academic situations. A general warning that "AI misuse is prohibited" leaves many ordinary situations unresolved. Can a student use GenAI to improve grammar? Is brainstorming acceptable? Must every interaction be disclosed? Does the answer differ for a reflective essay, a coding task, or a clinical case? Clear course-level examples are often more useful than a long institutional policy. They also reduce the risk that students interpret silence as permission or, conversely, avoid legitimate support because they fear punishment.

The wartime context gives these findings a particular weight. When learning is interrupted by air alerts, relocation, or connectivity problems, students may turn to GenAI because immediate human support is unavailable. Under such conditions, institutional guidance can provide a degree of continuity. Yet the same conditions make critical verification more difficult. A student working quickly from a mobile phone in a shelter may be less able to check sources or compare several explanations. Universities therefore face a difficult balance: students may need flexible digital support, but they also need realistic ways to verify information and understand the limits of the tool.

5. Implications for university practice

Universities do not necessarily need a long or highly restrictive AI policy. A short institutional position may be more useful if it explains the principles that apply across the university and allows departments to adapt them to different forms of study. Students should know that they remain responsible for submitted work, that personal and confidential data should not be entered into public tools, that substantial AI assistance may need to be disclosed, and that facts, quotations, and references must be checked. These principles become easier to follow when individual courses provide examples. A student should be able to see why language correction may be acceptable in one assignment, while generating an entire analytical response may not be.

Training should also reflect the situations that students and teachers actually encounter. For students, this includes checking whether a cited source exists, recognising when a response sounds confident but lacks evidence, deciding what information should not be shared, and documenting how an AI-generated draft was revised. For teachers, the more difficult issue is often assessment design. Learning how to use prompts is helpful, but it does not solve the problem of how to design assignments in which students must still demonstrate reasoning, subject knowledge, and personal judgement. Practical examples from particular disciplines may therefore be more useful than one general presentation for the whole university.

Access deserves equal attention. Students do not work under the same technical conditions, especially during wartime. Some rely on mobile phones, unstable internet connections, free versions of tools, or applications with limited Ukrainian-language performance. When the use of a particular tool becomes part of a course requirement, the institution should consider whether all students can realistically access it. Where this cannot be ensured, an equivalent non-AI option should remain available. Otherwise, the assignment may assess financial and technical access rather than learning.

University guidance should also be reviewed as practice develops. The relevant questions are not only how many students use GenAI or how many workshops have been organised. It is more useful to examine what teachers observe in submitted work, which rules students find unclear, what types of academic integrity cases arise, and whether the use of GenAI changes the quality of reasoning demonstrated in assessment. Regular discussion of such evidence can help institutions adjust their approach without moving between two equally unhelpful extremes: complete prohibition and uncritical promotion.

6. Limitations

The findings should be read in light of several features of the study design. The analysis is based on students' own accounts of their experience with GenAI, rather than on direct observation of how they used these tools or on measured changes in academic performance. The data were collected at one point in time, so the identified relationship between institutional readiness and perceived pedagogical value should be interpreted as an association, not as evidence that institutional support directly causes more effective learning.

The sample also represents one stage of a broader project and cannot be assumed to reflect the experience of all students in Ukraine. Wartime conditions differ considerably across institutions, regions, and individual circumstances, including access to electricity, internet connectivity, learning resources, and teacher support. In addition, the dimensions used in this paper were derived from a broader exploratory analysis and should be tested in larger and more diverse samples.

Further stages of the project will make it possible to compare results across countries, fields of study, and levels of education. Future research should also move beyond perceptions and examine whether specific forms of institutional guidance, training, and assessment design are reflected in students' actual academic practices and learning outcomes.

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Chapter 16: Digital Competence of Educators in the Era of Generative Artificial Intelligence

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Abstract. This study explores the evolution of educator digital competence in the AI era. As generative tools integrate into classrooms, professional requirements have expanded beyond basic literacy. We establish a comprehensive framework consisting of six interdependent foundations: computer literacy, AI literacy, analytical thinking, pedagogical mastery, legal literacy, and professional ethics. These pillars form a holistic system essential for effective knowledge transfer. Modern educators must master AI functionality while curating environments that foster authentic cognitive activity, manage risks, and ensure academic integrity. Our findings provide a basis for innovative training programs, emphasizing targeted methodological approaches to cultivate both technical proficiency and sophisticated pedagogical culture.

Keywords. Academic integrity, AI literacy, digital competence, pedagogical mastery.

1. Introduction

In today's environment, the educational process is increasingly characterized by the rapid adoption of digital technologies, which are evolving from supplementary tools into fundamental elements of learning. Artificial intelligence (AI) occupies a special place among these technologies, opening up new opportunities for improving educational processes. The sweeping changes brought about by AI necessitate a rethinking of traditional teaching methods and strategies. From a technological innovation, AI is transforming into a strategic resource capable of both significantly improving the efficiency and quality of education and creating certain challenges for the learning process. This issue is particularly relevant due to the widespread availability of AI technologies in today's digital environment. Students are increasingly using these tools on their own, often without the teacher's knowledge, to complete academic assignments. Consequently, successfully designing an effective learning process requires teachers to possess an appropriate level of digital competence. In the context of current transformations in the education sector, it is the competent teacher who serves as the key link between traditional pedagogical methods and innovative digital solutions. Teachers must not only effectively integrate AI tools into the educational process but also teach students to use them critically and ethically, and to understand the capabilities and limitations of such technologies. This creates new challenges for educators, who must be able to design the learning process with the active use of AI technologies by students in mind. Consequently, there is a growing need to create a comprehensive system for developing the digital competence of future educators, one that not only covers traditional skills in working with digital technologies but also ensures a deep understanding of the principles of operation, potential, limitations, and ethical aspects of using AI in education. This, in turn, necessitates the development of new theoretical and methodological foundations for teacher training, aimed at producing professionals capable not only of applying ready-made AI solutions but also of designing innovative educational environments that take into account the specificities of particular learning contexts. In this context, research into the theoretical and methodological foundations for developing the digital competence of future teachers takes on crucial importance for the modernization of the teacher education system. It is on a systematic and scientifically grounded solution to this problem that the ability of the domestic education system to effectively respond to the challenges of the digital age and ensure the training of competitive teaching staff for the educational landscape of the future depends.

2. Main text

An analysis of the current scientific literature indicates that researchers are paying increasing attention to issues of digitalization in education, particularly regarding the development of teachers' digital competence in the context of AI technology implementation. In the European context, the key reference remains the DigCompEdu framework (2017), developed for educators, which defines 22 digital competencies, grouped into six domains. At the same time, this framework does not include a separate category dedicated to AI literacy, which requires further theoretical and methodological justification of its place within the structure of a teacher's digital competence [1]. Given the active integration of AI into the educational process, this aspect becomes critical for ensuring educators' readiness to use AI tools effectively and ethically in educational activities. It is worth noting that in a number of contemporary studies, both foreign and domestic, devoted to the development of digital competence, the component related to understanding AI tools is not always distinguished. In particular, many studies from the past five years focused on developing teachers' digital skills do not include a separate area covering knowledge and skills in working with AI technologies. In the domestic discourse, there is also a growing interest in the topic of digital competence, but approaches to its structuring often remain fragmented. The model of professional-digital competence proposed by O. Humennyi [2] covers key aspects of a teacher's digital activities. At the same time, aspects related to the application of AI are not singled out as a separate component in this model, which leaves room for further theoretical exploration of this area. A similar situation is observed in the Teacher Digital Competency Framework proposed by G. Falloon [3], where the emphasis is on an approach that combines technical knowledge, pedagogical strategies, information literacy, ethical responsibility, and the ability to adapt to the dynamic conditions of the digital environment; however, the author does not single out a component related to AI. In contrast, other researchers emphasize the need to consider "AI literacy" as a distinct area within teachers' digital competence. For instance, I. Tenberga and L. Daniela [4] emphasize that AI literacy constitutes a distinct cluster of skills that only partially overlaps with general competencies but requires special attention to ensure high-quality professional training for educators A similar position is held by D. Tsz Kit Ng, J. Ka Lok Leung, J. Su et al [5], who note that the digital transformation of education requires the development of new competencies, including critical thinking, the ethical use of AI, and an awareness of the risks associated with the application of intelligent technologies in the learning process. However, each study forms its own vision of the structure of teachers' digital competence, proposing unique components depending on methodology, goals, and context. This leads to significant discrepancies between existing models and complicates the development of a unified approach to teacher training in the digital age. Thus, there is an objective need to systematize and generalize existing approaches and to establish theoretical and methodological foundations for the development of digital competence among future teachers, taking into account both international and national experience, especially in the context of the active integration of AI technologies into the educational process. The purpose of this article is to define and theoretically justify the foundations for developing the digital competence of future teachers in the context of integrating AI technologies into the educational process.

Research confirms that the integration of AI tools opens up new opportunities for education—in particular, it enables the personalization of the educational process, automates routine tasks for teachers, and expands access to high-quality educational services, which overall underscores the role of AI as a key component of the digital transformation of education [6]. The use of intelligent systems and AI algorithms in digital technologies makes it possible to adapt curricula to students' individual needs, which positively affects their motivation and overall learning effectiveness [7]. However, this transition necessitates a rethinking of the teacher's role in the context of the digital transformation of education. First and foremost, future teachers are expected to be the ones who can successfully integrate these technologies into educational practice, as many modern AI tools offer functional capabilities unavailable to previous generations of digital solutions. For example, English teachers already have the opportunity to enhance the learning process using AI platforms such as ChatGPT, providing their students with free practice in speaking skills within the scope of their own course. To do this, the teacher simply needs to conduct a demonstration lesson, during which students learn how to use ChatGPT's conversational feature on a web platform or via a mobile app, ensuring students' understanding and engagement in using AI tools to improve their oral communication skills. Thanks to this approach, students have the opportunity to practice communication continuously at no additional cost, and, as the course requires, to improve their public speaking skills as well. In the traditional format, such regular practice was possible mainly through interaction with tutors, which entails additional financial costs. However, for the integration of AI into the learning process to be truly effective, the instructor must possess an appropriate level of digital competence. First and foremost, it is worth noting that the European Digital Competence Framework for Educators (DigCompEdu) defines digital competence as the confident and effective use of information and communication technologies in professional activities, learning, leisure, and participation in public life [8]. It is important to emphasize that computer literacy forms the basis of confident use of digital tools; researchers define this as the basic ability to work with technical devices such as a computer, smartphone, or tablet, as well as an understanding of software capabilities, which enables users to adapt to rapid technological changes [8]. Furthermore, according to a study by E. Gallardo-Echenique et al., computer literacy is identified as a key element of digital competence [9]. In a dynamic digital environment where tools are constantly being updated, it is this very competence that allows teachers to quickly adapt to new conditions of professional activity. For example, following a Zoom update—which involves a change in the interface and the introduction of new features—the teacher must quickly adapt to the changes. Such updates should not hinder the conduct of classes; on the contrary, if possible, the educator can integrate the platform's new features into their own teaching practice. This requires the teacher to have information-searching skills, specifically the ability to use search engines such as Google to find up-to-date instructions, as well as the ability to quickly process these resources and extract relevant knowledge from them. Such skills take on particular importance in the context of the rapid development of AI technologies, when the functionality of these tools is constantly changing, and new platforms and services emerge that have the potential to be used in the educational sphere. Therefore, it is extremely important for teachers to be prepared for situations in which they will have to apply AI tools—both on their own initiative and within the framework of the educational program.

Research confirms that limited knowledge of information and communication technologies among teachers significantly complicates the integration of digital solutions into the educational process [10]. As a result, this can negatively affect the quality of instruction and reduce the effectiveness of digital tools in teaching. In particular, this creates the risk of losing pedagogical focus during technology-based lessons. This is particularly relevant in situations where digital platforms do not function as the teacher expects, and their attention shifts from achieving educational goals to resolving technical issues. This reduces the effectiveness of educational interaction and even creates the risk of disrupting the class. A telling example is when an English teacher plans to demonstrate the use of ChatGPT in class to develop oral communication skills. During the demonstration, a situation may arise where the chatbot does not respond to voice commands. One of the most common reasons is that after a browser update, the microphone was not properly configured.

Insufficient computer literacy can cause difficulties for an educator and lead to ineffective use of teaching time, whereas proper preparation allows for the quick identification and resolution of technical failures. For example, if an interface of a program or digital platform changes after an update, instructors with a sufficient level of digital awareness, even without prior experience with the updated version of that resource, are able to quickly orient themselves and resolve the issue. Thus, the ability to effectively use information and communication technologies allows an instructor to successfully perform their professional duties in a digital environment, achieve pedagogical goals, and adapt to new technologies [11]. However, for effective work with tools based on AI technologies, basic computer literacy skills are not enough. As I. Teberga and L. Daniela [4] note, the presence of general digital skills does not guarantee the formed competence in working with AI technologies. These authors emphasize that it is necessary to purposefully develop relevant competencies, in particular AI literacy, so that instructors can consciously and effectively integrate these technologies into educational practice [11]. Other studies support this position, which treat AI literacy as the ability to effectively use AI tools based on an understanding of their concepts and principles of operation [12]. In this context, a modern instructor must not only master the basic functionality of AI tools but also be able to configure and adapt them according to specific pedagogical goals. For example, when developing speech skills, it is advisable to suggest that students change the settings of ChatGPT so that the model provides short and clear answers, stylistically close to oral speech. For this, one can use the "Custom instructions" feature available in ChatGPT's settings. In the "What would you like ChatGPT to know about you?" field (or "How would you like ChatGPT to respond?"), it is worth entering an instruction such as: "Answer briefly, clearly, concisely, in the style of oral speech." This approach increases the efficiency of verbal interaction with the AI platform, which, in turn, contributes to improving the quality of the educational process. In addition, the instructor can advise students to use the "Deep Research" feature, which is already available in Gemini for free, to analyze educational topics based on external sources.

In current conditions, the implementation of the concept of academic freedom and institutional autonomy of higher education institutions is defined as a component of quality learning and knowledge transfer in the information society [13]. A responsible approach to the targeted selection of digital tools is becoming especially important. An educator must clearly understand when it is appropriate to use general-purpose AI services, such as ChatGPT, Gemini, Claude, copilot, etc. and when it is worth turning to highly specialized platforms designed to perform specific tasks. To do this, it is necessary to navigate a wide range of digital solutions and understand the functional advantages of specialized platforms, such as Napkin.ai, Gamma, Elicit, and Consensus, in comparison with universal AI services like ChatGPT, Grok, or Gemini, as well as with digital services that have integrated AI modules, such as Litmaps and Miro. For example, if there is a need to quickly create a structured flowchart, it is advisable to use Napkin.ai, which provides adaptive templates and real-time editing features—capabilities currently unavailable in ChatGPT. In the case of conducting a literature review, it is advisable to use Elicit, an AI tool that has a convenient interface in the form of a matrix, which provides the ability to ask questions and have the AI assistant provide an answer for each article. Effective use of such tools requires the instructor to have a deep understanding of their functional specifics, the ability to formulate precise, relevant queries, and a clear awareness of each platform's purpose for their rational selection and targeted application.

Also, an important component of AI literacy is the instructor's ability to navigate alternative solutions in cases where technical or financial limitations hinder the full use of a particular digital platform. For example, the Elicit service has an "Upload and extract" feature, which allows you to upload PDF files of scientific articles and automatically extract key quotes from them. This capability is especially valuable in research work, where, to justify hypotheses, it is necessary to cite precise quotations with page numbers from the document to ensure its relevance and avoid the need to review dozens of potentially tangential sources. However, in the free version, this capability is often limited only to abstract analysis, which reduces the efficiency of working with full texts. Under such circumstances, an instructor must possess knowledge about alternative tools, including the possibility of using universal AI platforms, such as ChatGPT or Gemini, to solve the corresponding task. At the same time, it should be taken into account that these tools sometimes generate inaccurate or distorted bibliographic references. Research confirms that even with the increasing overall accuracy of new versions of language models, it is impossible to avoid errors entirely. Thus, according to research, 18% of bibliographic references generated by GPT-4 were fabricated, and another 24% contained significant errors in author data, titles, dates, or other key elements [14]. In such a situation, it is advisable to turn to specialized resources for working with PDF documents that ensure higher accuracy of text processing. For example, services like NoteBookLM or Scholarcy, even in their free versions, are capable of automatically extracting key quotes from full-text scientific articles without distorting the content, precisely preserving the wording of the original. Thanks to this, an educator can be confident that the AI tool is referencing an actual fragment of text rather than generating an interpretation.

However, it is worth noting that AI literacy is a complex, multidimensional concept that goes beyond a technical understanding of AI tools. Scientific literature indicates that AI literacy involves the ability not only to create content using generative systems but also to critically evaluate it [15]. This means that users must carefully check the generated information, evaluating its quality and relevance to the query, as well as identifying potential biases or inaccuracies characteristic of AI work results.

This becomes particularly relevant when using generative language models like ChatGPT, as the generated content may contain inaccuracies, invented facts, or fictitious references that have no confirmation in scientific literature [14]. On the main page of any web interface, there is a notice that responses generated by the system may contain errors. This problem is especially critical in the educational process, where both instructors and students actively use AI platforms to search for information. In such cases, there is a risk of unintentionally citing non-existent sources or using fabricated data, which can lead to the spread of unreliable information. That is why an instructor must possess the relevant knowledge and skills, as well as teach students to work critically with information and verify the reliability of the obtained data. In particular, it should be explained that generative models can create so-called "hallucinations" — plausible but invented fragments of text, including references to non-existent sources [14]. In such cases, it is important to verify the information obtained using independent scientific search engines, such as Google Scholar, Semantic Scholar, etc. Therefore, after generating a response with the help of AI, a student must necessarily cross-check the facts provided using reliable sources. In addition to a critical attitude toward content, an important component of AI literacy is understanding the ethical aspects of using AI. As noted in the study, AI literacy encompasses an awareness of the social consequences and ethical challenges associated with the implementation of AI technologies in various fields, including education [13, p. 8]. Researchers emphasize that awareness of integrity, transparency, fairness, and accountability is critically important for forming full-fledged digital competence. This is because the modern educational environment, which actively integrates generative language models such as ChatGPT, Gemini, or ClaudeAI, creates new challenges related to the uncritical acceptance of generated information. Excessive reliance on the quick and convenient answers provided by AI systems can lead to a gradual loss of students' skills in independent analysis and critical thinking. As a result, there is an increased risk of forming a superficial understanding of the material. Specifically, a student studying programming might fail to master the skill of working with official documentation and technical manuals. In the absence of ready-made answers from an AI platform and without developed algorithmic skills, there is a risk that the student will be unable to perform even basic educational tasks independently. This, in turn, reduces their competitiveness as a specialist and hinders further professional development. In this context, the role of the future educator goes beyond technical support. Their task is to contribute to the formation of an ethical culture of interaction with information obtained by means of AI. An informationally literate pedagogue not only warns about potential risks but also teaches students to distinguish between acceptable and unacceptable scenarios for using AI. A student may use ChatGPT for stylistic editing and error detection in a text written in English, provided that the structure, logic, and argumentation remain the result of independent work. Studies have proven the effectiveness of using such platforms in academic writing, particularly for error correction and improving style [17]. At the same time, mindlessly copying generated materials contradicts academic integrity.

Despite the importance of an ethical culture of AI use, this is not enough to achieve the expected learning outcomes. Even if students are familiar with ethical principles of work and possess the relevant digital tools at a high level, this does not guarantee the effectiveness of the educational process. As current studies show, learners often use the capabilities of ChatGPT to complete coursework assignments, passing off AI results as their own. Such practice simultaneously covers several forms of academic integrity violations — plagiarism, cheating, and deception [18]. Therefore, even if a student declares ethical AI use, this does not guarantee that the principles of integrity have truly been upheld. Given that the key task of pedagogy remains the development of critical thinking, analytical abilities, and adherence to the principles of academic integrity, the risk of its violation grows under conditions of uncontrolled AI use. The ability to automatically generate texts, solve problems, or create code tempts students to avoid independent cognitive activity, replacing the processing of material with the simple copying of results. Furthermore, the situation is complicated by the decreasing reliability of traditional forms of assessment, which no longer always allow for the determination of the level of independence in task completion. Specifically, a student may provide formally correct answers without even reading the task requirements, simply by using the capabilities of AI. Such an approach not only contradicts the fundamental principles of pedagogy but also calls into question the quality of the entire educational process. Therefore, one of the key areas of an educator's digital competence in the face of new challenges is the development of analytical thinking and the capacity for deep pedagogical reflection. This refers to the reflective component, which involves the ability for self-assessment, critical analysis of the results of one's own digital activity, as well as an awareness of the need for its further improvement [19]. Studies on the digital competence of educators emphasize the necessity of being able to identify potential risks, as well as recognizing the ethical challenges that arise in the process of applying AI technologies in learning, teaching, and assessment [20]. An educator must be able to forecast potential threats, particularly those related to the misuse of AI tools by students when completing educational tasks without proper immersion in the content. This involves not only assessing the probability of abusing such tools but also identifying the types of tasks that practically lose their educational value when AI is used, as well as analyzing the potential consequences for the quality of the educational process. Specifically, an educator must realize that almost all types of independent written assignments — from reports and essays to solving applied problems — can be completely executed by students using generative AI systems without any comprehension of the material. At the same time, such work may outwardly appear thoroughly processed, which significantly complicates the detection of a lack of genuine cognitive activity.

Even if tasks are carefully designed to include elements of analysis, interpretation, or a personalized approach, there is still a high probability that students will take advantage of AI capabilities for automatic execution, often without even reading the requirements. Modern generative AI systems are capable of creating logically structured responses, which substantially complicates the detection of superficial mastery of educational material.

At the same time, analytical thinking as a component of an educator's digital competence goes beyond simply predicting AI misuse and identifying forms of learning activity whose effectiveness might decrease under conditions of uncontrolled AI use. It involves a deep analysis of the diverse motives that might prompt students to engage in dishonest actions or formal completion of tasks involving AI. The spectrum of such reasons is quite broad: from situational use of AI by responsible students to optimize time during preparation for priority events, such as an Olympiad, to systemic dependency caused by a desire to maintain an "excellent student" image, fear of mistakes, and lack of confidence in their own abilities, which is amplified by the possibility of obtaining a quick, guaranteed "correct" result through these technologies. Such variability in causes requires the educator to move beyond template responses, employing instead an analytical approach to each situation. The ability to see behind AI usage not only a desire to avoid learning activity, but also possible deep-seated causes—such as insecurity, overload, or a lack of understanding of the value of independent work—testifies to a high level of pedagogical reflection. Thus, developed analytical thinking allows the educator to document facts of academic dishonesty while also investigating their root causes, differentiating temporary circumstances from deep psychological barriers or gaps in motivation. Such understanding of nuances is critically important for developing adequate pedagogical strategies, the implementation of which requires high pedagogical proficiency aimed at fostering students' responsible attitude toward learning and the development of their authentic intellectual abilities.

Pedagogical proficiency is another key area of an educator's digital competence, ensuring high efficiency in the educational process. This is confirmed by the European Framework for the Digital Competence of Educators (DigCompEdu), which defines the core of digital competence as skills that ensure effective, inclusive, and innovative teaching and learning, particularly those related to planning, implementation, and assessment of the learning process [1]. Especially in today's conditions, which involve the active use of AI, pedagogical proficiency is not limited to teaching students how to use digital platforms. Its essence lies in creating an educational environment that promotes the development of critical thinking and a responsible attitude toward learning. As researchers note, pedagogical proficiency emerges as a high culture of organizational, managerial, and educational activity of an educator capable of effectively solving the tasks of the educational process [19]. When psychological approaches to student integrity do not yield the desired results, pedagogical proficiency requires the educator to adapt assessment methods to the new digital reality. Traditional testing and standard assignments are increasingly losing their effectiveness, as AI tools allow students to generate "correct" answers without genuine engagement or intellectual effort. To counter this, educators must shift toward methods that prioritize deep reflection and active cognitive involvement:

- analytical questioning and problem-based case studies that require unique synthesis rather than rote information retrieval;

- project-based work with mandatory oral defense, where students must explain their logic, justify their steps, and respond to clarifying questions.

Ultimately, true pedagogical proficiency in the AI era is the ability to curate an educational environment where digital tools amplify human intelligence rather than replace it, all while strictly adhering to the legal and ethical standards of the information society.

It can be noted that legal literacy is an integral component of the digital competence of a modern educator, especially in the context of the active digitalization of education. It encompasses knowledge of and adherence to current legislation governing the use of digital resources in pedagogical activity: in particular, copyright rules, personal data protection norms, privacy policies, and safe handling of information. Within the European framework of digital competences for educators — DigCompEdu — it is emphasized that teachers must respect copyright when using, modifying, and sharing resources, as well as protect confidential digital content, such as student test results or grades [1]. The importance of this very principle of digital competence is also highlighted in the model by G. Falloon [3], where emphasis is placed on knowledge and attitudes regarding the legal aspects of digital interaction, including privacy, digital identity, security, and the role of ICT in society. The authors stress that the rational use of ICT requires specific knowledge and dispositions concerning legal and ethical aspects, privacy and security, as well as an understanding of the role of ICT in society and a thoughtful attitude toward technology. Thus, legal literacy performs not only a protective function but also develops in the educator the capacity to critically assess the permissibility of using digital and AI tools in accordance with institutional policy and current legislation.

Thus, the effective use of AI in the educational sphere and in the professional activity of an educator is inextricably linked to the comprehensive development of their digital competence within the theoretical and methodological foundations set out in this article. All six principles of an educator's digital competence are equal and closely interconnected: each direction complements the others, forming a single cohesive system — which was consistently revealed in the article through a mutually complementary analysis of these components. At the same time, each principle interacts not only with adjacent ones but with all other components of the system.

A telling example of such interdependence is a situation in which an educator skillfully uses AI platforms and effectively implements their functionality in practice — which indicates a high level of AI literacy and pedagogical proficiency — yet encounters difficulties in adapting to a new digital environment or equipment, for example, when transitioning to the Linux operating system instead of the familiar Windows. Such a situation indicates an insufficient level of computer literacy, which complicates professional activity and reduces the effectiveness of digital technology use in teaching. To confirm the interdependence and integrity of the proposed principles, it is appropriate to analyze how the absence or insufficient development of each of them affects the overall level of digital competence of future educators in the context of AI application. A deficit in the development of any component of digital competence significantly complicates an educator's readiness for the effective fulfilment of professional duties in an educational process oriented toward the use of AI technologies, which can lead to a number of undesirable consequences and negatively affect not only the implementation of innovations but also the effectiveness of traditional pedagogical practices, which, without adequate digital support, gradually lose their efficacy.

3. Conclusions

The study confirmed that the effective implementation of AI technologies in the educational process directly depends on the level of digital competence developed by future educators. Within the scope of the stated purpose, six key foundations for the development of digital competence were theoretically substantiated:

- Computer literacy as the baseline proficiency required to operate in digital environments and address technical issues;

- AI literacy encompassing the specific ability to understand the concepts, principles, and functional application of AI tools;

- Analytical thinking, that being the capacity for deep pedagogical reflection, critical evaluation of AI-generated content, and understanding the root causes of student behavior.

- Pedagogical proficiency, which includes the ability to design innovative learning environments that use AI to stimulate active, critical cognitive activity rather than replace it;

- Legal literacy as an awareness of intellectual property rights, licensing agreements, and the legal status of software in accordance with national legislation;

- Professional ethics entailing commitment to academic integrity, transparency, and responsibility, while fostering these values in students.

It has been argued that these six foundations are closely interconnected, forming digital competence as a holistic, systemic phenomenon. It was determined that these pillars constitute the foundation for creating innovative training programs for future educators that meet the demands of the modern information society. Furthermore, it was established that an insufficient level of development in any one of these foundations complexly impacts the overall digital competence of future educators, significantly reducing the efficiency of AI integration and leading to a loss of pedagogical justification and the effectiveness of traditional teaching methods.

Prospects for further research lie in developing methodological approaches aimed at cultivating each of these foundations of digital competence, as well as in constructing and testing an experimental model for the formation of digital competence in future educators. This model is intended not only to reflect the contribution of each foundation to the overall level of competence but also to justify their internal interrelationships.

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Chapter 17: Performance Auditing of Education Policy in Wartime: A Resilience Framework for Ukraine

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Abstract. The war in Ukraine has made continuity, safety and equity central criteria for assessing national education policy. This article examines how performance auditing can move beyond expenditure compliance to determine whether public resources sustain learning and strengthen system resilience. Drawing on Ukrainian legislation, INTOSAI standards, and OECD, UNESCO and RDNA5 materials, it proposes a 3E-R framework integrating economy, efficiency and effectiveness with equity and resilience. The framework links expenditure to access, learning recovery, psychosocial support, infrastructure safety and adaptive capacity, offering practical audit questions and indicators for public authorities and education managers.

Keywords. accountability, education policy, performance audit, resilience.

1. Introduction

Education policy is tested most severely when the conditions required for ordinary schooling no longer exist. In Ukraine, air attacks, displacement, damaged infrastructure, interruptions to electricity and connectivity, and prolonged psychological stress have changed not only where education is delivered, but also what the public sector must protect. The legal obligation to ensure access to quality education remains in force [1], yet the meaning of effective implementation has expanded. A policy can no longer be judged solely by whether funding was allocated and procedures were followed. It must also be judged by whether learners can study safely whether teachers can continue working, whether vulnerable groups are reached, and whether the system can recover after repeated shocks.

The scale of the challenge is both material and human. The Fifth Rapid Damage and Needs Assessment estimates damage to the education and science sector at USD 13.9 billion, losses at USD 11.7 billion, and recovery and reconstruction needs at USD 33.5 billion for 2026–2035 [2]. According to data published by UNESCO, citing the Ministry of Education and Science of Ukraine, 4,163 educational institutions had been damaged or destroyed as of 25 June 2025 [3]. RDNA5 also identifies learning losses as the largest component of sectoral losses and shows that the immediate response cannot be reduced to rebuilding facilities. It must include safe in-person access, catch-up learning, psychosocial support, regulatory adaptation and institutional capacity. For 2026 alone, priority needs for education and science were estimated at USD 1.275 billion, while available financing was USD 405 million [2]. Such a gap makes prioritisation, transparency and evidence of results essential rather than optional.

International policy advice for Ukraine has appropriately focused on learning recovery, flexible educational pathways, teacher support and reform continuity [4, 5]. However, the governance question remains: how can public authorities know whether scarce resources are producing the outcomes that matter most under wartime conditions? Conventional financial and compliance audits are indispensable for legality and integrity, but they do not by themselves answer whether an intervention kept education accessible, reduced learning loss or improved the capacity of institutions to withstand the next disruption.

In our view, performance auditing should become a stronger instrument of education policy learning during war and recovery. The aim of this article is to develop a practical framework for assessing education policy through five connected dimensions: economy, efficiency, effectiveness, equity and resilience. The first three are established performance-audit principles; equity and resilience are added because a formally efficient programme may still exclude those at greatest risk or collapse when conditions change. The article examines two questions: what should a wartime education policy audit examine, and how can audit findings be translated into timely policy correction rather than retrospective fault-finding?

2. Auditing public policy in an emergency education system

Education systems are complex public systems. Decisions are distributed across ministries, local authorities, school founders, education institutions, donors, civil society organisations, families and learners. Results depend on interactions among finance, human resources, infrastructure, digital capacity, social protection and security. Research on complex education governance therefore emphasises coordination, reliable information and the ability to adapt policy to local conditions rather than relying only on hierarchical control [12]. Wartime conditions intensify this complexity: responsibilities overlap, emergency decisions must be made quickly, and the same national rule can have very different consequences in a frontline community and a relatively safe region.

Audit has traditionally been associated with verification: checking accounts, compliance and documentary evidence. Power's concept of the "audit society" warns that verification can become ritualistic when organisations produce evidence mainly to demonstrate conformity rather than to improve substantive performance [13]. In public policy, accountability is wider than documentary control. It requires public actors to explain and justify their actions, to be assessed against legitimate criteria, and to respond to findings [14]. For education in wartime, this means that an audit should protect integrity without creating a reporting burden that distracts schools and local authorities from service delivery.

INTOSAI defines performance auditing through the principles of economy, efficiency and effectiveness [6]. Economy concerns the timely acquisition of appropriate resources at a reasonable cost; efficiency concerns the relationship between resources used and outputs delivered; effectiveness concerns the achievement of intended objectives. GUID 3910 further requires clearly defined audit objectives, suitable criteria and an approach that can support defensible conclusions [7]. GUID 9020 distinguishes performance audit from broader policy evaluation, which also examines relevance, utility and longer-term societal effects [8]. In practice, wartime education requires the two perspectives to work together. Auditors should test operational performance while recognising that the policy objective itself may need revision as risks and needs change.

Education-in-emergencies standards reinforce this broader view. The 2024 INEE Minimum Standards connect preparedness, response and recovery with safe access, quality, participation and accountability [9]. Research shows that education during emergencies serves multiple functions: it supports learning, protection, social connection, psychological stability and future opportunity [10]. Displacement also reveals the distance that can arise between a formal right to education and a learner's practical ability to use that right [11]. Attacks on educational institutions further demonstrate that safety is not an external condition but a central policy outcome [15]. Therefore, audit criteria must reflect the lived continuity of education, not only administrative completion of programmes.

3. Materials and methods

The study uses qualitative policy analysis and framework development. The evidence base comprises Ukrainian education legislation; INTOSAI performance-audit and public-policy-evaluation standards; current international assessments of war-related damage and recovery needs; OECD policy reports on learning recovery and education reform in Ukraine; global education-in-emergencies standards; and peer-reviewed literature on crisis education, accountability and complex governance.

4. Results: the 3E-R framework

4.1. Audit logic and scope

The proposed 3E-R framework retains economy, efficiency and effectiveness and adds equity and resilience. The letter "R" refers to resilience, while equity is treated as a cross-cutting distributional test applied to all three performance dimensions. In practical terms, the audit asks not only whether resources were used well, but also who benefited, who remained excluded and whether the intervention strengthened the system's ability to continue operating under future disruption.

The audit object should be defined as a policy intervention rather than as an isolated transaction. Examples include the provision of school shelters, digital devices, learning-recovery programmes, teacher-support measures, transportation to safe schools, psychosocial services, or reconstruction projects. Each intervention is examined through the full logic shown in Fig. 1. This prevents two common errors: assessing expenditure without examining service delivery and assessing outputs without determining whether they contributed to learning, safety or inclusion.

Figure 1. Resilience-oriented policy audit logic

4.2. Dimensions, questions and evidence

Table 1 translates the framework into auditable questions. The indicators are illustrative rather than mandatory. They should be selected on the basis of materiality, risk and data reliability. A small local programme may require a limited set of indicators, whereas a national reconstruction programme should combine financial, operational, educational and distributional evidence.

Table 1. Core dimensions of the 3E-R education policy audit

Dimension and core question	Evidence
Economy **Were appropriate resources obtained on time and at a justified whole-life cost?**	Unit and lifecycle costs; emergency price premiums; procurement time; quality specifications.
Efficiency **How well were resources converted into safe and continuous education services?**	Cost per learner reached; shelter use; device utilisation; delivery time; teacher workload.
Effectiveness **Did the intervention achieve access, learning, safety and well-being objectives?**	Attendance; learning recovery; dropout; teacher retention; psychosocial-service uptake.
Equity **Were benefits distributed according to need and barriers to participation?**	Results by region, rurality, displacement, disability, gender and socioeconomic status.
Resilience **Can the system absorb, adapt to and recover from repeated disruption?**	Continuity plans; backup power/connectivity; recovery time; data redundancy; local response capacity.

Economy should not be interpreted as purchasing the cheapest option. In an emergency, a lower initial price can create higher costs if equipment fails, maintenance is unavailable or delivery is delayed. Audit criteria should therefore consider fitness for purpose, timing and lifecycle cost. A device purchased inexpensively but unusable during power outages is not economical in the policy sense. Similarly, a shelter project delivered after the school year has ended may be compliant yet fail the test of timely public value.

Efficiency should connect inputs to meaningful service outputs. Counting the number of devices, shelters or training sessions is insufficient unless the audit examines use. Relevant questions include whether devices reached learners who lacked access, whether shelters enabled additional days of in-person education, whether teacher training changed classroom practice, and whether administrative procedures delayed delivery. Efficiency analysis should also identify duplication among state, local and donor-funded initiatives.

Effectiveness requires explicit outcome criteria. For learning-recovery programmes, these may include changes in assessed learning, participation and progression rather than the number of lessons offered. For psychosocial support, the audit should examine access, referral pathways, continuity and user experience while respecting confidentiality. For infrastructure projects, effectiveness means that facilities are safe, accessible, used and connected to an education-delivery plan. Where causal attribution is not possible, auditors can assess contribution by testing whether the intervention's logic is plausible and supported by converging evidence.

Equity changes how averages are interpreted. A national attendance rate can improve while learners in frontline, rural or displaced communities fall further behind. Therefore, core indicators should be disaggregated whenever safe and lawful. The audit should examine whether resource allocation reflects exposure to risk and barriers to participation, whether accessibility requirements are met, and whether policy design unintentionally shifts costs to families or teachers. Participation by learners, parents and educators is a source of audit evidence, not merely a communication activity.

Resilience concerns the capacity to continue, adapt and recover. It is visible in contingency planning, redundant communication, backup energy, interoperable data, staff preparedness, flexible timetabling, alternative learning spaces and decentralised authority to act within clear safeguards. A resilience audit should measure recovery time after disruption and determine whether lessons from previous incidents changed procedures. The objective is not to expect every institution to withstand every shock, but to ensure that a disruption does not lead to prolonged exclusion from education.

4.3. Audit design and data strategy

A useful audit begins with a limited number of answerable questions. A national or local audit team could structure the engagement around the following sequence: Was the policy objective based on documented needs? Were resources prioritised according to risk? Were procurement and delivery timely and proportionate? Did intended learners receive and use the service? Did access, learning, safety or well-being improve? Were inequalities reduced or reproduced? Can the intervention continue under renewed disruption? What corrective actions were implemented after earlier monitoring or audit findings?

Evidence should be triangulated. Financial records and procurement data establish what was purchased and at what cost. Administrative records show enrolment, attendance, staffing and service coverage. Learning assessments provide information on educational outcomes. Facility inspections and geospatial data can verify infrastructure and access. Surveys, interviews and focus groups explain why a service was or was not used. Open-data sources can support comparison, but the auditor must assess completeness, security restrictions and changes in definitions over time. No single data source should carry the full conclusion where the operating environment is unstable.

The minimum data set should remain manageable. For each major intervention, public managers should record the objective, target group, risk profile, budget, financing source, responsible body, delivery milestones, output indicators, outcome indicators and continuity arrangements. Data should be disaggregated only to the level necessary for decision-making and should not expose sensitive information about learners or facilities. The quality of the data itself should be an auditable control: inconsistent or unverifiable information is a policy risk because it can direct scarce resources away from actual need.

Benchmarking should be used cautiously. Unit costs and performance can be compared across similar institutions or regions, but security conditions, distance, scale and infrastructure damage must be considered. An apparently high cost per learner may be justified in a frontline or sparsely populated area. Conversely, a low average cost may conceal exclusion. The purpose of comparison is to identify questions for investigation, not to produce automatic rankings.

4.4. Institutional use and follow-up

The framework is most valuable when embedded in the policy cycle. At the design stage, ministries and local authorities should define a small number of measurable outcome and resilience criteria. During implementation, internal control and monitoring should identify delivery risks early. Internal audit can examine governance, risk management and control processes. External performance audit can provide independent assurance and recommendations on economy, efficiency and effectiveness. Broader evaluation can later examine relevance, utility and long-term effects.

Follow-up is the decisive stage. Recommendations should name a responsible institution, a realistic deadline, the expected change and the evidence required to close the recommendation. Public reporting should distinguish completed administrative actions from verified improvements in service. A ministry may approve a new procedure, but the recommendation should remain open until the procedure is implemented and its effect is assessed. For security reasons, detailed facility-level information may need restricted access, while aggregated findings and corrective actions should remain public.

Coordination among audit and policy institutions is also necessary. Ukraine's public financial management reform is moving toward greater transparency, efficiency and harmonisation of internal-audit practice with updated international standards [16]. Education policy audits should align with public investment management, the Single Project Pipeline, donor reporting and local recovery planning so that institutions are not asked to report the same result in incompatible formats. A shared results vocabulary can reduce burden while improving comparability.

5. Discussion

The principal advantage of the 3E-R framework is that it connects accountability with learning. Wartime governance requires speed, but speed without feedback can institutionalise ineffective practices. Audit can create a disciplined pause in which decision-makers ask whether an intervention still addresses the problem it was designed to solve. This is especially important when programmes are scaled rapidly, financed from multiple sources or continued after conditions have changed.

Importantly, the framework also changes the tone of audit. In a punitive model, institutions may hide problems and optimise documentation. In a learning-oriented model, transparent identification of delivery failure is treated as a condition for correction, while fraud, negligence and deliberate misrepresentation remain subject to firm accountability. This distinction matters for educators and local managers working under extraordinary pressure. The audit should be rigorous, but its recommendations should be operationally realistic and proportionate to the risks faced.

Several implementation challenges remain. First, outcome data may be incomplete, delayed or incomparable because learners move between regions and countries. Second, attribution is difficult: learning outcomes are influenced by security, family circumstances, health and prior educational experience. Third, donor and government funding can create fragmented accountability. Fourth, detailed transparency may conflict with security. Fifth, excessive indicators can shift staff attention from teaching to reporting. These limitations do not justify abandoning performance assessment; they require transparent assumptions, triangulation, materiality and a clearly stated level of assurance.

Pilot implementation should therefore begin with selected high-risk interventions. Suitable cases include shelter investment, device distribution, catch-up programmes and psychosocial support. Each pilot should test the relevance of indicators, the cost of data collection, the usefulness of findings for managers and the feasibility of follow-up. Results should be discussed with auditors, education authorities, teachers, learners and communities. The framework can then be refined before wider institutionalisation.

The approach is also relevant beyond Ukraine. Armed conflict, climate emergencies, pandemics and displacement increasingly require education systems to operate under repeated disruption. The specific risks differ, but the governance lesson is similar: a resilient system is not one that merely restores its previous form. It learns, reallocates resources, protects those at greatest risk and improves its capacity to deliver education under uncertainty.

6. Conclusions

Performance auditing can strengthen public education policy in wartime when it moves beyond narrow expenditure compliance and examines the relationship between resources, services, outcomes and adaptive capacity. The proposed 3E-R framework integrates economy, efficiency and effectiveness with equity and resilience. It treats safety, continuity, learning recovery and psychosocial support as auditable policy results rather than secondary considerations.

For Ukraine, the framework offers a practical response to the combination of large recovery needs, constrained financing and continuing disruption. Its implementation requires a manageable results chain, disaggregated evidence, risk-based audit selection, coordination among oversight bodies and a credible follow-up process. The most important shift is conceptual: audit should not only confirm that public money was spent as authorised. It should help answer whether the spending kept education available, fair and capable of surviving the next shock.

Future research should test the framework through programme-level and local-government pilot audits, compare indicators across education levels, and examine how audit recommendations affect actual resource allocation and learning outcomes.

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Chapter 18: Digital inclusion, web accessibility and lifelong learning in the context of Ukraine's digital transformation reform

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Abstract. This paper analyses current trends and characteristics of creating a barrier-free virtual environment in the context of the country's digital transformation. It is argued that the rapid development of electronic services simultaneously gives rise to the problem of the digital divide, which significantly affects people with disabilities and socially vulnerable groups. The process of implementing international WCAG standards in the Ukrainian context was investigated.

It has been demonstrated that ensuring universal access to the web resources of government bodies and educational institutions is critically important for raising the level of digital literacy among citizens and guaranteeing equal opportunities for acquiring knowledge, particularly during difficult wartime conditions. It is emphasised that digital accessibility significantly contributes to the resilience of the Ukrainian education system and the realisation of the principle of lifelong learning.

An assessment of official online platforms of government bodies at various levels has been carried out. Recommendations have been made regarding a set of measures for the transformation of public policy.

Keywords. digital inclusion, web accessibility, digital literacy, lifelong learning, digital transformation, e-governance, educational resources.

1. Main text

In recent years, Ukraine has demonstrated steady progress in global rankings concerning the implementation of e-governance, the accessibility of e-services to the public, and overall digital transformation. These processes, despite the country's prolonged stay in conditions of deep crisis (initially caused by the COVID-19 pandemic, and now by full-scale Russian aggression), are actively contributing to the implementation of key systemic reforms, the reduction of corruption, and the transformation of the state. The problem of the constantly growing number of people with disabilities is becoming particularly acute, exacerbated by the hostilities. In its pursuit of European integration, Ukraine has committed to building a society of equal opportunities, guaranteeing all citizens equal access to public services.

The government has set itself the ambitious task of achieving maximum digital inclusion and social digitalisation for all citizens, taking into account their cultural, technological and socio-economic characteristics. However, despite the state's significant progress in this area, a substantial proportion of people with disabilities still do not have equal access to electronic public services.

At the same time, digital transformation encompasses not only the sphere of public services, but also the education system, professional development and lifelong learning for citizens. In the age of the information society, the accessibility of digital resources is becoming a key factor in building human capital, improving the digital literacy of the population and ensuring equal access to knowledge. This issue is particularly relevant in wartime, when a significant proportion of educational processes take place remotely, using electronic platforms and web resources.

Thus, the relevance of this study lies in a comprehensive examination of the processes of implementing digital inclusion within the framework of Ukraine's digital transformation reform, particularly in ensuring the web accessibility of internet resources of state authorities and local self - government bodies for people with disabilities. An analysis of best practices in this field will enable the identification of effective institutional approaches, management mechanisms, educational and digital tools that can be applied to improve and enhance the inclusivity of the national public services system by improving their web accessibility.

2. Literature Review

The formation and development of digital inclusion in Ukraine, particularly in the field of e-governance, is the subject of lively academic and practical debate. This is driven by the rapid digital transformation of the public and education sectors, as well as the need for public authorities to adapt to international governance standards, particularly those of the European Union.

Within the domestic academic community, the issues of digital inclusion and web accessibility in the public sector are being researched by many scholars and practitioners. For instance, O. Krykliy's works examine the theoretical foundations of digital inclusion and its impact on the state's information security [14]. H. Davydenko conducts an in-depth analysis of the problems of digital inclusion and accessibility as aspects of social digitalisation [11]. Y. Samus highlights key challenges and achievements in the field of accessibility of government websites in Ukraine in his publications [17].

V. Yegorov devotes his research to studying the interrelationships between digital inclusion and bridging the digital divide [13]. Also of interest are the results of applied research in the field of digital inclusion and web accessibility in the public sector, available on the resources of the World Wide Web Consortium and the European Commission.

However, given the insufficient level of digital inclusion in Ukraine's e-government and the need to adapt and implement EU experience, particularly through lifelong learning, further research in this area remains highly relevant.

The aim of this work is to analyse the current state and specific features of the formation and development of digital inclusion and web accessibility in the context of Ukraine's digital transformation. It also sets out to determine their role in ensuring the accessibility of public services, educational resources and opportunities for lifelong learning.

Today, in an era of rapid development of information and communication technologies, the problem of digital inequality is becoming increasingly acute, leading to a digital divide in society. Professor G. Davydenko concluded that addressing the problem of digital inequality through the promotion of digital inclusion has become highly relevant over the last decade and is critical to achieving sustainable development [11]. Therefore, when developing e-governance systems in modern democratic states, the comprehensive implementation of best practices in the field of digital accessibility must be a prerequisite.

In a broad sense, 'digital inclusion' is a guarantee of equal access to electronic technologies, the Internet and online services for every person, regardless of their physical or mental abilities, place of residence or age. This encompasses both the accessibility of web resources and the use of assistive tools, as well as the improvement of digital literacy [18]. Digital inclusion is defined as the ability of citizens to participate actively in the digital society [15]. At the same time, the concept of 'digital inclusion' focuses on the following aspects: the ability of individuals and communities to use ICT; the ultimate goals of digital inclusion, which are to engage people and communities in various spheres of the information society and to benefit from this; preventing digital divides and/or discrimination in the digital sphere; as well as civic or political activities aimed at ensuring an adequate level of digital inclusion [14].

In general, the following key components and objectives of digital inclusion are commonly identified: Web Accessibility: the creation of content, interfaces and applications that can be used by people with disabilities (visual, hearing, speech); Support tools: the development of applications for alternative communication; Socialisation and economic participation: technologies help integrate people with speech impairments or autism spectrum disorders into active social and economic life; Bridging the digital divide: ensuring access to digital public services, education and remote work for all sections of the population [8], [13], [19].

Thus, digital inclusion aims to eliminate discrimination and foster a culture in modern society where every person has equal opportunities in the digital space. As recent research shows, in many countries around the world, including Ukraine, there are still a number of barriers to achieving full digital inclusion for people with disabilities (due to physical disability, old age, mental health conditions, etc.).

In 1999, the World Wide Web Consortium (W3C) first published the Web Content Accessibility Guidelines (WCAG) [4]. Within the WCAG framework, there is a dedicated initiative responsible for accessibility and the direct developer of the aforementioned Guidelines (WAI – Web Accessibility Initiative) [2].

WCAG is a recognised international standard that describes the requirements for the accessibility of websites and services. It is used by governments in various countries, including Ukraine, and serves as the basis for ensuring digital inclusion in e-government worldwide. The current standard is WCAG 2.2, which is the fourth version since 1999 and incorporates the experience of all previous standards.

The WCAG web accessibility standard is based on four key principles (POUR), which define how content on websites should be presented to ensure maximum accessibility, particularly for people with disabilities:

1. Perceptibility: Information and the interface must be presented in such a way that all users can perceive them adequately, regardless of their physical abilities.

2. Usability: The interface must be user-friendly and accessible through various means of interaction.

3. Comprehensibility: The website's content and functionality must be clear and logical.

4. Reliability: The website's content must be technically sound and compatible with various technologies [3].

Adherence to these principles guarantees the long-term accessibility of public electronic services, ensuring they are easy to use regardless of the user's technical capabilities. This is why the EU has developed a corresponding regulatory framework governing general accessibility, as well as issues of digital inclusion in public services, particularly regarding WCAG web accessibility. Ukraine is also taking steps to implement the relevant EU legislation.

In 2016, Directive 2016/2102 'on the accessibility of public sector bodies' websites and mobile applications' came into force in the EU, and the European Accessibility Act (Directive 2019/882) has been in force since 2019. In particular, the European Commission has tasked European standardisation organisations, such as CEN, CENELEC and ETSI, with developing and implementing accessibility standards. Standards in the field of ICT include Mandate 376 'ICT Accessibility', which led to the adoption of the European standard EN 301 549 (European standard for ICT accessibility), which came into force in June 2025 [1].

In this context, the interconnection between digital inclusion and the concept of lifelong learning is highly relevant, as the digital transformation of society is significantly changing approaches to knowledge acquisition, professional development and continuous learning. In today's world, digital literacy is regarded as one of the key competencies required for effective participation in economic, social and educational life [20].

This issue takes on particular significance in Ukraine amidst a full-scale war. Some educational programmes, professional development courses, vocational training and retraining are delivered via digital platforms, e-libraries, distance learning courses and other web resources. Under such conditions, web accessibility becomes not only a matter of user comfort but also a crucial prerequisite for realising the right to education for all sections of the population, including people with disabilities, internally displaced persons and older people [21].

Web accessibility of educational resources enables the use of alternative formats for presenting information, screen-reading technologies, subtitling of learning materials, adaptive navigation and other user support tools. Compliance of digital resources with WCAG principles allows for a significant increase in the inclusivity of the educational environment and broader access to knowledge [2], [3], [5].

The concept of lifelong learning, which is actively supported by the EU, involves the continuous updating of a person's knowledge and skills throughout their life [22]. The implementation of this concept depends directly on the level of digital literacy among the population and the accessibility of digital resources. This is precisely why the development of digital inclusion must encompass not only the sphere of e-governance, but also the education sector, the vocational training system and the professional development of the adult population.

Thus, digital inclusion and web accessibility are key factors in ensuring the sustainability of Ukraine's education system, the development of human capital, and the promotion of lifelong learning in the face of contemporary crises.

It is worth noting that since the establishment of the Ministry of Digital Transformation of Ukraine in 2019, the issue of achieving a high level of accessibility to public digital services for all sections of the population has become one of the priority areas of its development. Thus, in 2022, Ukraine adopted the national standard DSTU EN 301 549:2022 (EN 301 549 V3.2.1 (2021-03), IDT) 'Information technology. Requirements for the accessibility of ICT products and services'. This standard is a translated and identical version of the European standard EN 301 549 V3.2.1 (2021 - 03) (English version) 'Accessibility requirements for ICT products and services' and also complies with EU Directive 2016/2102. This document regulates the WCAG 2.1 methodology in Ukraine [10]. This is enshrined in law by Resolution of the Cabinet of Ministers of Ukraine No. 757 of 21 July 2023 'Certain issues regarding the accessibility of information and communication systems an documents in electronic form' [12]. It is worth noting that the draft law "On Digital Accessibility" is currently being finalised.

A key aspect for the implementation of digital inclusion of citizens in the sphere of public services is the continuous training and development of staff in state and local government bodies. At the end of 2024, thanks to cooperation between the Ministry of Digital Transformation, the UNDP programme and the Swedish government, the Centre of Excellence for Digital Accessibility was launched. Its main task is to conduct training for public sector specialists with the aim of ensuring the inclusivity of electronic resources and services for all Ukrainians. An important outcome of the Centre of Competence's activities is also the fostering of a culture of digital accessibility among developers of electronic resources, public sector employees and educators. Disseminating knowledge about the principles of web accessibility helps to raise digital literacy levels and create an inclusive digital environment for the population's learning and professional development [16].

Currently, the Ministry of Digital Transformation conducts annual monitoring of the web accessibility of government websites. In 2025, 100 such websites were assessed. The assessment was based on checking 10 key parameters in line with the WCAG 2.1 standard: text descriptions for non-text content; headings and their hierarchy; text contrast; the ability to change text size; keyboard accessibility; keyboard focus; page title; page language; navigation (repeatable blocks); responsiveness [5].

Overall, 52 out of 100 tested websites demonstrated a sufficient or high level of basic accessibility. At the same time, the number of sites with low and medium levels of accessibility decreased – from 76 in 2024 to 48 in 2025. 16 websites received the maximum possible 10 points for accessibility in 2025 [9]. By comparison, in 2024, 7 websites had a high level of web accessibility, 17 had a sufficient level, and almost half (55) had a moderate level of accessibility [17]. A steady increase in web accessibility was observed between 2022 and 2025. Thus, the Ministry of Digital Transformation's programme, which covers web development, consultancy and training, is proving its relevance and effectiveness.

In 2025, the accessibility of mobile apps was analysed for the first time. Two versions of the five most popular apps for Android and iOS – 'Diya', 'State Employment Service', 'Kyiv Digital', 'My Tax Service' and 'Helsi' – were assessed against 10 key criteria. Only 20% of them achieved a high level of accessibility, scoring nine out of ten. A further 20% had only a low level of accessibility, scoring just three out of ten [9].

In 2025, Ukrainians most frequently used the services of the state e-services app and web portal 'Дія' – 48% (which is 6% more compared to 2024). Other popular services in 2025 included: paid access to information from government registers or digital extracts from them (15%), as well as services relating to pensions (15%), personal transport (13%), obtaining subsidies (12%) and tax matters (12%) [7].

In addition, the problem of employment for a significant proportion of people with disabilities, particularly the blind, remains unresolved. On the one hand, there are few remaining enterprises in Ukraine where such individuals can work, and modern entrepreneurs lack the necessary knowledge and equipment; on the other hand, there is a shortage of specialised vocational training programmes that have a direct link with employers. Consequently, the majority of such individuals are unemployed and receive a minimal income in the form of a disability pension. In addition, there is also a technical problem in this area – the inability of most blind people to purchase suitable computer equipment (a laptop or personal computer) due to a lack of funds. It should be noted that Ukrainian legislation already provides for compensation mechanisms for people with disabilities to purchase technica l and other rehabilitation aids (Resolution of the Cabinet of Ministers of Ukraine No. 321 of 5 April 2012). However, under this scheme, the most one can purchase is a mobile phone. This significantly reduces such individuals' ability to access digital resources, and most importantly, to receive educational services via electronic platforms. Consequently, it is proposed to amend the relevant Resolution and provide for the possibility of compensation for the purchase of a computer or laptop (even a second-hand one, but with a warranty).

3. Conclusions

The results of the analysis of the implementation of digital inclusion in Ukraine indicate that there has been a steady improvement in its level in recent years, particularly in terms of ensuring web accessibility of electronic resources of state authorities and local self-government bodies for people with disabilities. The main body in this area is the Ministry of Digital Transformation of Ukraine. The situation with government websites is significantly better. As for mobile applications, only 20% of them meet the requirements to a sufficient standard.

It is important that Ukraine is developing its digital inclusion programmes based on the Web Content Accessibility Guidelines (WCAG) international standard, relevant EU standards and legislation. The issue of implementing digital inclusion at the local government level remains unresolved. Digital accessibility should already be actively implemented in the non-governmental sector, and relevant educational programmes (for people with disabilities, government officials, and employer representatives) should be developed and promoted.

The findings indicate that digital inclusion and web accessibility today extend beyond the realm of e-governance alone. They are becoming essential prerequisites for ensuring access to education, fostering digital literacy among the population, and realising the concept of lifelong learning. In the context of the war and Ukraine's post-war recovery, the accessibility of digital educational resources is of strategic importance for sustaining the resilience of the education system and the development of human capital in general.

The research conducted allows us to formulate the following recommendations:

1) standardise accessibility standards by introducing, at national level, mandatory compliance with WCAG 2.2 for web portals and mobile applications across all central and local government bodies, and subsequently in the non-governmental sector;

2) develop official nationwide accessibility guidelines in accordance with the requirements of the European Accessibility Act (EAA) for integration into Ukrainian legislation;

3) improve the web accessibility of mobile services, ensuring a high level of accessibility for people with disabilities;

4) organise ongoing digital literacy training by introducing special courses for people with disabilities;

5) expand programmes to develop digital literacy among the population and support lifelong learning by creating accessible online courses and digital educational resources (for people with disabilities, public authorities and employers);

6) ensure the accessibility of public and educational digital platforms in accordance with WCAG web accessibility guidelines to support continuous learning for various sections of the population;

7) continuously update training programmes for civil servants to ensure ongoing monitoring of the accessibility of their digital resources;

8) conduct regular monitoring and evaluation of the web accessibility of websites and mobile

applications for compliance with WCAG and EU standards;

9) design new digital services based on the principle of inclusivity;

10) review compensation mechanisms for technical equipment purchased by people with disabilities.

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Chapter 19: Economic Evaluation of Biodiversity's Oxygen-Related Ecosystem Services for Human Sustainable Development

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Abstract. Biodiversity plays a critical role in sustaining atmospheric oxygen levels, yet its contribution to this fundamental life-supporting function remains underappreciated in global environmental policy and ecological valuation. This study provides a conceptual and analytical framework for evaluating the oxygen production function of biodiversity as an essential ecosystem service. Drawing on interdisciplinary data from plant physiology, ecosystem modeling, and global biogeochemical cycles, we assess the contribution of terrestrial and aquatic biodiversity – particularly photosynthetic organisms such as phytoplankton, macroalgae, and forest biomes – to atmospheric oxygen renewal. We identify key biodiversity components and functional groups that underpin oxygen generation and explore how anthropogenic pressures, including habitat degradation, climate change, and biodiversity loss, threaten this capacity. The findings underscore the urgent need to integrate oxygen-related functions into biodiversity conservation strategies and environmental accounting systems. By foregrounding the oxygen production function of biodiversity, we highlight its pivotal role not only in sustaining life on Earth but also in securing long-term planetary health and human well-being. This perspective supports a paradigm shift in how biodiversity is valued – beyond species richness – to include its indispensable regulatory and life-supporting functions for the global community.

Keywords. biodiversity; oxygen production; ecosystem services; photosynthesis; forest ecosystems; planetary health; climate changes.

1. Introduction

Oxygen is an essential component of Earth's atmosphere, sustaining aerobic life forms and regulating biogeochemical processes vital for climate stability and planetary health. While the process of photosynthesis – particularly its role in generating atmospheric oxygen – has been well established for decades (Falkowski et al., 2008), the biological diversity underpinning and maintaining this function remains undervalued in environmental science, economics, and policy. Biodiversity, particularly the variety of photosynthetic organisms such as terrestrial plants, macroalgae, and marine phytoplankton, serves as the engine of atmospheric oxygen production. However, the degradation of biodiversity due to anthropogenic pressures directly jeopardizes the stability of this life-supporting function.

It is estimated that approximately 50–80% of the oxygen produced annually originates from marine phytoplankton (Field et al., 1998; Sarthou et al., 2005), while the remaining share is largely attributable to terrestrial forests and wetland ecosystems (Beer et al., 2010). These systems are not merely carbon sinks or habitats but active contributors to global atmospheric equilibrium. The loss of biodiversity – through deforestation, land-use change, eutrophication, and climate-driven ocean deoxygenation – disrupts the delicate balance required to sustain oxygen levels (IPBES, 2019; Diaz & Rosenberg, 2008).

Recent scholarship has begun to highlight the critical role of functional biodiversity in maintaining Earth system processes (Mace et al., 2012; Cardinale et al., 2012). However, key ecosystem services like oxygen production have received disproportionately less attention compared to provisioning or cultural services in major assessments such as the Millennium Ecosystem Assessment (MEA, 2005) and subsequent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports. This gap persists despite clear warnings that crossing biospheric boundaries—such as biodiversity loss and climate destabilization—could undermine the oxygen-generating capacity of natural systems (Steffen et al., 2015).

Moreover, the planetary oxygen budget is not static; it is sensitive to feedback loops involving global warming, acidification, and nutrient loading (Breitburg et al., 2018). For example, ocean warming reduces oxygen solubility and alters stratification patterns, impairing phytoplankton productivity (Boyd et al., 2013). Similarly, deforestation not only reduces the oxygen produced by terrestrial photosynthesis but also accelerates carbon release, compounding atmospheric instability (Pan et al., 2011).

Despite mounting evidence, biodiversity's role in regulating atmospheric oxygen is rarely included in national accounting systems, global sustainability indicators, or conservation finance mechanisms. As biodiversity continues to decline at unprecedented rates, recognizing and quantifying its oxygen production function becomes an urgent scientific and policy priority.

This article aims to examine the contribution of biodiversity to the production and maintenance of atmospheric oxygen as a critical ecosystem service. By synthesizing evidence across ecological, physiological, and geochemical domains, we seek to highlight the mechanisms through which biodiversity supports life-sustaining oxygen levels, and to propose pathways for embedding this function into environmental assessment and conservation policy.

2. Main part

Our analysis shows that terrestrial and marine ecosystems collectively produce approximately 530–560 Pg O_2 annually, with marine phytoplankton contributing ~52%, and terrestrial vegetation ~48% of total atmospheric oxygen generation. The highest terrestrial oxygen outputs were observed in tropical rainforests (Amazon, Congo, Southeast Asia) and boreal forests, with mean gross oxygen production (GOP) values exceeding 2500 g O_2 m^{-2} yr^{-1}. In contrast, arid and semi-arid biomes showed the lowest GOP, often below 500 g O_2 m^{-2} yr^{-1}.

Oceanic GOP was greatest in equatorial upwelling zones, such as the Eastern Pacific and the Benguela Current, with annual productivity above 3000 g O_2 m^{-2} yr^{-1}, driven by dense phytoplankton blooms (see Table 1). Coastal ecosystems with high chlorophyll-a concentrations – especially estuaries and mangroves – also displayed elevated oxygen outputs.

Sensitivity to Biodiversity Loss. Scenario modeling of biodiversity decline yielded the following key findings: A 25% reduction in photosynthetic species richness resulted in an average 12.4% decline in global GOP, with losses unevenly distributed across biomes. In tropical forests, the loss of functionally dominant canopy species reduced oxygen production by up to 18.7%. In marine systems, shifts from diatom- to cyanobacteria-dominated communities under nutrient stress led to a 14–19% drop in modeled oxygen output per unit chlorophyll.

Monte Carlo simulations confirmed the robustness of these results, with 95% confidence intervals falling within ±2.8% of the mean GOP change under each scenario (Table 1).

Critical Ecosystems and Oxygen Hotspots. Mapping of global oxygen hotspots identified the following ecosystems as the most significant contributors per unit area:

Table 1. Sources: author's work based on [2; 3; 6; 7; 14; 15; 22; 31; 33; 36; 37; 50]

Ecosystem Type	Mean GOP (g O_2 m^{-2} yr^{-1})	Contribution to Global GOP (%)
Tropical Rainforest	2780	24.5
Boreal Forest	1980	12.8
Coastal Phytoplankton	3050	18.6
Oceanic Upwelling Zones	3250	21.7
Wetlands and Peatlands	2140	6.9

Oxygen Stability under Climate and Biodiversity Stressors. In integrated biodiversity–climate stress scenarios, GOP declined more steeply under combined pressures than under either stressor alone. Under SSP5-8.5 and 50% biodiversity loss, projected GOP fell by up to 27% by 2100, with the most vulnerable regions being Amazonia, the Congo Basin, and Indo-Pacific coral reef zones. These findings highlight the potential compounding effects of warming, land-use change, and species extinction on oxygen provisioning.

3. Conclusions

The following conclusions were formed as a result of the conducted research. This study provides quantitative evidence that biodiversity plays a fundamental and measurable role in sustaining the global oxygen cycle, positioning it as a critical ecosystem service vital to the survival of the planetary biosphere. Our key conclusions are as follows:

1.Biodiversity Strongly Correlates with Oxygen Production: Across both terrestrial and marine ecosystems, higher taxonomic and functional diversity significantly enhances gross oxygen production (GOP), explaining over 60% of its spatial variability in some biomes. Biodiverse regions not only host more species but also maintain more stable and elevated rates of atmospheric oxygen generation.

2.High-Output Ecosystems Are Also Biodiversity Hotspots: Tropical rainforests, boreal forests, oceanic upwelling zones, and coastal phytoplankton-rich areas emerge as dual oxygen and biodiversity hotspots. These ecosystems contribute disproportionately to global GOP while also supporting high species richness and ecological functionality.

3.Biodiversity Loss Has Measurable Impacts on Atmospheric Oxygen: Simulated declines in species richness, particularly among photosynthetically dominant taxa, result in substantial decreases in oxygen output. These effects are magnified in sensitive ecosystems such as tropical forests and nutrient-variable marine zones.

4.Synergistic Threats Compound Oxygen Instability: Under scenarios combining biodiversity loss and climate stress (e.g., SSP5-8.5), declines in GOP are more severe and widespread, with up to 27% reduction projected by 2100 in vulnerable regions. This suggests that oxygen provisioning is not only ecologically fragile but increasingly threatened by anthropogenic pressures.

5.Policy and Conservation Implications: Safeguarding biodiversity is not solely an ethical or conservationist priority – it is essential to the atmospheric life-support functions upon which human civilization depends. Integrating oxygen function metrics into conservation planning and environmental accounting could provide a compelling rationale for preserving biologically rich ecosystems under growing climate and land-use stress.

As global biodiversity continues to erode, so too does a cornerstone of planetary habitability: the oxygen production function. Future strategies for sustainability must explicitly account for this invisible, but vital, service – linking species survival to atmospheric resilience and, ultimately, to human well-being.

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Chapter 20: E-democracy as a tool for fostering civic engagement at the local level

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Abstract. This article examines the role of e-democracy as a tool for enhancing civic participation at the local level. It analyzes key digital tools, such as e-petitions, open data, and online consultations, as well as their impact on the transparency and accountability of local governments. Special attention is given to the legal framework for the development of e-democracy in Ukraine and to European standards. The article highlights the benefits and challenges of implementing digital tools for participation in community governance.

Keywords. Civic engagement, e-democracy, e-petitions, local self-government, transparency.

1. Introduction

In today's information society, digital technologies have a significant impact on all areas of life, particularly on the system of public administration and citizens' interactions with government agencies. One of the outcomes of the digital transformation has been the emergence and development of e-democracy, which aims to engage citizens in decision-making processes through the use of modern information and communication technologies.

E-democracy is viewed as a key mechanism for improving democratic processes, as it ensures government openness, promotes transparency in government activities, and creates new opportunities for public participation. The use of digital tools enables citizens to access information more quickly, express their views on issues of public importance, and participate in shaping local policy [1].

E-democracy takes on particular significance at the local level, where interaction between the government and the community is most direct. It is local governments that have the ability to promptly address residents' needs and involve them in solving pressing issues related to regional development. Therefore, studying the role of e-democracy as a tool for fostering civic participation is relevant from both a theoretical and a practical perspective.

2. Theoretical Foundations of E-Democracy

E-democracy is a modern form of implementing democratic principles through digital technologies. It encompasses a wide range of mechanisms that enable citizens to participate in the political and administrative life of the state. Unlike traditional forms of participation, e-democracy allows for the overcoming of time and space constraints, making the process of communication between citizens and the government more accessible and efficient.

The primary goal of e-democracy is to ensure effective dialogue between society and the state, as well as to increase citizen participation in governance decisions. Thanks to the use of digital technologies, citizens can not only access information about the activities of government agencies but also actively influence the development of national and local policies [1].

Council of Europe documents emphasize that the development of e-democracy must be based on the principles of openness, accessibility, accountability, and the protection of human rights [2]. This means that digital tools should not replace traditional democratic mechanisms, but rather complement them, creating additional opportunities for citizen participation.

An important prerequisite for the functioning of e-democracy is ensuring citizens' right to access information. In Ukraine, this right is guaranteed by the Law of Ukraine "On Access to Public Information" [3]. Transparency of information allows citizens to exercise public oversight over the activities of government bodies and increases their trust in state institutions.

3. E-democracy tools at the local level

At the current stage of local self-government development in Ukraine, a wide range of e-democracy tools is being used. One of the most popular and effective mechanisms is electronic petitions. They allow citizens to draw the attention of government authorities to issues of public importance and to initiate their consideration [5].

Online petitions help boost civic engagement by giving people the opportunity to directly influence the government's agenda. To support a petition, citizens simply need to use the online platform and verify their identity. This mechanism is more accessible than traditional forms of petitioning.

Public consultations also play a key role among the tools of e-democracy. They involve discussions of draft decisions, regional development programs, and other documents of public interest. This allows local governments to take residents' views into account when making administrative decisions.

Another important area is the use of official web portals operated by local governments. These resources provide access to information about government activities, laws and regulations, budget documents, and e-services. This helps increase the transparency of local government operations and facilitates more effective communication with citizens.

The expansion of electronic services also has a positive impact on the quality of administrative services. Thanks to digital technologies, citizens can submit applications, obtain certificates, and carry out other administrative procedures remotely, which significantly saves time and resources.

4. Legal Framework for E-Democracy in Ukraine

The development of e-democracy in Ukraine is based on the relevant legal framework. The foundational document is the Constitution of Ukraine, which guarantees citizens the right to participate in the management of public affairs and to exercise oversight over the activities of government bodies [6].

The Law of Ukraine "On Access to Public Information" plays a key role in the functioning of digital mechanisms, as it ensures the transparency of the activities of state and local government bodies [3]. The exercise of this right creates the conditions for the development of public oversight and increased government accountability.

Equally important is the Law of Ukraine "On Electronic Documents and Electronic Document Management" [4], which establishes the legal framework for the use of electronic documents and facilitates electronic interaction between citizens and government agencies.

In addition to national legislation, international standards and recommendations from the Council of Europe have a significant impact on the development of e-democracy in Ukraine [2]. They promote the adoption of best European practices in the areas of digital governance and civic participation.

5. The Benefits and Challenges of E-Democracy

The implementation of e-democracy offers a number of benefits for citizens and government agencies. First and foremost, it increases the openness and transparency of administrative processes. Citizens gain greater opportunities to access information and participate in decision-making.

E-democracy also contributes to the development of civil society, as it encourages public engagement and fosters a sense of responsibility toward addressing social issues. Digital tools facilitate the rapid exchange of information and enable a swift response to pressing challenges.

At the same time, there are certain challenges and risks. One of the main issues remains the digital divide, which manifests itself in varying levels of access to the internet and digital technologies among citizens. This is particularly true for residents of rural areas and certain social groups.

Ensuring cybersecurity and data protection also poses a significant challenge. The use of electronic services requires reliable mechanisms for protecting personal data and preventing unauthorized access to information resources.

Researchers also point out the risk of e-democracy tools being used merely as a formality, where public opinion is gathered but not sufficiently taken into account in the decision-making process [2]. Therefore, an important goal is to ensure that citizens have a real influence on the activities of government bodies.

6. Conclusions

E-democracy is a key component of the development of a modern democratic society and effective local self-government. Its implementation helps expand opportunities for civic participation, increase the transparency of government activities, and strengthen trust between the government and the community.

Ukraine has already established the necessary legal framework for the development of e-democracy, and digital tools for engaging with citizens are being actively implemented. At the same time, further development in this area requires improvements to the digital infrastructure, an increase in the population's digital literacy, and the assurance of an adequate level of information security.

Thus, e-democracy is not only a modern technological phenomenon but also an important mechanism for improving the effectiveness of public administration and fostering the development of civil society in Ukraine.

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Chapter 21: Analysis of Criteria and Indicators of Professional Communicative Competence of Future Officers of the Naval Forces of the Armed Forces of Ukraine

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Abstract. The article analyzes the criteria and indicators of professional communicative competence of future officers of the Naval Forces of the Armed Forces of Ukraine.

Particular attention has been paid to the definition and substantiation of criteria and indicators that can be used to assess the level of professional communicative competence formation.

The article emphasizes the importance of integrating communicative training into professional military education through innovative teaching methods, simulation-based learning, communicative tasks, and the use of digital technologies.

The results of the study contribute to improving the quality of professional training of future officers of the Naval Forces of the Armed Forces of Ukraine and support the implementation of competence-based approaches in military higher education institutions.

Keywords. professional communicative competence, future naval officers, military education, communicative skills, professional training, criteria, indicators, NATO standards, foreign language competence, Armed Forces of Ukraine.

In order to diagnose the level of formation of professional communicative competence of future officers of the Navy of the Armed Forces of Ukraine at different stages of the study, it is necessary to determine a scientifically substantiated system of criteria and corresponding indicators of its formation. This will provide a quantitative and qualitative assessment of the dynamics of the development of professional communicative competence in the educational process of higher educational institutions and create a methodological basis for conducting research and experimental work.

The aim of the research is to determine the criteria and indicators of formation of professional communicative competence of future officers of the Navy of the Armed Forces of Ukraine

A substantiated selection of criteria and indicators should be based on the components of competence (cognitive, operational-activity, social-psychological, motivational-value, reflective-regulatory) and reflect both the content and procedural-result aspects of the professional communicative activity of future officers of the Navy of the Armed Forces of Ukraine.

Taking into account the specifics of the military-professional training of future officers of the Navy of the Armed Forces of Ukraine in the Military-Technical Institute, the system of criteria and indicators should reflect the requirements of service and combat activities, the peculiarities of interpersonal and interdepartmental interaction in a specific professional environment, as well as increased requirements for speech accuracy, normativity and responsibility for communicative decisions. This necessitates the combination of quantitative assessment procedures with a qualitative interpretation of the levels of formation of the studied competence.

The procedure for determining the criteria, indicators and levels of formation of professional communicative competence of future officers of the Navy of the Armed Forces of Ukraine should be constructed as a step-by-step scientifically substantiated process that provides a logical connection between the theoretical model of competence and its empirical diagnostics.

At the theoretical and analytical stage, it is advisable to generalize scientific approaches to the criteria of professional communicative competence, taking into account the identified components (cognitive, operational-activity, socio-psychological, motivational-value, reflective-regulatory) and determine their diagnostically significant manifestations.

The design stage involves formulating criteria and defining a system of indicators for each of them that meet the requirements of operationalization, observability, measurability and professional relevance. At the same time, it is necessary to select methods for collecting empirical data (testing, questionnaires, expert evaluation, analysis of the results of cadets' activities, situational tasks), which ensure the receipt of quantitative and qualitative parameters.

At the expert verification stage, as a rule, the content validity of the proposed system is checked by involving an expert group and the consistency of expert judgments.

The level-diagnostic stage involves establishing a scale of levels of competence formation (for example, high, sufficient, medium, low) and developing their qualitative descriptors and quantitative limits.

The final testing and correction stage consists of pilot application of diagnostic tools in the educational process of higher educational institutions, checking its reliability and discriminativeness, and further refining the system of criteria, indicators, and levels.

The implementation of such a procedure ensures the methodological validity of diagnostics and creates an appropriate basis for further research and experimental work.

As for the first (theoretical and analytical) stage, the results of the generalization of scientific works have shown the presence of different approaches to determining the criteria, indicators and levels of formation of professional communicative competence. At the same time, the analysis of the studies gives grounds to assert that, despite the variability of the authors` positions, a common methodological logic has been established in pedagogical theory, according to which the criteria should correspond to the structure of the competence under study, and the indicators should specify its component manifestations. In particular, in the works of O. Lazarev [8; 210–216], O. Ivannikova [3; 59–65.], N. Zuenko and I. Andrela [11; 64–69.], T. Drozd [2; 163–166], N. Kalashnik [4; 62–67.] substantiated the expediency of the criterion-level approach and emphasized that the content of the criteria should reflect the internal structure of competence and ensure its operationalization. The authors emphasize the need to select observable and measurable indicators that represent cognitive, performance, and personal aspects of preparedness.

At the same time, studies devoted to the professional training of future officers emphasize the need to adapt general pedagogical approaches to the conditions of military-professional activity. Researchers I. Bloshchynsky [1; 77–82], Ye. Kyrpenko, V. Yagupov, S. Zhembrovsky [7; 200–211], Yu. Lisnichenko [9; 8–9], S. Reshetnyk [10; 217–223], O. Kravchenko [6; 178–189.] emphasize that the system of criteria and indicators should take into account the regulated nature of official communication, managerial interaction and the officer's increased responsibility for communicative decisions.

Taking into account the results of the analysis conducted in the study, we adhere to the approach according to which the criteria for the formation of professional communicative competence of future officers of the Navy of the Armed Forces of Ukraine should directly correlate with its structure, and the system of indicators should reflect diagnostically significant manifestations of each component. Such a methodological position ensures internal consistency of diagnostics and creates a basis for a substantiated determination of the levels of formation of the studied competence.

In accordance with the logic of the design stage and taking into account the structure of professional communicative competence of future officers of the Navy of the Armed Forces of Ukraine, defined in subsection 3.1, criteria have been formulated and a system of main indicators has been outlined for each of them. Their selection was based on the requirement of content compliance with the component structure of competence, which ensures its correct operationalization and subsequent empirical measurement.

The content of the criteria specifies the relevant components of competence (cognitive, operational-activity, socio-psychological, motivational-value, reflective-regulatory), and the indicators reflect diagnostically significant manifestations of the readiness of future officers for professional communicative activity in the naval environment. Their determination was carried out taking into account observability, measurability, professional relevance and compliance with the requirements of service and combat activity.

An important condition for the development of the diagnostic toolkit was the combination of quantitative and qualitative methods of collecting empirical data. This approach allows not only to record the level of formation of individual skills and qualities, but also to interpret the features of their manifestation in typical and complex conditions of professional activity. For this purpose, a complex of complementary methods was used: testing, questionnaires, expert evaluation, analysis of the results of educational and professional activity of cadets, situational modeling and observation.

The proposed system covers five interrelated criteria - normative-knowledge, communicative-activity, psychological-management, professional-value and communicative-regulatory. Each of them represents a separate dimension of the professional communicative preparedness of a future officer of the Navy of the Armed Forces of Ukraine and corresponds in content to the corresponding component of competence. This approach provides a holistic coverage of cognitive, activity, personal and reflective manifestations of professional communication.

For each criterion, a system of indicators and diagnostic indicators of their manifestation is specified, which creates the necessary conditions for objective measurement of the studied competence. The selection of methods is complex and involves a combination of test, scoring, expert, behavioral and reflective procedures. Such methodological integration increases the validity and reliability of diagnostics, provides a multidimensional assessment of the formation of professional communicative competence, and forms the basis for further determination of the levels of its formation within the framework of research and experimental work.

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Chapter 22: Problems of Preserving Scientific Human Capital in Wartime

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Abstract. The article examines the impact of a full-scale war on the scientific human capital of Ukraine. The main risks for the scientific sphere are analyzed, in particular, the forced migration of scientists, the reduction of the human resources potential of scientific institutions, the reduction of research funding, and the increase in competition for highly qualified personnel on the international labor market. Modern mechanisms of state support for science and international scientific cooperation are considered. Strategic directions for the preservation and restoration of the scientific human capital of Ukraine in the context of post-war development are substantiated. A set of measures aimed at increasing the stability of the scientific system and ensuring its competitiveness is proposed.

Keywords. Gross domestic expenditure on research and development, human capital, recovery strategies, scientific potential.

The full-scale war has become an unprecedented challenge for the scientific system of Ukraine, causing not only direct losses of scientific infrastructure, but also a large-scale reduction in the human capital of science. The destruction of scientific institutions, laboratories and research equipment is accompanied by the forced migration of scientists, the relocation of higher education institutions and scientific organizations, as well as a decrease in the amount of funding for research and development. Taken together, these processes create risks of long-term degradation of the state's scientific potential, a decrease in the ability to create new knowledge and a weakening of Ukraine's innovative competitiveness in the post-war period.

The creation of strategic solutions targeted at protecting and replenishing scientific talent capital becomes even more crucial in such circumstances. Priority areas include expanding international scientific cooperation, modernizing and rebuilding research infrastructure, supporting programs for the return of Ukrainian scientists from foreign countries, guaranteeing steady funding for scientific endeavors, and integrating Ukrainian research space into the European research space. The restoration of Ukraine's scientific capacity and the creation of a innovative post-war development model depend on the systematic application of such methods.

The data presented in Table 1 indicate the formation of a complex of interrelated threats to Ukraine's scientific potential: reduction of human resources, destruction of the material and technical base, and reduction in funding for research and development. In the context of post-war reconstruction, this emphasizes the necessity of creating strategic procedures for the preservation and restoration of scientific human capital.

Table 1. Impact of the War on Ukraine's Scientific and Research Potential

Indicator	Value
Researchers forced to relocate internally or abroad	approximately 10–15% of researchers
Research institutions affected by physical damage	29.4% of research institutions
Relocated higher education and research institutions since 2014	more than 40 institutions
Damaged or destroyed educational and research infrastructure facilities	1,443 facilities
Estimated cost of restoring scientific infrastructure	more than USD 1.26 billion
Financial support for Ukrainian researchers under the MSCA4Ukraine programme (2025)	EUR 10 million

Note:

Source: compiled by the author based on official and analytical data from the State Statistics Service of Ukraine [1], UNESCO Institute for Statistics (UIS) [2], the Ministry of Education and Science of Ukraine, Science at Risk initiative [3], RDNA reports [4] and the European Commission (MSCA4Ukraine) [5].

A feature of the current situation is that Ukraine faces not only the risk of "brain drain", but also the threat of losing the institutional memory of science due to the destruction of research teams and infrastructure.

At the same time, to assess long-term trends in the preservation and reproduction of scientific human capital, it is necessary to analyze the dynamics of the number of personnel engaged in research and development. The corresponding results are shown in Fig. 1.

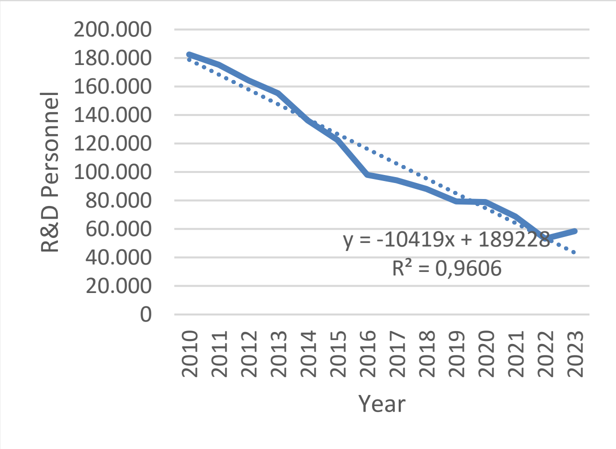

Figure 1. Dynamics of R&D Personn, 2015–2022

Note:

Source: compiled by the author based on data from the State Statistics Service of Ukraine (official statistical publications on research and development activities, 2010–2023). el in Ukraine (2010–2023) [1].

The projected convergence of the linear trend toward a near-zero level of R&D personnel around 2027 should be interpreted as a theoretical boundary rather than a realistic forecast. Nevertheless, it highlights the potential long-term consequences of sustained negative dynamics in scientific human capital. Such a trajectory reflects cumulative structural pressures within the national research system, including the weakening of institutional capacity, reduced attractiveness of research careers, and insufficient renewal of scientific personnel. According to this viewpoint, the 2027 threshold serves as an analytical warning signal, marking the moment at which, in the absence of focused governmental interventions and systemic investment in science, the continuity of the national research system would become dangerously fragile.

While Fig. 1 illustrates the contraction of scientific human capital, a comprehensive understanding of this trend requires an analysis of the underlying financial conditions of the research system. In this context, the dynamics of gross domestic expenditure on research and development (GERD) are presented in Fig. 2 as a key explanatory factor of the observed structural decline.

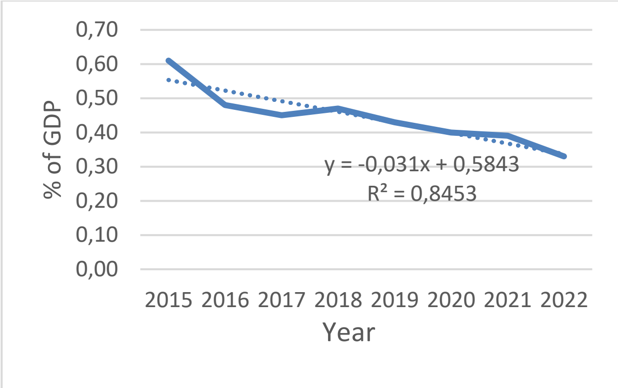

Figure 2. Dynamics of gross domestic expenditure on research and development (GERD), 2015–2022 (% of GDP)

Note:

Compiled by the author using data from the State Statistics Service of Ukraine [1] and the UNESCO Institute for Statistics (UIS) [2] on gross domestic expenditure on research and development (GERD), expressed as a percentage of GDP.

As shown in Fig. 2, gross domestic expenditure on research and development (GERD) in Ukraine demonstrates a persistent downward trend over the analyzed period, reflecting a gradual weakening of the financial foundation of the national research system. The linear trend approximation further indicates a continued decline in R&D intensity, suggesting that if current dynamics persist, GERD may approach a critically low level of approximately 0.2% of GDP around 2027.

Rather than being an exact forecast, this estimated threshold should be seen as a structural warning indicator. Reaching this level would mean that the national research system would become highly underfunded, severely limiting its ability to maintain scientific activity, guarantee the replication of human capital, and promote innovation-driven development. The trajectory that has been found in this context highlights how urgent it is to implement deliberate policy measures that would stabilize and restore appropriate levels of support for research.

The development of an adaptive model of scientific governance that combines internal stability mechanisms with international support is especially pertinent in the context of a protracted war and structural decrease of Ukraine's scientific capabilities. In addition to protecting science's current human capital, it is crucial to establish the framework for its growth, reproduction, and integration into European research.

One of the most effective tools in this context is the support programs of the European Union, in particular MSCA4Ukraine, which have the potential to transform from an instrument of individual support for researchers into a mechanism for institutional renewal of Ukrainian science. To this end, it is advisable to reorient part of the program's resources to the creation of long-term research positions in Ukrainian universities and scientific institutions, the development of joint laboratories, as well as the financing of projects that are directly linked to the restoration of critical sectors of the economy and public administration. Another important direction is to stimulate the mechanisms of “circulation of scientists” instead of the complete loss of personnel through emigration, which will allow scientists to maintain contact with the national system even in the case of temporary work abroad [5, 6, 7, 10].

An alternative strategic model could be the formation of mixed research ecosystems, in which EU funding is combined with national recovery priorities. This involves supporting thematic research clusters in the areas of security, infrastructure recovery, digitalization of public administration and social sustainability. In such a model, MSCA4Ukraine performs not only a compensatory function, but also becomes a tool for long-term building of scientific potential integrated into European research policy [7, 8, 9].

Thus, the effective use of international science support programs requires a transition from the logic of “retaining personnel” to the logic of “restoration and development of the system”, which will allow gradually overcoming the consequences of war losses and forming a sustainable model of scientific development of Ukraine in the post-war period.

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Chapter 23: Public Governance under Martial Law and Post-War Reconstruction: Practices of Self-Governing Communities

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Abstract. This study conceptualizes the transformation of public governance paradigms through the lens of self-governing community practices during wartime and post-war reconstruction. By analyzing the structural interactions between state authorities and civil society institutions, the paper explicates a strategic matrix mapping community interventions across national security, economic resilience, and social inclusion. The research demonstrates that resource scarcity drives a shift from hierarchical administration toward co-management models. Ultimately, the integration of civic monitoring practices into state digital platforms like the DREAM ecosystem institutionalizes public accountability, offering a framework for co-creation and a renewed social contract.

Keywords. Co-management, public governance, self-governing communities, strategic co-creation.

1. Introduction

Martial law, as a specific legal regime governing society and the state in Ukraine, carries a constitutional status and operates through defined regulatory instruments: the centralization and expansion of public authorities' mandates; the restriction of constitutional rights, individual freedoms, and the legitimate interests of corporate entities; rigorous economic intervention alongside intensified state oversight; and information control [1].

Concurrently, under acute state resource constraints, the wartime environment has forced unconventional conditions that broaden the social baseline of public policy. This dynamic increasingly shifts policy execution toward structured co-participation among state institutions, local self-government, enterprises, and civil society networks.

Within this paradigm, the state focuses on configuring an adaptive, resilient institutional and legal infrastructure via:

Legislative and regulatory framing – enacting statutory acts that formalize and sustain civic interventions (e.g., the Laws of Ukraine "On Volunteer Activity", "On National Resistance", "On Charitable Activity and Charitable Organizations", "On Cooperation", and "On Bodies of Self-Organization of the Population").

2. Main text

Financial and material backing – embedding self-governing units into state budgetary programs, launching targeted funds for volunteers and voluntary formations of territorial communities, and developing public-private partnerships.

Structural coordination – institutionalizing operational linkages connecting civic and volunteer networks with state defense and administrative bodies, including the Armed Forces of Ukraine, the State Emergency Service, the Ministry of Defense, and regional administrations.

Operational security for civil actors – implementing legal safeguards and protection mechanisms for civic activists executing missions within combat zones [2].

Current academic literature delineates two primary approaches to public governance, both reflecting a global reconceptualization of the state's administrative role. The first approach conceptualizes self-governing frameworks as polycentric arrangements driven by state retraction, where traditional hierarchies are supplanted by overlapping, competitive, and autonomous decision-making nodes.

The second approach defines public governance through the redistribution of state functions, emphasizing the engagement of non-state actors via voluntary agreements, private initiatives, and polycentric civic networks, while the state retains a coordinating role based on the principles of good governance [3; 4].

In either context, the ontological essence of public governance manifests in the continuous reproduction of collective interests within self-governing networks aimed at resolving socially significant issues. The definitive attributes of this paradigm include voluntariness, situational mobilization around specific objectives, non-hierarchical internal coordination, and network-based interaction.

The theoretical and methodological framing of public governance within policy execution remains formative. Consequently, further research must prioritize a rigorous analysis of the legislative and regulatory frameworks that institutionalize public governance within the policy-making process.

Concurrently, this study evaluates the institutional capacity of public governance practices to execute public policy objectives. Expanding on this trajectory, we examine self-governing communities as active agents of public policy implementation, structuring their operational strategies, analyzing effective community practices during wartime, and assessing their potential for post-war reconstruction.

Empirical indicators underscore an accelerating mobilization within Ukrainian civil society under martial law. This trend is evidenced by the registration of 4,365 new civil society organizations (CSOs) within the first four months of 2022 alone, with 49% operating at the local level. Furthermore, the number of officially registered volunteers expanded by a factor of 21 by the end of 2023, while up to 86% of citizens engage in volunteer and charitable activities, and approximately 100,000 individuals have joined voluntary formations of territorial communities [5].

Wartime conditions have catalyzed a systemic institutionalization of self-governing communities, whose legitimacy is generated via what Pierre Bourdieu conceptualizes as the symbolic capital of trust, rendering the self-organization process an organic imperative for the community. These self-governing units consistently demonstrate dense intra-communal ties at the micro-level, horizontal network interactions across groups, and established channels of communication with public authorities [6].

Co-creation—the process whereby public and private actors collectively articulate problem definitions and design innovative solutions to generate public value—is increasingly conceptualized as a critical strategic principle of modern public governance.

This paper defines self-governing communities as civil society entities (encompassing social groups, private and social initiatives, organizations, and informal networks) that act as proactive socio-economic and political actors addressing issues of public significance. Admittedly, this definition is exceptionally broad and complicates framing these entities as distinct legal subjects; nevertheless, this inquiry represents an initial attempt at a scholarly systematization of the phenomenon.

The resulting systematization of wartime self-governing practices forms the basis of the strategic priority matrix presented below (Table 1).

Table 1. (after the References)

The data in Table 1 indicate that the operational response to emerging threats served as the starting point for the functioning of self-governing communities under wartime conditions. Nevertheless, the large-scale and pervasive nature of these self-governing community practices substantially contributes to the implementation of strategic public policy priorities. Furthermore, under the conditions of war, this model of public governance has acquired an existential dimension, ensuring the vitality of society and the state as a whole, while preserving social capital, culture, education, and other vital spheres.

The operational mechanisms of self-governing communities within the scope of public policy implementation are anchored in the principles of public participation, collaborative governance, subsidiarity, and network governance. Consequently, these mechanisms enhance the effectiveness of administrative decisions and foster institutional trust in public authorities (Table 2).

Table 2. (after the References)

The analyzed primary management mechanisms and interaction channels between self-governing communities and public authorities within the scope of public policy implementation demonstrate a strengthening of both the institutional and functional agency, as well as the capacity of self-governing institutions as core actors in public governance.

This evolution enhances the effectiveness of public policy by expanding participatory mechanisms for self-governing communities—specifically advisory, oversight-analytical, financial, and communicative tools—thereby substantially transforming the overarching public governance model.

A synthesis of these demonstrated mechanisms allows for the categorization of the baseline operational characteristics of self-governing entities within the public governance framework (Table 3).

Table 3. (after the References)

The provided data indicates that self-governing communities demonstrate the ambition to form the institutional foundation of a new public governance model. This is achieved through the creation of an open space for collaborative action, the adaptation of management decisions to the actual needs of the population, and the deployment of modern technological solutions for participation, monitoring, and communication.

Consequently, the analysis of effective public governance practices within the scope of public policy implementation demonstrates the efficacy of strategies and mechanisms employed by self-governing communities. As actors in public governance, these entities are capable of responsibly assuming the integrative and instrumental functions of the state, while also swiftly adapting society to operational realities during wartime.

The accumulated experience of self-governing communities establishes an empirical foundation for conceptualizing their potential in post-war reconstruction. In the logic of the National Recovery Plan of Ukraine, the ultimate objective is not merely the rebuilding of the country, but the renewal of the social contract on a partnership basis—a goal that resides directly within the domain of public governance [7].

Based on the research objectives, this study focuses on the strategic framework outlined by the Recovery Plan, specifically "Strengthening Institutional Capacity."

The conceptual essence of this direction encompasses:

The modernization of the governance system;

Governance transparency and accountability;

Decentralization and subsidiarity in decision-making;

Civic engagement in public policy formulation and oversight;

Human capital development;

The development of digital services and management standards.

Broadly, the strategic goals of strengthening institutional capacity serve as systemic variables within the Plan, securing the institutional architecture of recovery. Accordingly, integrating self-governing communities as repositories of social capital into the capacity-building process forms a networked governance architecture. The potential of self-governing communities is systematized into the following functional components: operational efficiency, institutional audit, and innovation dynamics (Table 4).

Table 4. (after the References)

As noted by J. Torfing et al., the transition to strategic co-creation allows for both the accumulation of resources and the generation of new public value through the synergy of public and private actors. In the Ukrainian context, this manifests in the formation of an adaptive governance model, where self-governing communities emerge as agents of innovation dynamics and institutional audit. The practical embodiment of such synergy is the regulatory integration of civic oversight tools into national digital systems (specifically, the DREAM ecosystem), which transforms declarative citizen participation into a legally significant element of recovery process management [8].

The future outlook for public governance lies in strengthening the institutional and functional agency of self-governing communities, which emerge as integral participants in the architecture of public administration.

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Table 1. Core strategies and practices of self-governing communities within the context of public policy implementation

Policy priority	Strategies	Practices
National security and defense	Local mobilization and community security	Territorial defense: voluntary formations of territorial communities – securing settlements and supporting the armed forces; Civic patrols: maintaining public order and countering sabotage threats; Coordination with security agencies: integrating local initiatives with the National Police, the State Emergency Service, and military administrations.
	Volunteer assistance to the military and civilians	Material and technical support for the Armed Forces: fundraising, procurement of equipment, and manufacturing of unmanned aerial vehicles (UAVs) and military gear; Humanitarian assistance: providing food, medical supplies, and essential goods for both military personnel and civilians; Evacuation and social adaptation of displaced persons: establishing temporary shelters, organizing transport logistics, and providing social support networks.
Social policy	Social protection and welfare	Partnership with public social protection institutions: volunteer initiatives supporting internally displaced persons (IDPs); civic monitoring of access to social services; Social partnership and civic engagement: public-private partnerships in social service delivery; participation in public advisory councils and the establishment of co-governance platforms; Psychosocial support: initiating local psychological assistance programs; advocating for and promoting healthy lifestyle initiatives; rehabilitation projects for veterans and war-affected children.
	Social integration and inclusion	Advocacy for the rights of persons with disabilities: designing accessible environments; enhancing socialization pathways for children with disabilities; Promotion of gender equality; Fostering social capital: organizing community festivals and youth development events; establishing vibrant, inclusive public spaces.
	Employment and human capital development	Professional reintegration of veterans and IDPs: Job placement and mentorship programs for veterans and IDPs; civic (specialized) educational platforms; fostering women's entrepreneurship and business development.
Information policy	Information security and strategic communications	Countering disinformation: debunking fake news, conducting media literacy and information security awareness campaigns; Documentation of war crimes and advocacy: developing grassroots citizen journalism networks; Cybersecurity support: building platforms to safeguard personal data and protect critical digital infrastructure.
Economic policy	Economic security and recovery	Housing and infrastructure rehabilitation: grassroots reconstruction initiatives; co-financing through public grant support networks; Financial support for businesses: engagement of local cooperatives in food security programs; mutual assistance networks for entrepreneurs.
	Economic resilience	Collaborative planning and implementation of socio-economic strategies: participation in grant-funded and public programs; consulting services for SMEs; analytical support for local economic strategies; developing developmental roadmaps; Innovative employment initiatives: providing equipment and co-working spaces; social entrepreneurship; local business development; women's entrepreneurship; self-help projects; socio-economic cooperatives.

Culture and education	Cultural heritage preservation and the culture of recovery	Reconstruction of cultural infrastructure: community-led assessment and prioritization of sites for preservation and reintegration; expert advisory support; promoting cultural recovery initiatives; Partnership with public cultural authorities: establishing cooperative platforms to support cultural reconstruction projects; forming joint working groups; implementing participatory budgeting frameworks.
	Cultural participation	Advocacy for sector reforms: providing analytical and policy support; Ensuring access to culture in small and remote communities: digitization of heritage sites and museum collections; establishing ethno-cultural hubs, private museums, and exhibitions; developing virtual tours; Creation of memorials and commemorative sites.
	Safe educational environment	Supporting educational continuity: provisioning technical equipment and communication tools; retrofitting and equipping bomb shelters; Learning recovery programs: establishing mentorship networks and remedial tutoring groups; Civic-educational-administrative dialogues: restructuring school networks; facilitating public multi-stakeholder discussions on educational models.
International policy	International cooperation	Public diplomacy: joint projects, forums, and academic conferences; organizing informal expert-level meetings; Lobbying and advocacy.

Table 2. Mechanisms of self-governing community activities in public policy implementation

Policy priority	Strategies	Practices	Mode of Realization
Organizational -Institutional	Institutionalization of civic participation Delegation of authority and subsidiarity	Establishing permanent and temporary structures for public participation in governance; Devolution of select state functions to self-governing communities for the effective resolution of socially significant local issues.	Public advisory councils, consultative bodies, and joint commissions Agreements, collaborative projects, and local initiatives
Legal and Regulatory	Legal regulation of public participation Guaranteeing citizen rights to participate in governance	Defining the legal foundations for cooperation between public authorities and civil society organizations; Ensuring the statutory right of citizens to influence public policy decisions.	Laws, government decrees, and local regulatory acts E-petitions, public hearings, and public information requests
Information-Communicative	Public communication and governmental openness Civic monitoring and feedback loops	Collaborative implementation of projects, programs, or policies based on the alignment of stakeholder interests; Conducting consultations with representatives of self-governing communities prior to the adoption of policy decisions.	Memorandums, grants, co-funding arrangements, and public-civic councils; Public consultations.
Financial-Economic	Participatory budgeting State support for civic initiatives	Empowering self-governing communities to participate in the allocation of budgetary resources; Financial or material assistance for the implementation of socially significant projects.	Participatory budgeting, participatory planning Grants, subventions, and support programs
Educational and awareness-raising	competence in the field of public governance	Developing knowledge and skills for participation; Building the capacity of community opinion leaders	Training courses, awareness-raising campaigns, and active citizenship schools; Educational programs, internships, and experience-sharing initiatives

Table 3. Baseline operational characteristics of self-governing communities as actors in public governance

Characteristics	Means and tools of implementation
Horizontal coordination	Creation of volunteer and private networks to coordinate the supply of aid & resources; Information sharing via social media and messaging platforms.
Interaction with public authorities	Formulation and implementation of public policy: participation in public councils and expert working groups for the preparation of strategic documents; Measures to enhance economic resilience and defense capacity: economic self-sufficiency initiatives; monitoring of needs; military-patriotic education; training in first aid and civil defense skills; Public oversight and analytical activity: monitoring and evaluating the efficiency of resource utilization; risk analysis and assessment; Material-technical and humanitarian support: volunteer activities; provision of technical equipment; Information and awareness-raising work: countering disinformation and hybrid threats; information campaigns on mobilization and crisis response; other public awareness campaigns.
Utilization of digital technologies	Technological solutions for management and coordination automation: crowdfunding platforms for resource mobilization targeting military and humanitarian needs; databases for internal displacement tracking and registration; co-governance platforms. Cyber-volunteering: initiatives led by IT activists focusing on the cyber defense of state and civic assets.
Subsidiarity	Optimal allocation of authority within the community

Table 4. Alignment between the potential of self-governing communities and the key components of the national recovery policy for strengthening institutional capacity

Recovery Plan component	Potential of self-governing communities	Expected institutional effect
Operational efficiency		
Enhancing the efficiency of the public governance system	Presence of horizontal governance structures, self-organization practices, rapid resource mobilization, and collective decision-making	Reduction of local authorities' response times to crisis requests; Optimization of local budget expenditures through the mechanism of delegating social services to certified CSOs.
	Rapid redistribution of resources; Minimization of transaction costs.	Transition from rigid administration to collaborative management of recovery resources; Streamlining and digitization of local compliance and approval procedures.
Decentralization and the development of local governance	Operation of bodies of public self-organization, local initiatives, coalitions, and residents' associations	Deepening the principle of subsidiarity by granting bodies of public self-organization the authority to manage recovery micro-grants; Integration of volunteer networks and volunteer formations of territorial communities (VFTCs) into municipal community safety programs.

Institutional audit		
Institutionalization of the principles of openness, transparency, and accountability	Public monitoring, volunteer reporting practices, and an established culture of public accountability	Implementation of public expert oversight tools; Minimization of corruption risks; Increased mutual trust between local self-government bodies and community residents.
Strengthening of anti-corruption infrastructure and integrity mechanisms	Execution of institutional control functions through the public monitoring of recovery funds, transparency in resource allocation, and volunteer audits.	Institutionalization of volunteer and civic audit as a mandatory element of monitoring the use of funds; implementation of anti-corruption compliance procedures and ethical standards in local self-government bodies.
	Implementation of ethical practices.	Formulation of ethical standards in the management of recovery funds
Innovation dynamics		
Institutionalization of public-private and civic partnerships	Joint volunteer-state-business projects, charitable foundations, and civic coalitions	Creation of a networked governance model for the recovery process; Regulatory formalization of the tripartite partnership (government-business-community) in the development of local industrial and social parks.
Implementation of digital management tools and open data	Diffusion of innovations, crowdfunding platforms, and cyber-volunteering	Official integration and legitimization of data from non-governmental monitoring platforms into state registries; Scaling of e-democracy tools (electronic hearings, digital surveys).
	Building an economic base through private-initiative job creation and the restoration of economic life in de-occupied territories	Reduction of the unemployment rate among IDPs (internally displaced persons) and veterans; Legalization and institutional support of social entrepreneurship and cooperation as the foundation for community self-sufficiency.

Chapter 24: The Role of Staff Emotional Intelligence in Enhancing Human Capital Efficiency

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Abstract. In the contemporary operating environment of energy companies, workforce efficiency increasingly relies not only on professional knowledge and technical skills but also on employees' social and emotional competencies. This article substantiates the role of emotional intelligence as a factor in enhancing workforce efficiency and as a component of human capital within energy enterprises, and develops an approach for its assessment. The research methodology integrates direct, behavioural, and outcome indicators, constructs an integrated emotional intelligence index, normalises indicators, applies weighting coefficients, and employs regression analysis. The proposed approach was tested using a simulated example of the Joint Stock Company 'Energy Company of Ukraine'. The results indicate high internal consistency of the emotional intelligence subscales, hierarchical differentiation of their levels across employee groups, and statistically significant correlations between emotional intelligence and work performance, the generalised employee effectiveness indicator, absenteeism, and error rates. These findings demonstrate that emotional intelligence is a measurable managerial resource that influences the quality of interactions, process stability, productivity, and the effective utilisation of human capital within energy enterprises.

Keywords. emotional intelligence; human capital; workforce efficiency; energy company; human resources management; organisational effectiveness.

1. Introduction

In the contemporary business environment, the effective utilisation of human capital is becoming as important as technical and technological aspects of operations. This is especially significant for energy companies, whose activities require a high degree of responsibility, complex production and management processes, continuous coordination, regulatory compliance, rapid adaptation to change, and sustained operational stability. Under these conditions, workforce effectiveness depends not only on professional knowledge and technical skills, but also on employees' abilities to communicate, self-regulate, adapt to stress, resolve conflicts constructively, and participate in coordinated teamwork.

In this context, emotional intelligence (EI) assumes particular importance; in contemporary academic literature, it is regarded as the collection of skills to recognize, comprehend, and regulate one's own emotions and those of others. In human resource management practices, EI is increasingly considered a resource that impacts work productivity, communication quality, teamwork, conflict levels, staff resilience to stress, and the overall coherence of work processes [1; 2]. For energy companies, these aspects are particularly important, as even minor disruptions in interactions among employees, departments, or management levels can affect the quality of task execution, the speed of decision-making, and the stability of operational processes.

The current state of research in this domain demonstrates a persistent interest in emotional intelligence as a determinant affecting both individual and organizational effectiveness. The preponderance of academic investigations corroborates a statistically significant correlation between EI and various indicators such as work performance, employee conduct within the organization, emotional well-being, and resilience to stress [1; 2]. Simultaneously, a distinct domain of research concentrates on the significance of Emotional Intelligence (EI) in leadership and teamwork. It is associated with leadership effectiveness, organizational citizenship behavior, and the attainment of team objectives [3; 4].

Simultaneously, there continue to be certain disagreements within the academic community concerning the interpretation of the construct of emotional intelligence itself, the methodologies employed for its measurement, and the degree to which it impacts performance outcomes. The debate persists regarding whether EI should be regarded chiefly as an ability, a personality trait, or a hybrid construct integrating emotional, cognitive, and behavioural elements. Similarly, research findings are heavily influenced by whether self-report scales or more behaviourally oriented assessment instruments are utilized [5; 6; 7].

Despite the extensive body of research examining the correlation between emotional intelligence and behavioural and organisational outcomes, the practical application of assessing its impact on enhancing workforce effectiveness within a specific organisation remains underdeveloped. Numerous studies have demonstrated that emotional intelligence indirectly affects performance outcomes by increasing labour productivity, enhancing internal coordination, minimising losses attributable to conflicts, reducing staff turnover, and improving the quality of interactions alongside staff stability [8; 9]. Simultaneously, in practical applications, the shift from the psychological assessment of emotional intelligence (EI) to its managerial interpretation is often hindered by the widespread use of self-report scales, the risk of common method bias, and the lack of models that explicitly link EI to quantifiable operational metrics.

For an energy company, this issue is particularly significant in practice. The emotional intelligence of employees and managers affects not only the socio-psychological atmosphere within the team but also the quality of professional skills, the speed and accuracy of internal communication, willingness for training and retraining, the effectiveness of teamwork, conflict reduction, and staff resilience under high pressure. In this context, EI should be seen as a component of human capital that boosts the development of employees' skills and helps to increase workforce productivity. It is especially important that its impact is not seen in isolation, but through a system of behavioural and operational indicators that can be recorded, evaluated, and incorporated into HR management practices [10; 11].

Despite the existing findings, there remain at least three unresolved issues. Firstly, the studies lack a universal framework for aligning Emotional Intelligence (EI) measurements with specific indicators of work performance and organisational effectiveness. Secondly, models that enable the distinction of the effect of EI from other factors—particularly professional competencies, cognitive abilities, and the organisational environment—have not been sufficiently developed. Thirdly, there is a deficiency of applied methodologies that facilitate the use of EI as a practical tool for enhancing workforce effectiveness, not merely in theory, but through specific, measurable indicators and assessment procedures within the human resource management system.

In this regard, the aim of this study is to substantiate the role of emotional intelligence as a factor in enhancing workforce efficiency and as a component of human capital within an energy enterprise, as well as to develop an approach to its assessment based on direct, behavioural, and performance indicators. The main conclusion of the study is that emotional intelligence should be regarded as a measurable managerial resource that influences the quality of interaction, the stability of processes, labour productivity, and the effective use of human capital within the enterprise.

2. Materials and methods

The research methodology is founded on the premise that the practical significance of staff emotional intelligence—as a component of human capital and a factor in improving workforce efficiency—is only realised when it is operationalized. This entails its transformation into a system of explicitly defined, measurable indicators that can be systematically recorded, compared over time, and correlated with the operational and organizational outcomes of the enterprise. Scientific research underscores that emotional intelligence (EI) is a multidimensional construct; therefore, its assessment should not comprise a single generalized characteristic, but rather a system of components—such as self-awareness, self-regulation, empathy, interaction management, and others—that influence employee behavior and organizational performance [12; 13].

The study employs a multi-level assessment approach, under which the indicators are grouped into three interrelated categories:

1. direct EI indicators that measure employees' emotional abilities and competencies;

2. behavioural indicators in the workplace that reflect manifestations of emotional intelligence in professional interactions;

3. performance indicators that measure the impact of EI through operational and organisational KPIs.

This approach is consistent with empirical evidence suggesting that EI exerts its influence not directly, but through a cascade of behavioural and organisational variables that shape its measurable contribution to labour productivity, the quality of interactions, staff retention and the organisation's overall performance [14].

The empirical validation of the approach is carried out on a simulated dataset compiled from materials provided by the Joint Stock Company 'Energy Company of Ukraine'. This article employs a model designed to demonstrate the logic behind indicator construction, the EI composite index, and the statistical verification of the relationship between emotional intelligence and workforce performance indicators. This approach allows for the demonstration of the methodology's practical application without disclosing sensitive corporate data.

Three types of information are used to build the model:

- EI standardised assessment results;
- behavioural and competency-based staff assessments;
- operational and organisational performance indicators.

Data sources may include staff surveys, 360-degree feedback results, performance review data, internal HR analytics, ERP/HRM systems and the company's management reports. Should the methodology subsequently be applied to real corporate data, any restrictions on access to the source information must be explicitly stated in the manuscript when the article is submitted. In the present study, the dataset is simulated and therefore does not require citing registration numbers for external public databases.

Direct indicators of emotional intelligence

Direct indicators focus on assessing EI as a set of abilities or competencies. In organisational research practice, standardised scales adapted for the workplace are the most common. Self-report standardised questionnaires suitable for group use in an organisational context can serve as basic measurement tools. In this study, the following are methodologically relevant:

- The Schutte Self-Report Emotional Intelligence Test (SSEIT), which provides a comprehensive assessment of emotional intelligence and is suitable for group analysis of staff [6].
- The Wong and Law Emotional Intelligence Scale (WLEIS), which assesses EI across four applied components:
  a) assessing one's own emotions;
  b) assessing other people's emotions;
  c) using emotions to achieve a result;
  d) emotional regulation [7].

The application of these tools yields individual and collective emotional intelligence (EI) profiles. These profiles facilitate comparisons among employees, departments, professional roles, and management levels, and enable the analysis of changes in performance metrics before and after the implementation of a staff development programme.

To reduce the risk of self-reporting bias, EQ questionnaire assessments should be supplemented with behavioural indicators using the 360° approach, which includes evaluations by managers, colleagues, subordinates, and self-assessment. Empirical evidence indicates that emotional competencies, when measured as behavioural manifestations, can predict the performance of managers and teams [15; 16].

In practical terms, relevant indicators may include the ability to manage emotional tension within a team, maintain constructive behaviour under pressure, resolve conflicts without escalation, and sustain effective collaboration during periods of change. These indicators can then be compared with departmental key performance indicators (KPIs), performance review outcomes, and other organisational metrics.

Behavioural indicators of emotional intelligence within an organisation

Behavioural indicators play a critical role because they represent the mechanisms through which emotional intelligence (EI) translates into performance outcomes. Meta-analyses demonstrate that EI is associated with job performance metrics and behaviours that enhance organisational effectiveness [1; 18].

The study identified three groups of behavioural indicators:

1. Indicators of self-regulation and stress resilience include the frequency of emotional outbursts or conflict escalations, the number of disciplinary incidents and behavioural complaints, assessments of constructive behaviour during stressful situations in performance appraisals, and absences or lateness as indirect markers of burnout or low self-regulation. Empirical research confirms the relationship between emotional intelligence and employee resilience, as well as the impact of stress on behavioural outcomes [2].

2. Key indicators of social interaction and team effectiveness comprise the frequency and effectiveness of team meetings, the extent of cross-functional conflict, evaluations of communication quality by neighbouring departments, and the frequency with which managers are required to mediate conflicts. Empirical research demonstrates that a manager's emotional intelligence affects subordinate behaviour and performance outcomes through the quality of interactions, as evidenced by these teamwork indicators [3].

3. Indicators of professional interaction and task performance, which reflect the number of communication breakdowns during task execution, repeated coordination or delays arising from ineffective interaction; an assessment of the quality of internal service between departments; and the consistency of task execution under stressful or changing conditions. For specific functional areas involving external interaction, additional indicators may be applied, such as the number of complaints, repeat enquiries due to conflicts, service quality assessments, and customer or partner retention rates. It has been empirically confirmed that EI can predict employee performance in areas where interaction, communication and service quality are important [18].

2.4. Performance indicators and operational KPIs

Given that a company's performance is dictated by operational efficiency and the caliber of human capital utilization, it is prudent, in a practical framework for evaluating Emotional Intelligence (EI), to differentiate operational Key Performance Indicators (KPIs) as intermediate variables from organisational effectiveness indicators as ultimate outcomes. This methodology exemplifies the cascading influence of EI on overall performance. [5; 17].

Operational metrics are most sensitive to changes in employee behavior and the quality of team interactions, so they should be the first step in assessing the impact of EI. Unlike financial metrics, which reflect aggregate results with a time lag and depend on many external factors, operational KPIs respond more quickly to management interventions (training, coaching, changes in leadership style) and allow for regular monitoring of dynamics. It is through metrics such as productivity, errors, process speed, turnover, absenteeism, and conflict that EI is translated into costs and productivity, and therefore indirectly affects profitability. A list of key operational KPIs that are appropriate to use as intermediate variables in a practical model is provided in Table 1.

Table 1. (after the References)

From a scientific perspective, these variables follow logically from the results of meta-analyses on the relationship of EI with productivity, employee behavior, and organizational outcomes [1; 2]. It is advisable to form financial indicators in two dimensions: general profitability indicators and profitability per staff (per 1 worker), which is presented in Fig. 1.

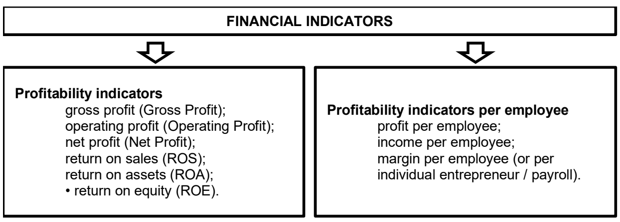

Figure 1. Financial indicators for assessing profitability

Source: formed by the authors based on [1; 2]

It is "people-centric" financial metrics that are most useful for this topic, as they allow us to link EI not to abstract "efficiency" but to the measurable contribution of personnel to profit.

Below is a generalized system of indicators that can be the basis for a corporate assessment panel (Table 2).

Table 2. (after the References)

The proposed system of indicators allows us to move from a general statement about the “usefulness of EI” to a managerially measurable mechanism, as depicted in Fig. 2.

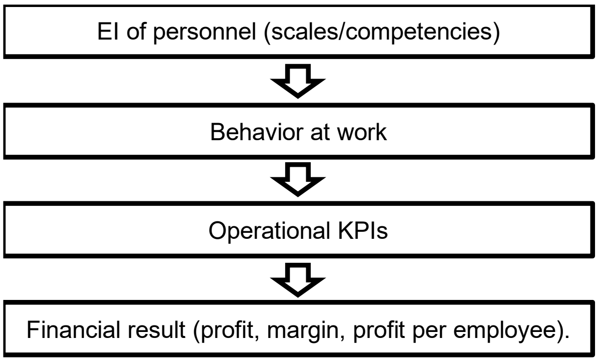

Figure 2. Cascade model of the influence of emotional intelligence of personnel on the financial result of the company

Source: formed by the authors based on [1; 2]

This approach is consistent with empirical findings on the relationship between EI and work performance, employee behavior, and organizational outcomes, as well as with the scientific logic of the cascading effects of EI [1; 5].

Construction of the EI composite index

To move from theoretical statements about the significance of emotional intelligence of personnel to verifiable empirical conclusions, it is advisable to apply a two-step evaluation logic:

1. Construction of an integral index of EI of personnel based on practical indicators and measurement scales (questionnaires, behavioral assessments, or combined approaches).

2. Quantitative verification of the impact of EI on profitability indicators through regression models with control of key factors that can simultaneously affect the financial results of the enterprise.

This construction is consistent with the scientific position that EI is statistically related to labor productivity and behavioral manifestations in the workplace, and therefore can act as a factor of productivity and financial results through a set of intermediate mechanisms [1;5].

In practical EI research, the use of standardized scales is widespread, in particular:

1. WLEIS (Wong and Law Emotional Intelligence Scale), which includes 4 blocks:

a) assessment of one's own emotions;

b) assessment of the emotions of others;

c) use of emotions to support activities;

d) regulation of emotions [7].

2. Trait EI (mostly a survey concept of "rice" EI) as an approach to measuring self-perceived emotional abilities within established personality taxonomies [13].

Within the framework of this article, it is advisable to apply a structured EI model with sub-indicators, since it is more suitable for constructing an index and subsequent statistical testing. For example, for each employee, the average values are determined for four EI dimensions (for example, in the WLEIS logic):

$EI_{i1} = \bar{x}_{i,\text{SEA}}, EI_{i2} = \bar{x}_{i,\text{OEA}}, EI_{i3} = \bar{x}_{i,\text{UOE}}, EI_{i4} = \bar{x}_{i,\text{ROE}}$

where $\bar{x}$— the mean value of the relevant set of statements (Likert 1–5 or 1–7).

Cronbach’s α is used to assess the internal consistency of scales [19]:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k} \sigma_j^2}{\sigma_T^2}\right) \quad (1)$$

where k— number of items in the block, σ_j^2— point variance, σ_T^2— variance of the total block score.

The parameters are normalised prior to aggregation. The primary method is min-max normalisation to an interval [0;1]:

$$z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (2)$$

where x_{ij}— значення j-го підіндикатора для працівника i; $\min(x_j)$, $\max(x_j)$— minimum/maximum of the sample.

An alternative approach involves standardisation through z-score:

$$z_{ij} = \frac{x_{ij} - \mu_j}{\sigma_j} \quad (3)$$

where μ_j— average, σ_j— standard deviation.

The rationale behind this dual approach lies in the fact that the choice of normalisation method can significantly influence the ranking and interpretation of the results [20; 21; 22].

For weighting factors w_j— the weight of its sub-indicator is determined by the limits:

$$w_j \geq 0, \sum_{j=1}^{m} w_j = 1 \quad (4)$$

The basic specification is based on weighting:

$$w_j = \frac{1}{m} \quad (5)$$

However, a data-driven approach is also permissible, in which weights are determined on the basis of factor loadings or an analysis of the importance of variables [21; 23].

The EI index for employee i is calculated as:

$$EI_{Index_i} = \sum_{j=1}^{m} w_j \cdot z_{ij} \quad (6)$$

6)At the level of a department or company, an aggregate index is used:

$$EI_{Firm} = \frac{\sum_{i=1}^{n} a_i \cdot EI_{Index_i}}{\sum_{i=1}^{n} a_i} \quad (7)$$

where a_i— an employee's weighting factor (e.g. 1 for equal weighting; or FTE; or weighting based on job role — managers/key functions).

Impact matrix and econometric model

To prevent the oversimplification of the situation, wherein EI is presumed to be the direct determinant of an organisation's ultimate performance, an impact matrix is introduced to elucidate the operational and behavioural pathways through which individual components of EI are translated into organisational outcomes. If the componenTo prevent the oversimplification of the situation, wherein EI is presumed to be the direct determinant of an organisation's ultimate performance, an impact matrix is introduced to elucidate the operational and behavioural pathways through which individual components of EI are translated into organisational outcomes. If the components of EI constitute a setts of EI constitute a set $D = \{d_1, \ldots, d_m\}$, and intermediate KPIs — a set $K = \{k_1, \ldots, k_p\}$, then the influence matrix takes the form:

$$M = [\mu_{dj}], d \in D, k \in K \quad (8)$$

where μ_{dk}— the degree of influence of the EI component on a specific KPI, as estimated empirically or determined by experts.

Within the framework of the proposed concept, the emotional intelligence of personnel is considered not as an abstract "soft" competence, but as a factor capable of launching quite specific cause-and-effect chains in the organization. Its influence is manifested through behavioral mechanisms that reduce losses (conflicts, burnout, error, staff turnover) and enhance sources of value creation (quality of interaction, service, customer loyalty, productivity). In order to make these mechanisms transparent for managerial analysis, it is advisable to present them in the form of generalized "chains of influence" - from individual components of EI to operational consequences and, ultimately, financial results (Fig 3).

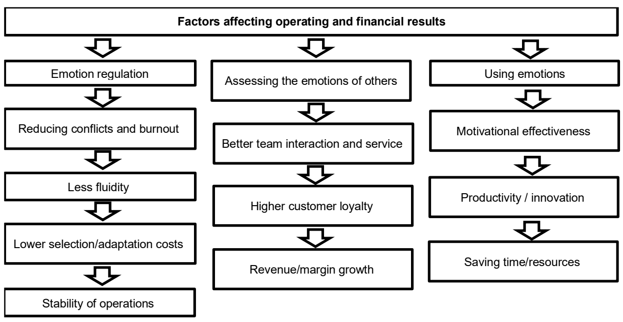

Figure 3. Cascade model of the influence of emotional intelligence of personnel on the financial result of the company

Source: formed by the authors based on [1; 2]

Figure 3 visually depicts empirically similar relationships, supported by generalizable evidence of the impact of EI on employee performance [1; 5].

For quantitative testing of the hypothesis, a basic regression design is proposed - a model (cross-sectional or panel). Let Profit_(f,t) be the profitability index of firm f in period t:

$$Efficiency_{f,t} = \beta_0 + \beta_1 EI_{Firm_{f,t}} + \sum_{r=1}^{R} \gamma_r Control_{r,f,t} + \delta_{industry} + \tau_t + \varepsilon_{f,t} \quad (9)$$

where $EI\_Firm_{f,t}$— the overall EI index for staff (or selected groups of staff); $Control_{r,f,t}$— control variables that may influence performance outcomes (company size, labour productivity, capital intensity, proportion of administrative costs, workload intensity, specific characteristics of departments, etc.); $\delta_{industry}$— industry-specific fixed effects; τ_t— fixed-effects models (for the panel); ε— random error.

Within the scope of this study, the dependent variable should reflect not only the financial outcome but, above all, the effectiveness of human capital utilisation.

Reliability, measurement limitations and verification of the stability of results

As EI is often assessed using questionnaires, there is a risk of bias due to potential methodological errors. It is therefore advisable to combine self-reported EI assessments with behavioural indicators, employee performance data, HR analytics and operational efficiency metrics [24; 25].

To verify the robustness of the results obtained, alternative specifications of the EI index are proposed, in particular:

- adjustment of weighting factors;
- change in the normalisation method;
- sensitivity analysis with respect to the thresholds of minimum and maximum values;
- the use of alternative performance metrics;
- enabling or disabling individual EI sub-indicators.

Consequently, the development of the Emotional Intelligence (EI) composite index and its subsequent integration into the regression model establish an analytical framework for the quantitative examination of the contribution of emotional intelligence to enhancing workforce efficiency within an organization. The proposed methodology facilitates the combination of psychological, behavioural, and operational dimensions within a unified assessment system, thereby rendering the research findings applicable for practical implementation within the human resources management system of an energy company.

3. Results

This section presents the results of a quantitative analysis carried out using a simulated dataset compiled from materials provided by the Joint Stock Company ‘Energy Company of Ukraine’. The analysis aims to demonstrate how the proposed methodology can be applied to assess the relationship between staff emotional intelligence and workforce performance indicators. The simulated workforce structure comprises 167 employees: 140 production staff, 20 middle management, and 7 senior management. To assess emotional intelligence, an approach similar to the WLEIS framework was applied, which analyses it through four components: self-awareness, understanding others’ emotions, using emotions to achieve goals, and emotional self-regulation. The scores obtained were compared with a set of operational indicators characterising workforce effectiveness, including performance, disciplinary stability, error rates and other parameters of organisational effectiveness.

The initial phase of the analysis entailed evaluating the validity of the emotional intelligence measurement. The internal consistency of all EI subscales was demonstrated to be robust: Cronbach’s alpha coefficients ranged from 0.811 to 0.869 (Table 3). This signifies adequate reliability of the measurement instrument employed and permits the utilisation of individual EI components and their aggregate score in subsequent statistical analyses.

Table 3. Reliability indices for the EI subscales (Cronbach’s alpha) *

Subscale	Cronbach’s alpha
SEA	0.854
OEA	0.863
UOE	0.869
ROE	0.811

Source: formed by the authors based on [1; 2]

In practical terms, this means that emotional intelligence, within the framework of the proposed model, can be used as a sufficiently stable psychometric construct for analytical comparisons between groups of employees and for constructing a comprehensive EI index.

The next step involved comparing the average EI scores across groups of employees at different job levels. The results show a clear upward trend in emotional intelligence as the managerial level increases (Table 4).

Table 4. (after the References)

The lowest mean EI index values were recorded among production staff (EI_mean ≈ 4.15 on a scale of 1–7), higher values among middle managers (≈ 4.86), and the highest among senior managers (≈ 5.63). Analysis of variance confirmed the statistical significance of these differences ($p < 0.001$). The results indicate that an increase in managerial responsibility is accompanied by a rise in emotional intelligence, which corresponds to the functional requirements of roles involving coordination, influencing people, and decision-making in complex conditions. At the same time, even at this stage, a link can be observed between higher EI and better performance indicators, as well as the overall indicator of work efficiency (Fig. 4).

Figure 4. Average EI score by job level *

* Source: compiled by the authors

The fact that EI levels differ between groups does not directly answer whether these differences are substantively linked to work performance. Therefore, the next step was to perform a correlation analysis between the combined EI indicator and key operational metrics. The correlation results revealed that the combined EI_mean has a strong positive correlation with the generalised performance indicator per employee ($r \approx 0.83$; $p < 0.001$) and with the performance index ($r \approx 0.83$; $p < 0.001$). This suggests that employees with higher emotional intelligence not only exhibit better behavioural traits but also demonstrate greater individual effectiveness within the organisation.

Concurrently, significant negative correlations were identified between Emotional Intelligence (EI) and variables that may be construed as sources of efficiency losses. As the EI score increases, there is a corresponding decrease in absenteeism ($r \approx = -0.48$; $p < 0.001$), along with a reduction in error rates ($r \approx = -0.64$; $p < 0.001$). The observed relationships align with the cascade effect theory: a higher level of emotional intelligence correlates with enhanced behavioural stability, discipline, and attentiveness to processes, as well as reduced emotional instability, ultimately contributing to increased productivity and diminished operational losses (Fig 5).

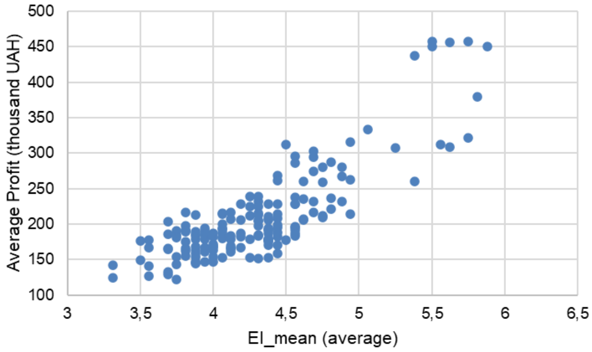

Figure 5. Relationship between EI and the overall performance indicator for employees of JSC ‘Energy Company of Ukraine *

* Source: compiled by the authors

A regression analysis was performed to ascertain whether the impact of EI remained statistically significant after accounting for additional variables. The dependent variable was the comprehensive employee performance indicator, while the primary independent variable was the EI_mean composite score. The model further incorporated the following control variables: length of service and job level. The findings are illustrated in Table 5.

Table 5. (after the References)

The results show that emotional intelligence (EI) is a statistically significant positive predictor of employee performance ($p < 0.001$), even after controlling for length of service and employment status. The model’s overall explanatory power is high ($R^2 \approx 0.90$). This confirms that emotional intelligence cannot be reduced solely to the influence of experience or job status: it maintains its own contribution to explaining differences in work performance. Therefore, EI can be considered an additional resource that enhances an employee's ability to achieve better results within their professional activities.

Further insight is provided by analysing not only the direct impact of EI on performance, but also the presence of a mediating mechanism via operational KPIs. To this end, indicators of performance, absenteeism and errors were included in the regression model. After adding these variables, the EI coefficient decreases but remains statistically significant. This result indicates a dual nature of the effect: on the one hand, part of the EI effect flows through operational channels: employees with higher EI demonstrate greater stability, discipline and quality of task performance, which directly increases labour productivity. On the other hand, the fact that EI remains significant after controlling for these KPIs suggests the presence of additional channels of influence not fully captured by standard operational indicators. Such channels include team effects, influence on the psychological climate, the ability to resolve conflicts constructively, the quality of interaction between departments, and an indirect influence on the speed of decision-making and the coordination of managerial actions.

The results obtained permit several general conclusions to be drawn. First, emotional intelligence is a quantifiable, statistically validated concept that can be utilised in personnel analysis. Second, EI varies across job levels, offering a foundation for customized management decisions concerning the development of competencies among various employee groups. Third, EI exhibits a systematic association with workforce performance through operational and behavioural indicators, such as reductions in errors and losses, and increases in productivity and job stability. Fourth, regression models indicate that EI contributes independently to enhanced performance, a relationship that remains significant even after accounting for baseline variables such as length of service and job level. Collectively, these findings support the notion of EI as a controllable intangible resource of the organisation, whose integration into HR practices can aid in optimising human capital utilisation and enhancing overall organisational performance.

4. Discussion

The findings indicate that staff emotional intelligence is a practical factor associated with workforce efficiency and organisational performance in an energy company. This conclusion aligns with previous studies that identify emotional intelligence (EI) as a predictor of job performance, behavioural stability, interaction quality, and organisational citizenship behaviour. Unlike earlier research that primarily examined the general relationship between EI and individual or behavioural outcomes, the present results enable interpretation of this link through specific operational and organisational indicators. This distinction is particularly relevant given the study's working hypothesis, which posits that emotional intelligence influences performance indirectly through intermediate mechanisms such as the quality of interaction, disciplinary stability, error reduction, and improved execution of work functions.

A primary finding is that emotional intelligence levels exhibit hierarchical differentiation across job groups. The observed increase in average EI scores from production staff to senior managers is consistent with previous research highlighting the critical role of EI in contexts where performance depends on coordination, leadership, influence, and decision-making under complex conditions. This supports the view that greater responsibility and more complex managerial functions require enhanced social-emotional competencies. Additionally, this finding expands practical understanding by indicating that exclusive focus on EI development for managers may overlook the largest staff groups, where risks of conflict, communication breakdowns, behavioural instability, and loss of coordination are most prevalent.

A second key finding addresses the relationship between emotional intelligence and operational indicators. Positive correlations between the integrated EI score, the work performance index, and the generalised employee effectiveness score corroborate previous meta-analytical studies demonstrating a stable association between EI and work performance. Negative correlations with absenteeism and error rates are particularly noteworthy, as they suggest that emotional intelligence contributes not only to positive outcomes but also to loss reduction. In a broader context, these results imply that EI may enhance organisational resilience by stabilising daily operations, reducing friction, and optimising the utilisation of human capital. Regression analysis further reveals that emotional intelligence remains statistically significant after controlling for variables such as length of service and job level, indicating its independent contribution to employee performance. This finding is important in light of debates over whether EI's effect is attributable to experience, professional maturity, or job status. The results support the interpretation that EI is an independent resource distinct from other employee characteristics. Additionally, the reduction in the EI coefficient after including intermediate operational indicators supports the hypothesis of a cascade mechanism, whereby part of EI's influence operates through behavioural and process variables, while another part may relate to less formal aspects of organisational interaction, such as psychological climate, informal coordination, conflict management, or adaptation to change.

A broader interpretation of the results positions emotional intelligence as a critical component of human capital, essential for both individual employees and overall organisational functioning. This is especially pertinent in the energy sector, where efficiency depends on process continuity, coordinated actions, precise communication, adherence to procedures, and the capacity to operate under high responsibility. In this context, EI emerges as a resource that enhances individual productivity, organisational resilience, adaptability, and interdepartmental interaction. Consequently, the practical significance of these findings extends beyond human resources analysis to inform a wider array of management decisions, including staff development, risk assessment in workplace interactions, and organisational process improvement. However, these results should be considered alongside the study's limitations. The dataset employed is simulated, so the observed relationships illustrate methodological logic and expected dependencies but require validation with real corporate data. Additionally, reliance on survey methods to measure EI introduces risks of self-report bias, social desirability bias, and common-method bias. Future research should therefore integrate scale assessments with behavioural indicators, 360-degree feedback, and operational system data.

Furthermore, even when models demonstrate high explanatory power, company performance is influenced by numerous external and internal factors. As a result, causal conclusions require confirmation through more complex empirical studies, such as panel observations, time-series comparisons, and extended performance analyses.

Future research should proceed along several directions. First, empirical testing of the proposed model with real-world data from energy companies is necessary, incorporating a broader range of control variables and multiple time periods. Analysing which specific components of emotional intelligence are most strongly linked to outcomes such as productivity, interaction quality, error rates, or staff stability would be valuable. Additionally, evaluating the effectiveness of emotional intelligence development programmes using a before-and-after design would facilitate assessment of the practical impact of managerial interventions. It is also recommended to investigate the broader role of EI in human capital development, organisational resilience, and enterprise adaptation within complex, technology-intensive, and high-stress environments.

In summary, the research findings confirm that staff emotional intelligence is a key factor in enhancing workforce effectiveness by improving work performance, reducing losses, stabilising employee behaviour, and enhancing the quality of organisational interaction. These conclusions are consistent with previous scientific research and extend existing knowledge by providing the first practical attempt to link emotional intelligence with specific, measurable operational indicators. The primary interpretative value of these results lies in their implications for future research and management practice.

5. Conclusions

The approach proposed in this article for assessing personnel emotional intelligence as a tool for profit growth was tested using a simulated example of the company "KhAS." The results demonstrated that emotional intelligence can be formalized through a system of practical indicators, aggregated into an integral metric, and quantitatively linked to the company's key operational and financial metrics. This creates a methodological basis for moving from general statements about the importance of EI to the management level, where it can be assessed as a factor in performance and profitability.

Calculations confirmed the high quality of the EI measurement instrument: the internal consistency of the subscales is stable (Cronbach's alpha 0.81–0.87), allowing the survey results to be used for analytical comparisons and index construction. Within the simulated organizational structure, a clear hierarchical differentiation of emotional intelligence was identified. The average EI level for production personnel was 4.15 (on a scale of 1-7), 4.86 for mid-level administrative staff, and 5.63 for senior managers. Accordingly, the company potentially faces an "uneven" distribution of emotional competencies across employee groups, which is an important signal for HR policy: developing EI makes sense not only as an element of management training but also as a tool for stabilizing and improving the quality of processes in numerically dominant production teams.

Correlationship analysis revealed the systemic nature of EI's influence on key performance indicators. The integral EI_mean has a strong positive correlation with labor productivity ($r \approx 0.83$; $p < 0.001$) and with the financial indicator of the employee's conditional "income contribution" ($r \approx 0.83$; $p < 0.001$). In parallel, a negative relationship was recorded between EI and variables that generate direct or hidden costs in a real company: absenteeism decreases with increasing EI ($r \approx -0.48$; $p < 0.001$), and the error/defect rate also shows a decline ($r \approx -0.64$; $p <$). In practical terms, this means that emotional intelligence can be considered a factor influencing profits through two groups of mechanisms: increased productivity and a simultaneous reduction in losses associated with poor performance, behavioral instability, or organizational friction in processes.

Regression testing confirmed that emotional intelligence retains its contribution to explaining profitability even after accounting for controls. In a model where the income contribution was explained by EI, tenure, and job title, the EI coefficient remained statistically significant ($p < 0.001$), and the overall explanatory power of the model is high ($R^2 \approx 0.90$). This allows us to conclude that EI does not This is limited to the effect of experience or job status and can be viewed as an independent resource that enhances employee performance within their roles. Adding operational characteristics to the model reduces the magnitude of the EI effect, confirming the cascading logic of action: part of the economic effect of emotional intelligence is realized through intermediate KPIs—efficiency, discipline, and task performance quality. At the same time, the continued significance of EI in the expanded specifications points to possible additional channels of influence, in particular through teamwork, conflict management, and communication quality, which are not always fully captured by standard operational performance indicators.

Thus, the results demonstrate that personnel emotional intelligence can be included in a profitability management system as a measurable factor influencing productivity, quality, and process stability. The practical value of the proposed approach lies in the ability to create an "impact matrix" of EI on financial performance, where each EI component is correlated with specific operational KPIs and financial metrics. This opens the possibility for companies not only to assess the current level of EI in personnel but also to design and measure the impact of training programs, adaptation programs, and other measures. Activities, management interventions, and HR decisions over time.

A promising direction for further work is the application of real-world corporate data with an expanded set of control variables, the use of panel measurements over time, and the combination of EI survey assessments with 360-degree assessments and actual CRM/ERP/HRM data. This will allow us to refine the magnitude of effects, identify the most profitable EI components for different job groups, and strengthen the evidence base for implementing EI as an element of a company's economically oriented HR strategy.

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Table 1. Operational KPIs sensitive to the level of emotional intelligence (EI) *

KPIs (example)	What does it measure?	How is it related to EI?	Why is it important for the bottom line?
Labor productivity (output / volume of tasks per employee)	Productivity per employee	EI affects self-organization, motivation, team interaction	Productivity gains reduce costs and increase output/revenue
Quality and errors (defect rate, rework, complaints)	Number and frequency of errors/defects	EI reduces conflict, increases attentiveness and responsibility	Less defects → less waste, fewer returns/compensations
Process/case processing time (AHT in the service, order fulfillment speed)	Speed of operations or service	EI improves communication, reduces escalations, accelerates agreement	Faster execution → less time spent, higher throughput
Turnover rate and employee replacement cost	Frequency of layoffs and replacement costs	EI affects the climate in the team, loyalty, quality of leadership	Less turnover → less hiring/adaptation costs, more consistent productivity
Absenteeism (absence from work, sick leave)	Frequency of employee absence	EI is associated with stress resistance and prevention of burnout	Less absences → less downtime and replacement costs
Internal conflict ratio (number of cases / resolution time)	Frequency of conflicts and speed of their resolution	EI directly affects the constructiveness of interaction and de-escalation	Less conflicts → less time wasted, lower indirect costs, higher team efficiency

* Source: compiled by the authors based on [5].

Table 2. Generalized system of indicators for a corporate assessment panel *

Evaluation Level	Indicator group	Examples of practical indicators	Data source
EI (Direct Measurement)	EI scales	WLEIS (4 components), SSEIT (integral score)	Employee survey
EI (Behavioral Evaluation)	360° / competences	self-regulation, empathy, conflict management, constructiveness under pressure	360°, performance review
Customer Level	Service/sales quality	CSAT/NPS, complaints, repeat purchases, conversión	CRM, customer survey
Financial Level	Profitability	operating margin, net profit, profit/employee, revenue/employee	financial reporting, management accounting

* Source: Created by the authors

Table 4. Summary of average EI scores and results (by job grade)

Level	Number of employees	Average EI	Average performance	Average productivity per employee (thousand UAH)
Production staff	140	4.15	61.45	186.81
EI (Behavioral Evaluation)	20	4.86	76.70	295.00
Customer Level	7	5.63	94.91	447.31

* Source: compiled by the authors

Table 5. Results of the regression model *

Variable	Coefficient (β)	Std. error	t-statistics	p-value
Constanta	-13.672	19.091	-0.72	0.4749
EI_mean	46.321	4.621	10.02	0.0000
Years of experience	1.097	0.387	2.83	0.0052
Job level (0–2)	84.767	4.740	17.88	0.0000

* Source: compiled by the authors

Chapter 25: Future Competencies of Generation Z Female Leaders in the Era of Digital Transformation

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Abstract. Digital transformation and dynamic changes in the labour market are influencing the competencies required of contemporary leaders. The aim of this paper is to identify the key future competencies of Generation Z women preparing for leadership roles. The study is based on original research, including a survey conducted among 50 young women and 7 in-depth interviews. The findings indicate that communication, emotional intelligence, resilience, creativity, adaptability, and digital competencies are considered the most important future skills. The participants perceive leadership as a process based on authenticity, collaboration, and social responsibility.

Keywords. digital transformation, female leadership, future competencies, Generation Z, leadership development.

1. Introduction

Ongoing digital transformation and the rapid development of new technologies are changing the way contemporary societies, organisations, and labour markets operate. Increasing importance is being placed on competencies that enable individuals to function effectively in a VUCA environment, characterised by volatility, uncertainty, complexity and ambiguity [1]. Under such conditions, future leaders are expected not only to possess technological competencies but also communication skills, adaptability, creativity, and emotional intelligence.

An important group operating within the digital reality is Generation Z, whose members have grown up surrounded by modern technologies from an early age. Women belonging to this generation are increasingly engaging in social, educational, and leadership activities, shaping new leadership models based on collaboration, authenticity, and social responsibility.

The aim of this paper is to identify the future competencies considered essential by Generation Z female leaders in the context of digital transformation. The paper is based on a review of the relevant literature and the results of original research conducted among young women belonging to Generation Z.

2. The New Leadership Paradigm

Generation Z is entering the workforce with values and expectations that greatly differentiate them from previous generations. Young women of this generation are taking on leadership roles and leading from a different place, reshaping leadership in a way that is historically unprecedented and challenging traditional leadership norms. Studies show that the most important value for the Generation Z workforce is self-fulfillment, followed by positive labor relations, ethics, respect for employees, personal growth and trust. In their dreams and aspirations, rather, happiness, family, personal passions, environmental responsibility and freedom were the guiding themes [2]. Women of Generation Z expect more from work than financial security. They want meaningful work, they want to have an impact on the world in a positive way, and they want to work in organizations where the culture aligns with their personal values. Work is now more often seen as a place for personal growth and development, rather than just a material source. To have a good work life balance, to be able to keep learning and so forth, are also seen as important parts of one's working and professional life. As Generation Z makes its way into the workforce, new leadership styles are emerging that focus on teamwork, adaptability, and mutual values. Modern leadership theories such as servant and transformational leadership are conducive to the development of young female leaders [3]. In an era of evolving employee expectations, young women assert themselves as leaders through the power of authenticity, empathy, transparent communication, and social responsibility. Consequently, there is a new leadership model emerging - one that is more transparent, sustainable and purpose-driven, and focused on collaboration and positive social impact.

3. Key Future Competencies in the Era of Digital Transformation

Despite the growing professional activity of women and their high career aspirations, numerous barriers still hinder their advancement to leadership positions. Women are more likely than men to encounter gender stereotypes, the “glass ceiling” phenomenon, and challenges related to balancing professional and family responsibilities [4]. Data presented by the United Nations Global Compact Network Poland [5] indicate that women remain underrepresented in top management structures despite possessing qualifications and competencies comparable to those of men. The report also highlights persistent gender pay inequalities and barriers limiting women’s access to decision-making positions.

At the same time, contemporary organisations increasingly recognise the value of diversity in management processes and the role of women in building innovative and effective teams. In the context of rapid social and technological change, there is a growing demand for competencies that enable individuals to function effectively in complex and unpredictable work environments. These competencies include communication skills, emotional intelligence, resilience, creativity, adaptability, and digital literacy.

Female leadership styles are more frequently based on supportive behaviours, trust-building, and the development of team members’ potential, making them particularly effective in environments that require collaboration and adaptability [6]. Contemporary female leaders increasingly combine strong interpersonal competencies with the ability to adapt to social and technological change, responding effectively to the challenges of digital transformation.

The rapid development of digitalisation, automation, and artificial intelligence is transforming expectations towards organisational leaders operating in the BANI reality. Contemporary leadership requires not only traditional managerial skills but also adaptability, analytical thinking, and the ability to integrate technological and social competencies. In this context, increasing attention is being paid to so-called future competencies, understood as the knowledge, skills, and attitudes that enable individuals to function effectively in a rapidly changing work environment.

The importance of future competencies is highlighted by numerous reports and analyses concerning the contemporary labour market. In the face of rapid technological change and the growing role of artificial intelligence, organisations increasingly seek employees and leaders who can operate effectively under conditions of uncertainty, acquire new knowledge quickly, and adapt to changing circumstances.

According to the Future of Jobs Report key future competencies include analytical thinking, resilience, flexibility, leadership and social influence, technological literacy, knowledge of artificial intelligence and data analytics, as well as creative thinking [7]. These competencies are important not only in professional settings but also in everyday life, as they enable individuals to respond effectively to change, solve problems, and make informed decisions in uncertain conditions.

Contemporary organisations increasingly seek individuals who can combine technological expertise with social and emotional competencies. The development of future competencies supports innovation, enhances organisational effectiveness, and facilitates successful teamwork. These competencies are particularly important for individuals preparing to assume leadership roles, as they enable not only effective change management but also the ability to inspire others, build engagement, and create an environment that fosters collaboration and development.

4. Research Methodology

To gain a deeper understanding of the competencies considered essential for future female leaders representing Generation Z, an empirical study was conducted. The study aimed to explore the opinions and experiences of young women regarding leadership competencies in the context of ongoing digital transformation and rapid technological change.

A mixed-method approach combining quantitative and qualitative research methods was applied. Data were collected through an online survey conducted among 50 women aged 18–25 belonging to Generation Z. Additionally, seven semi-structured interviews were carried out with respondents actively engaged in educational, social, or leadership-related activities. The study was conducted in June

2025. Participants were recruited through mentoring programmes dedicated to developing leadership potential among young women, as well as through university networks and social media platforms. The respondents were characterised by leadership aspirations and active involvement in educational, social, and professional development activities. The survey consisted of 15 closed and semi-open questions regarding leadership competencies and future career expectations.

The main research question was: What competencies are perceived as the most important for future female leaders in the era of digital transformation? Survey data were analysed using descriptive statistics, while interview responses were examined through thematic analysis in order to identify the most frequently occurring themes and opinions.

5. Results

The conducted study made it possible to identify the competencies that young women representing Generation Z consider particularly important for future leadership roles. The findings indicate that communication, team management, strategic thinking, emotional intelligence, creativity, and resilience are perceived as the most important competencies. Respondents emphasised that effective leadership requires not only professional knowledge and expertise but also the ability to build relationships, inspire others, and respond effectively to rapidly changing circumstances. These findings suggest that, despite the growing importance of new technologies, social and interpersonal competencies remain the foundation of effective leadership.

Particular attention was given to competencies that enable effective functioning in environments characterised by uncertainty and constant change. Respondents highlighted adaptability, openness to learning, and willingness to collaborate with people representing diverse experiences and perspectives. According to the participants, future female leaders should be able to combine technological knowledge with well-developed social and emotional competencies, allowing them to respond more effectively to the challenges associated with digital transformation.

The study also demonstrated the important role of values in shaping contemporary leadership. Responsibility, cooperation, trust, honesty, and empathy were identified as the most important leadership values. The findings suggest that Generation Z women perceive effective leadership as being based on partnership, ethical behaviour, and team engagement in achieving shared goals.

The results indicate that although digital competencies are becoming increasingly important in today's world of work, they do not replace human-centred competencies. Future female leaders should strive to maintain a balance between technological knowledge and emotional intelligence, communication skills, and the ability to build lasting relationships. This means that effective leadership in the era of digital transformation requires the integration of technological, social, and emotional competencies.

6. Conclusions

The conducted study provided a deeper understanding of how Generation Z women perceive leadership and identified the competencies and values they consider particularly important in the context of future professional challenges. The findings indicate that contemporary leadership is no longer associated solely with expert knowledge or decision-making abilities. Increasing importance is attached to the ability to build relationships, communicate effectively, and function successfully in an environment characterised by rapid social and technological change.

The study also revealed that Generation Z women place great importance on values that form the foundation of responsible and ethical leadership. Cooperation, responsibility, trust, honesty, and empathy were identified as particularly significant. The findings suggest that future female leaders perceive their role primarily as supporting team members, fostering engagement, and creating an environment conducive to development and collaboration.

The results further demonstrate that, in the view of Generation Z women, effective leadership is closely linked to the ability to navigate an increasingly complex and uncertain environment. Future leaders are expected not only to understand ongoing technological developments but also to collaborate effectively with others, build trust, and motivate people towards shared goals. It is this combination of capabilities that forms the foundation of successful leadership in the era of digital transformation.

The findings may provide valuable insights for organisations, educational institutions, and leadership development programmes that support young women preparing for leadership roles. They highlight the importance of creating environments that foster the development of both professional and interpersonal competencies, which will play a crucial role in shaping the next generation of female leaders

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Chapter 26: Healthcare Expenditure Associated with Diabetes Mellitus in a Tertiary Care Hospital Population

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Abstract.
Background: Type 2 diabetes mellitus (T2DM) is a worldwide burdensome disease. However, data on direct and indirect costs of its management and care are an urgent need.

Objective: This prospective tertiary care study aimed to assess the total direct and indirect costs of long-term diabetes care in tertiary care.

Methods: A total of 320 participants with T2DM fulfilling the American Diabetes Association screening and diagnostic guidelines were recruited for cost assessment. Group I (n=160) received education and empowerment in addition to standard treatment, while Group II (n=160) received only standard treatment. Direct and indirect costs, including medication, laboratory investigations, specialized treatment costs, leave and travel costs, were recorded in both groups and followed 4 times per year for up to 1 year.

Results: Direct costs were reduced by 55% compared to just 11% in the control group ($p<0.001$), with medication costs decreasing by 89.9% versus 31.5% in controls ($p<0.001$). Importantly, these substantial cost reductions were achieved while maintaining equivalent glycemic control, with nearly identical HbA1c levels between groups (7.69% vs 7.68%; $p=0.886$). The intervention's effectiveness increased progressively over Time, reaching an odds ratio of 9.75 for cost reduction at 24 months ($p<0.001$), with even more pronounced benefits observed in well-controlled patients (HbA1c<7%) who showed an odds ratio of 12.5 for cost reduction.

Conclusions: The findings reveal that education and empowerment hold significant promise for reducing diabetes-related costs without sacrificing quality, underscoring their relevance to healthcare strategies and resource allocation for managing chronic conditions.

1. Introduction

Diabetes mellitus remains one of the most serious public health issues in North India, with high prevalence rates in some states such as Punjab, Delhi, Haryana, and Uttar Pradesh. The prevalence of diabetes in Punjab stands at 16.3%, whereas Delhi registers 14.2%, far higher than the national average of 11.4%, according to ICMR-INDIAB. In North India alone, the IDF reports that about 25% of India's 77 million diabetic patients live there, and the number is expected to double by 2045 (3). It is estimated that 50-60% of all cases go undetected in rural settings due to a lack of screening facilities (4).

Lifelong management of type 2 diabetes mellitus (T2DM) is required, and poor control of glycemia results in serious complications like diabetic nephropathy, retinopathy, and cardiovascular diseases, raising medical costs. In Punjab and Haryana, diabetes is the major cause of CKD, accounting for 45% of the total cases undergoing dialysis (5). The cost of hemodialysis per session was found to be ₹4,148, decreasing to ₹3,025 at 100 percent capacity (6). For each hemodialysis session, patients had to pay ₹2,838 as part of their personal expenses. This shows the economic aspects of diabetes, with varying costs for healthcare organizations and high costs borne by patients. Economic burden of diabetes on the North Indian population is huge, with a yearly medical cost exceeding ₹50,000-1,00,000 (7). Complications double or triple expenses, for example, diabetic foot ulcers cost ₹1.5–3 lakhs per hospitalization

(8). Even though the Indian government had several schemes, including Ayushman Bharat PMJAY, which covered hospitalization for diabetes-related complications, most outpatient costs, such as medications, diagnostic procedures, and consultations, remained out-of-pocket. Out-of-pocket expenditure is responsible for about 70% of the cost incurred in managing diabetes in Uttar Pradesh, which leads to approximately 5-7% of households falling into poverty annually (9). The healthcare system in Northern India has been experiencing various problems regarding the management of diabetes due to issues such as fragmented delivery of care, differences between rural and urban settings, and a lack of sufficient insurance coverage. In India, diabetes patients go through uncoordinated referrals from governmental hospitals to multispecialty chain hospitals, and finally to private clinics, where patients undergo repetitive diagnostic procedures. Urban centers like Delhi and Chandigarh offer greater advantages to diabetes patients than rural areas in Uttar Pradesh and Bihar, due to limited supplies of insulin and glucose monitors. Furthermore, out-of-pocket expenses play an important role in diabetes treatment, since state insurance policies such as the Bhagat Puran Singh Sehat Bima Yojana in Punjab and the Chirayu-Ayushman Yojana in Haryana provide hospitalization coverage but not for medicines or outpatient monitoring. For example, despite the availability of free dialysis services in Haryana, ignorance among the potential patients is such that 70% of the eligible population remains uninsured. The lack of an effective telecommunication system linking hospitals, physicians, laboratories, and other entities further complicates the process, and patients end up visiting multiple facilities for treatment. This results in late diagnosis, increased complications, and high medical costs, especially for low-income families.

2. Research design and methods

2.1. Study Design

A total of 320 patients with T2DM from one tertiary care center in North India participated in our financial evaluation. Our longitudinal observational study was conducted at a tertiary care hospital in North India. Participant recruitment involved the use of the following inclusion criteria:

(i) age 25-65 years regardless of gender; (ii) recently (<6 months) diagnosed with type 2 diabetes mellitus (T2DM) using glycaemia criteria that included either FPG ≥126 mg/dL (7.0 mmol/L), 2-hr PG ≥200 mg/dL (11.1 mmol/L) after 75-g OGTT, HbA1c ≥6.5% (48 mmol/mol) on an NGSP-certified method, or random PG ≥200 mg/dL (11.1 mmol/L) associated with typical hyperglycemic symptoms; (iii) no requirement for insulin therapy (latent autoimmune diabetes and severe T2DM excluded); and (iv) ability to give informed consent and follow the study protocol.

Criteria for exclusion included:

(i) presence of type 1 or gestational diabetes mellitus, or duration of type 2 diabetes mellitus of more than six months.

(ii) use of insulin therapy.

(iii) renal impairment (estimated glomerular filtration rate <30 mL/min/1.73 m2).

(iv) active cancer condition/treatment.

(v) comorbidity with psychiatric conditions.

(vi) pregnancy or lactation.

(vii) substance abuse.

(viii) development of microvascular complications; and

(ix) non-compliance with study visits.

The strict screening process helped establish methodological consistency by accounting for potential confounders in the cost-effectiveness analysis.

2.2. Education and empowerment implementation strategy

As part of the intervention protocol for the enrolled participants, a detailed educational curriculum was designed that consisted of weekly 2-hour classes. The content covered many aspects of diabetes management, including awareness about the disease, individual counseling, the basics of diabetes pathology, psychosocial complications of the disease, complications of diabetes, blood sugar monitoring techniques, behavioral motivation techniques, meal preparation methods, physical activity guidelines, and quality of life improvement, as outlined in a previous study (10). In designing the pedagogy, the importance of social support mechanisms was highlighted and achieved through certified diabetes educators using multiple teaching techniques. Linguistic adaptations were made to the curriculum, including printed materials, animated videos, audio-visual presentations, interactive sessions, individual coaching, short educational videos, knowledge assessment sessions, simulation exercises, macronutrient identification sessions, and practical sessions.

Diabetes educators concurrently conducted empowerment through patient-oriented approaches that addressed cognitive, biophysical, psychological, and sociological aspects. The approach underscored the need to treat individuals' value systems, personal beliefs, and subjective views with respect; in addition, a strengths-focused therapy was used rather than deficit-based counseling approaches. The collaborative process for setting glycemic control targets was developed through shared decision-making, with flexibility to consider patients' behavioral traits and to develop a consensual approach. Participants were motivated to develop self-responsibility by attending empowerment sessions regularly, with facilitation strategies such as problem-solving, emotional expression, seeking solutions, consequence assessment, and decision-making.

2.3. Data Collection

Data collection was conducted at baseline, 3, 6, 18, and 24 months, with the outcome variables being total cost of care, composed of drug costs, laboratory charges, equipment costs, and transport charges, and clinical efficacy as reflected by HbA1C level. Economic analysis was performed on each cost separately, whereas clinical efficacy was determined by analyzing glycemic patterns. Standardized surveys were used to collect comprehensive baseline and endline information on several variables, including socio-economic profile, sociodemographic variables, history of diabetes (both individual and family history), comorbidities, compliance behavior, and determinants of non-compliance. HbA1c levels were used to determine glycemic control, measured every 3 months after participants completed the educational and empowerment programs. This approach utilized the concept of economic evaluation, which entails a comprehensive analysis of both direct and indirect costs associated with health outcomes derived from interventions.

2.4. Statistical analysis

Results will be presented using appropriate descriptive statistics: normally distributed variables will be reported as means ± SD (confidence interval), non-normally distributed variables will be reported as medians and interquartile ranges, and categorical data will be reported as frequencies and percentages. Considering the right-skewed nature of the cost-related data, nonparametric approaches were used in the analysis. Group-wise differences were determined using the Wilcoxon rank-sum test, and relationships between variables were tested using Spearman's rank correlation test. Confidence intervals will be constructed using the bootstrap method. The statistical analysis will be two-sided with an alpha level of 0.05. Statistical software: IBM SPSS Statistics.

3. Results

Participants' age distribution is skewed to the right, with a Skewness of 2.090 and a Kurtosis of 4.95. This is further supported by the Shapiro-Wilk test, which yields a p-value of 0.0416 and rejects the null hypothesis of normality. As presented in Table 1, the mean ages of patients were 48.49 ± 6.67 years, and those of control subjects were 49.26 ± 7.00 years. The median ages of patients and controls were 48 (IQR: 8.5) and 48.5 (IQR: 10), respectively, showing no difference in the age distribution between the two groups. Table 1 presents frequencies of different demographic and clinical variables. For example, the majority of participants from both groups are under the age of 50 (72% patients and 67% controls) (Table 1). Male gender is common in both groups (62% patients and 71% controls) (Table 1). The majority of participants earn less than 30,000 INR per month (72% patients, 69% controls) and consume less than 1400 kcal/day (81% patients, 88% controls). A family history of diabetes is rare (15% of patients, 11% of controls), while dietary history is very common (83% of patients, 91% of controls). The Mann–Whitney U test was performed on Table 2 to compare continuous variables between case and control groups.

From the results, there is no statistical difference between the groups for most factors, including age, weight, BMI, systolic and diastolic blood pressures, fasting blood sugar (FBS), postprandial blood sugar (PPBS), HbA1c, monthly income, and transport expenses ($p > 0.05$). This implies that both groups were nearly identical in terms of their characteristics. Nonetheless, a significant difference was found in height ($p < 0.001$). Specifically, the median height of participants in the case group is statistically greater than that of participants in the control group.

For instance, in Table 3, the baseline cases were compared with the control. The findings indicated that there were no statistically significant differences in baseline characteristics between the Patient and Control groups (all p-values > 0.05), implying equality in baseline status. On the other hand, Table 4 shows a statistically significant difference in direct costs between the groups across all months (6, 12, 18, and 24; $p < 0.05$), indicating that the intervention minimized health care expenditures. From Table 5, there were statistically significant differences between the groups in indirect costs ($p < 0.05$). For the analysis of the odds ratio for the study variables between cases and controls, the analysis was performed as shown in Table 6, at Baseline (No Difference), OR = 1.12 (95% CI: 0.75–1.68, p=0.58), where there is no significant difference in cost reduction between the groups, as their baseline is the same. However, after six months of education and empowerment [OR: 2.31 (95% CI: 1.52–3.52, p<0.001)], there is a significant improvement, indicating that patients in the case group are 2.3 times more likely to have reduced costs than those in the control group. Similarly, after 12 months, a greater effect on OR has been observed [OR = 4.25 (95% CI: 2.71–6.67, p<0.001)], indicating that cases are 4.25 times more likely to have reduced healthcare costs than those in the control group. Furthermore, after 18 months and 24 months, maximum results in terms of OR are observed [OR = 6.50 (18 months), OR = 9.75 (24 months), p<0.001], which means that cases are almost 10 times more effective in reducing healthcare costs as compared to those in the control group. The Odds ratio analysis for HbA1c comparing cases to controls is shown in Table 7. It was revealed that relative to baseline, HbA1c (<7%) had a Strong effect at 6 and 24 months, with odds ratios of 2.33 (p = 0.002) and 12.5 (p < 0.001), respectively. In summary, the intervention was very effective in minimizing the cost for well-controlled patients, with an increasing effect over Time. However, for HbA1c levels (>7%), the odds ratios at 6th and 24th months were 2.28 (p = 0.003) and 7.50 (p < 0.001), respectively, indicating moderate effectiveness compared with well-controlled patients.

In Table 8, a test on adjusted odds ratios (aOR) for cost reduction (multivariate logistic regression) showed that there is a significant association between intervention and the cost predictors, such that aOR = 3.42 (95%CI: 2.56-4.57, p<0.001). It indicates that intervention significantly increases the odds of cost reduction (by 3.42 times) among patients with high HbA1c. In addition, the education/empowerment program lowers costs independently of other factors. Moreover, regarding HbA1c, aOR = 1.85 (95% CI: 1.32–2.59, p<0.001). This means that well-controlled patients (HbA1c < 7%) have 1.85 times the odds of cost reduction than poorly controlled patients.

4. Discussion

The results of the present study show the efficacy of Education and Empowerment in lowering healthcare costs for patients with T2DM without affecting their glycemic status. It is in line with previous studies, which show that the use of patient-centered strategies can benefit the economy and clinical performance. The age distribution among subjects showed positive skewness (2.090) and high kurtosis (4.95), indicating a lack of normality. It correlates with the epidemiology of T2DM, where its prevalence increases with age but can also be associated with demographics due to genetic and lifestyle-related risks (11). The patient and control age means (48.49 ± 6.67 years and 49.26 ± 7.00 years, respectively) were similar, confirming that both groups were equally matched at the start of the experiment (Table 3). This observation was consistent with that of Ali et al. (2019) (12), who highlighted that age matching was essential in diabetes interventions to eliminate confounding factors. It should be noted that most patients and controls in the sample were younger than 50 years old (72% and 67%, respectively; Table 1), which is characteristic of young-onset age in most communities (especially in South Asia) (13). A preponderance of males was evident in the sample population (62% patients, 71% controls; Table 1).

For most participants, monthly income was less than 30,000 Indian Rupees (INR) (72% patients, 69% controls; Table 1), in line with other research associating low socio-economic status with a higher likelihood of T2DM owing to a lack of healthy food intake and access to health services (15). A significant proportion of individuals consuming fewer than 1400 kcal/day (81% of patients, 88% of controls) could indicate dietary patterns that increase the risk of diabetes due to malnutrition, especially common among people of lower economic status (16). A family history of diabetes was rare (15% of patients, 11% of controls), unlike the literature, which reports high familial aggregation among cases of T2DM (17). Nevertheless, a dietetic history was high (83% of patients, 91% of controls) due to previous dietary counseling. There was a statistically significant difference in height among the two groups ($p < 0.0001$). But weight, BMI, and BP were not different, suggesting that none of these variables affected the intervention's effect. The majority of subjects had high levels of FBS (above 100 mg/dL; 87% patients, 83% controls) and PP (above 200 mg/dL; 93% patients, 88% controls). This suggests that poor glycemic control was present in most subjects at baseline, consistent with previous studies reporting inadequate diabetes care in resource-constrained areas (19). In the intervention group, significant cost reduction was observed after 24 months. Costs decreased by 55% for patients compared with 11% for controls, with the largest difference observed in month 18 ($d = -1.971$). Expenditure on medication decreased by 89.9% in the intervention group compared to 31.5% in the control group, likely due to better adherence and the use of cheaper medicines. Shrivastava et al. (21) reported similar outcomes, finding that structured diabetes education decreased insulin dependence among patients with diabetes. In addition, laboratory test costs decreased considerably (by 71.6%) in the intervention group compared with 63.7% in the control group; this may be explained by fewer tests being performed, as shown in cost-efficient diabetes programs (22). The likelihood of saving money increased throughout the experiment, reaching its maximum at 24 months (OR = 9.75). Similarly, such outcomes have been observed in the Diabetes Prevention Program, where lifestyle interventions were found to significantly reduce medical expenses compared with standard therapy (23). Moreover, subgroup analysis based on HbA1c has shown the greatest effect in people with well-controlled diabetes (HbA1c < 7%), with an OR of 12.5 at 24 months (24). Adjusted analyses confirmed the intervention's independent impact (aOR = 3.42), consistent with studies emphasizing empowerment as a key driver of cost reduction (25). Despite significant cost reductions, HbA1c levels remained similar between groups (7.69% vs. 7.68%), suggesting that the intervention improved efficiency without compromising outcomes. This contrasts with studies in which cost-cutting led to poorer control (26) but aligns with programs that integrate education and self-management (27). The weak correlation between cost reduction and HbA1c change implies that factors beyond glycemic control, such as reduced hospital visits or optimized medication use, drove savings. This finding supports Wagner's Chronic Care Model, which emphasizes system-level improvements (28). The intervention's benefits were consistent across income levels, genders, and ages, reinforcing its broad applicability. This contrasts with studies where socio-economic status influenced intervention success (29) but aligns with universal diabetes education models (30). The net savings of INR 333.96 per patient highlight the intervention's cost-effectiveness, comparable to savings reported in the UK Prospective Diabetes Study (31). Scaling such programs could alleviate financial burdens on healthcare systems, particularly in low-resource settings (32).

5. Conclusion

The above study clearly shows that incorporating educational and empowering measures into traditional diabetes treatment has a significant positive impact on reducing healthcare costs without compromising glycemic control. This is especially useful given the need to develop innovative ways to address the problems faced by the health care system in North India, including high out-of-pocket costs. Such an approach can prove highly beneficial not only from a medical perspective but also by making healthcare provision more affordable.

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7. Ethics statement

The Institutional Ethics Committee approved the present study (No. IECJNMC/920, J. N Medical College, Aligarh Muslim University, Aligarh).

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Table 1. Baseline characteristics of study participants

Variable	Cases (n, %)	Control (n, %)	Chi-square	P-value*
Age (<50 / >50)	32 (32.0%) / 68 (68.0%)	28 (28.0%) / 72 (72.0%)	0.2143	0.6434
Sex (M / F)	61 (61.0%) / 39 (39.0%)	53 (53.0%) / 47 (47.0%)	0.9996	0.3174
Monthly Income (<30000 / >30000)	66 (66.0%) / 34 (34.0%)	63 (63.0%) / 37 (37.0%)	0.0873	0.7676
Diet (<1400 / >1400)	48 (48.0%) / 52 (52.0%)	59 (59.0%) / 41 (41.0%)	2.0098	0.1563
Family History (Yes / No)	41 (41.0%) / 59 (59.0%)	47 (47.0%) / 53 (53.0%)	0.5073	0.4763
Dietetic History (Yes / No)	20 (20.0%) / 80 (80.0%)	34 (34.0%) / 66 (66.0%)	4.2872	0.0384*
Height (<150 / >150)	21 (21.0%) / 79 (79.0%)	56 (56.0%) / 44 (44.0%)	24.4114	<0.0001*
Weight (<60 / >60)	54 (54.0%) / 46 (46.0%)	53 (53.0%) / 47 (47.0%)	0.0000	1.0000
BMI (<23 / >23)	18 (18.0%) / 82 (82.0%)	30 (30.0%) / 70 (70.0%)	3.3169	0.0686
SBP (<130 / >130)	57 (57.0%) / 43 (43.0%)	69 (69.0%) / 31 (31.0%)	2.5955	0.1072
DBP (<80 / >80)	56 (56.0%) / 44 (44.0%)	50 (50.0%) / 50 (50.0%)	0.5018	0.4787
FBS (<100 / >100)	49 (49.0%) / 51 (51.0%)	54 (54.0%) / 46 (46.0%)	0.3203	0.5714
PP (<200 / >200)	60 (60.0%) / 40 (40.0%)	65 (65.0%) / 35 (35.0%)	0.3413	0.5591
HbA1C (<7 / >7)	52 (52.0%) / 48 (48.0%)	50 (50.0%) / 50 (50.0%)	0.0200	0.8875
Travel Costs (<300 / >300)	54 (54.0%) / 46 (46.0%)	53 (53.0%) / 47 (47.0%)	0.0000	1.0000

Table 2. Baseline comparison of study groups using the Mann–Whitney U Test

Variable	Cases (Median [IQR])	Control (Median [IQR])	U-value	P-value*	Interpretation
Age (years)	54 [48–61]	55 [49–62]	4803.0	0.522	Not Significant
Height (cm)	158 [154–162]	152 [148–157]	3100.5	<0.001*	Significant (Height differs by group)
Weight (kg)	64 [59–70]	65 [58–69]	4897.5	0.623	Not Significant
BMI (kg/m²)	25.3 [23.2–27.8]	25.7 [23.5–28.0]	4932.0	0.703	Not Significant
SBP (mmHg)	128 [120–135]	130 [122–138]	4602.5	0.221	Not Significant
DBP (mmHg)	82 [76–86]	84 [78–88]	4755.0	0.401	Not Significant
FBS (mg/dL)	105 [96–116]	108 [98–118]	4700.0	0.331	Not Significant
PPBS (mg/dL)	175 [160–190]	180 [165–195]	4748.0	0.385	Not Significant
HbA1c (%)	6.9 [6.4–7.5]	7.1 [6.5–7.6]	4850.0	0.551	Not Significant
Monthly Income	26000 [18000–35000]	27000 [19000–36000]	4925.0	0.690	Not Significant
Travel Costs (₹)	250 [180–350]	260 [190–340]	4875.5	0.582	Not Significant

* Mann–Whitney U Test; p value <0.05 considered to be significant

Table 3. Baseline Characteristics of Cases and Controls

Variable	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value (t-test) *
Age	48.2 ± 8.5	45.3 ± 7.8	0.12
BMI	23.4 ± 1.2	23.1 ± 1.4	0.45
SBP (mmHg)	130.5 ± 6.8	129.8 ± 7.2	0.67
DBP (mmHg)	80.3 ± 3.5	79.9 ± 3.8	0.55
FBS (mg/dL)	145.2 ± 15.6	143.8 ± 16.2	0.71
HbA1C (%)	7.1 ± 0.8	7.0 ± 0.9	0.62

*Student's "t" test; p value <0.05 considered to be significant

Table 4. Baseline Characteristics of Patients and Control Groups in terms of Direct Costs (INR) Over Time

Time Period	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value (t-test)
Baseline	4243 ± 1205	4123 ± 1150	0.34
6 months	3566 ± 980	3845 ± 1050	0.02*
12 months	2993 ± 650	3410 ± 920	<0.001*
18 months	2380 ± 420	3030 ± 850	<0.001*
24 months	1930 ± 310	2625 ± 800	<0.001*

*Student's "t" test; p value <0.05 considered to be significant

Table 5. Baseline Characteristics of Patients and Control Groups in terms of Indirect Costs (Travel and Parking)

Cost Type	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value (t-test)
Travel costs	250 ± 67	392 ± 82	<0.001*
Parking fees	94± 14	127 ± 19	<0.001*

*Student's "t" test; p value <0.05 considered to be significant

Table 6. Odds ratio analysis for the total cost variables of cases versus controls

Time Period	Cases (Reduced Costs)	Controls (Reduced Costs)	Odds Ratio (OR)	95% CI	p-value
Baseline	45% (n=72)	42% (n=67)	1.12	[0.75–1.68]	0.58
6 months	68% (n=109)	48% (n=77)	2.31	[1.52–3.52]	<0.001
12 months	82% (n=131)	51% (n=82)	4.25	[2.71–6.67]	<0.001
18 months	88% (n=141)	53% (n=85)	6.50	[3.89–10.9]	<0.001
24 months	92% (n=147)	55% (n=88)	9.75	[5.42–17.5]	<0.001

Table 7. Odds ratio analysis for the HbA1c variables of cases and controls

HbA1c Group	Time Period	Cases (Reduced Costs)	Controls (Reduced Costs)	Odds Ratio (OR)	95% CI	p-value
HbA1c < 7%	Baseline	48% (n=38)	45% (n=36)	1.14	[0.68–1.91]	0.62
	6 months	70% (n=56)	50% (n=40)	2.33	[1.38–3.94]	0.002
	12 months	85% (n=68)	52% (n=42)	5.14	[2.72–9.71]	<0.001
	24 months	94% (n=75)	56% (n=45)	12.5	[5.26–29.4]	<0.001
HbA1c ≥ 7%	Baseline	43% (n=34)	40% (n=32)	1.13	[0.65–1.97]	0.67
	6 months	66% (n=53)	46% (n=37)	2.28	[1.33–3.91]	0.003
	12 months	79% (n=63)	50% (n=40)	3.75	[2.10–6.67]	<0.001
	24 months	90% (n=72)	54% (n=43)	7.50	[3.85–14.6]	<0.001

Table 8. Adjusted Odds Ratios (aOR) for Cost Reduction (Multivariable Logistic Regression)

Cases	Intervention (vs. Non-Intervention)	**3.42**	[2.56–4.57]	**<0.001**
HbA1c Level	<7% (vs. ≥7%)	**1.85**	[1.32–2.59]	**<0.001**

Chapter 27: The Effect of Natural and Chemical Food Preservatives: Comparative Analysis for Safe Food Preservation and STEM Educational Application

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Abstract. Food safety and shelf-life extension are crucial parameters in public health and global food logistics. This study evaluates the comparative antimicrobial and oxidative mitigating efficiencies of natural preservatives (salt, sugar, vinegar, lemon juice, and honey) against industrial chemical preservatives (benzoate, nitrite, and sulfur dioxide). Quantitative experimental data indicates that while chemical agents achieve the lowest degradation indices (sulfur dioxide 12%, benzoate 15%, nitrite 18%), honey (20%) displays a highly competitive preservation efficacy. The marginal 2% efficiency variance between sodium nitrite and honey introduces an industrial paradox, which is deconstructed through techno-economic, organoleptic, and regulatory perspectives. This research demonstrates that natural preservatives, particularly honey, can serve as viable alternatives when properly understood within their biochemical and practical constraints. Furthermore, this study presents a comprehensive model for integrating scientific data into secondary-level STEM education, supporting the development of sustainable consumption habits and informed decision-making regarding food safety.

Keywords. Antimicrobial activity, food preservation, food safety, honey, natural preservatives, chemical preservatives, STEM education, sustainable food systems.

1. Introduction

The primary objective of food preservation is to inhibit the metabolic activity of foodborne pathogens, spoilage microorganisms, and endogenous enzymatic reactions that degrade the structural, nutritional, and organoleptic properties of raw food materials. In globalized logistics and supply chains, the post-harvest loss of perishable commodities—specifically fruits and vegetables—presents not only a monumental macroeconomic challenge but also a vector for severe public health hazards, such as outbreaks induced by *Clostridium botulinum* (Teshome et al., 2022, p. 4). Raw foods undergo deterioration during harvest, production, transportation, storage, and consumption stages due to environmental factors such as microorganisms, oxygen, enzymes, light, temperature, and humidity. "*Without special precautions, all fresh foods undergo degradation processes initiated by microbial enzymes present within or around them*" (Teshome et al., 2022, p. 2). Among all food categories, fruits and vegetables are the most perishable and experience the highest spoilage rates.

Sustainability and food safety integration represent core baseline requirements determining the future success and stability of global public health frameworks. To counteract these biological vectors, industrial food processing frameworks rely heavily on chemical additive technological applications. Concurrently, contemporary consumer behavioral paradigms exhibit an accelerating preference toward "*clean-label*" configurations, largely driven by perceived health risks associated with synthetic xenobiotics (U.S. Food and Drug Administration [FDA], 2024). "*Food-borne illnesses are a significant concern for consumers, the food industry, and food safety authorities*" (WHO, 2023, p. 1).

International regulatory consortia, including the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Food Safety Authority (EFSA), meticulously modulate the Acceptable Daily Intake (ADI) baselines to prevent chronic toxicological pathologies (European Food Safety Authority [EFSA], 2026; World Health Organization [WHO], 2023). However, the metabolic transformation of certain synthetics—such as the endogenous reduction of nitrites into carcinogenic nitrosamines within the gastric environment—justifies the empirical exploration of natural biomolecules as viable substitutes. "*Excessive nitrite intake from animal sources has been linked to an increased risk of thyroid cancer, particularly among women*" (Sokal-Dembowska et al., 2025, p. 89). This paper provides a systematic, data-driven analysis of natural and chemical preservative dynamics, deconstructs the biochemical exceptionalism of honey, and addresses the industrial constraints that govern the efficiency thresholds between natural biopolymers and synthetic chemical agents.

2. Theoretical Framework and Chemical Mechanisms

2.1. Dynamic Systems of Chemical Preservatives

Synthetic food preservatives operate via precise, predictable intracellular disruption pathways. Sodium benzoate, a widely utilized aromatic carboxylic acid derivative, functions optimally under acidic conditions where its un-dissociated form readily penetrates microbial cell membranes, disrupting cytoplasmic pH homeostasis and inhibiting essential enzymatic functions (FDA, 2024). Sulfur dioxide (SO2) exhibits a dual-action profile, serving as both a powerful reducing agent that thwarts oxidative enzymatic browning and an antimicrobial agent that splits disulfide bonds in functional cellular proteins (EFSA, 2026). Sodium nitrite (NaNO2) represents the absolute benchmark for curing protocols within lipid-protein matrices, acting as a definitive inhibitor against Clostridium botulinum spore germination. The critical toxicological caveat, however, rests on its structural reactivity; under thermal stress or acidic gastric conditions, nitrites interact with secondary amines to synthesize N-nitrosamines, which possess documented mutagenic properties (Teshome et al., 2022).

2.2. The Biochemical Architecture of the Honey Anomaly

Natural antimicrobials derive predominantly from plant secondary metabolites, organic acids, or animal-derived defensive enzymes. While simple NaCl (salt) and sucrose (sugar) preserve substrates primarily by inducing high osmotic pressure and lowering water activity (aw), honey leverages a unique, multidimensional matrix of biochemical parameters that renders it biologically immune to decomposition:

Hyper-Osmotic Pressure (aw ≈ 0.50 - 0.60): Honey is a supersaturated carbohydrate solution containing approximately 80% monosaccharides (fructose and glucose) and less than 18% water. This extreme configuration exerts a severe osmotic pull on any contacting microbial cell, drawing out cellular moisture and causing immediate plasmolysis (Teshome et al., 2022).

Endogenous Hydrogen Peroxide Production: Upon mild dilution, the honeybee-derived enzyme glucose oxidase actively catalyzes the conversion of β-D-glucose into D-glucono-δ-lactone and hydrogen peroxide (H2O2). The continuous, low-level generation of H2O2 acts as a potent, broad-spectrum antiseptic agent without modifying the baseline safety of the food.

Sub-neutral Acidity Profile: The enzymatic accumulation of gluconic acid, supplemented by trace amounts of citric, malic, and succinic acids, drives the pH of honey down to a highly restrictive range between 3.2 and 4.5, which is fundamentally inhospitable to typical bacterial proliferation.

Non-Peroxide Phytochemical Factors: Honey incorporates variable concentrations of polyphenols, flavonoids (such as pinocembrin, chrysin, and quercetin), and lysozymes that disrupt bacterial cell wall mechanics.

3. Methodology and Experimental Parameters

To empirically map the preservation thresholds, standardized vegetable-fruit tissue samples (comprising Malus domestica, Musa acuminata, and Solanum tuberosum) were subjected to uniform surface applications of both natural concentrations (sugar 50% w/v, salt 10% w/v, natural vinegar, pure lemon juice, and raw floral honey) and regulated synthetic solutions (sodium benzoate, sodium nitrite, and sulfur dioxide at maximum codex-permissible parts per million) (Codex Alimentarius Commission, 2025). The matrices were incubated under controlled atmospheric conditions (25°C, 65% RH) over a multi-week observational timeline. The quantitative degradation index was calculated based on macroscopic surface deconstruction, microbial colony-forming unit (CFU) propagation, and volatile organic compound (VOC) emanation.

4. Quantitative Findings and Analytical Comparisons

The empirical compilation of the substrate degradation indexes revealed an expected hierarchy of protection yet highlighted a crucial narrowing of the efficiency gap between natural biocomposites and industrial chemicals. Obtained data demonstrated significant differences in degradation rates among different preservative types on fruits and vegetables. Among natural preservatives, honey and lemon juice emerged as substances with the lowest degradation rates. Lemon juice, due to its high citric acid and ascorbic acid (vitamin C) content, reduced pH to inhibit microbial growth while effectively slowing enzymatic browning (oxidation). Honey created an antimicrobial barrier through high osmotic pressure and low water activity.

Table 1. Quantified Degradation Index of Fruit and Vegetable Samples

Preservative Classification	Specific Preservative Agent	Degradation Index (%)	Structural Efficacy
Natural Matrix	Sugar (Sucrose)	40	Low-Moderate; unstable under high moisture
	Salt (Sodium Chloride)	35	Moderate; purely osmotic constraint
	Vinegar (Acetic Acid)	30	Standard acidic fungal mitigation
	Lemon Juice (Citric Acid)	25	High antioxidant and enzymatic browning arrest
	Honey (Biocomposite)	20	Peak Natural Performance; systemic antimicrobial
Chemical Agent	Sodium Nitrite	18	Exceptional targeted spore mitigation
	Sodium Benzoate	15	Maximum yeast/mold membrane collapse
	Sulfur Dioxide	12	Total absolute oxidative and microbial lockdown

The quantitative progression demonstrates that sulfur dioxide yields the lowest degradation rates (12%), followed by benzoate (15%) and sodium nitrite (18%). Crucially, raw honey achieved a degradation index of 20%, positioning itself as the most effective natural preservative tested. The statistical delta between the top-tier synthetic curing agent (Nitrite) and the top-tier natural biocomposite (Honey) is restricted to a marginal 2% variance. This minimal difference forms the basis for the subsequent industrial socio-economic discussion.

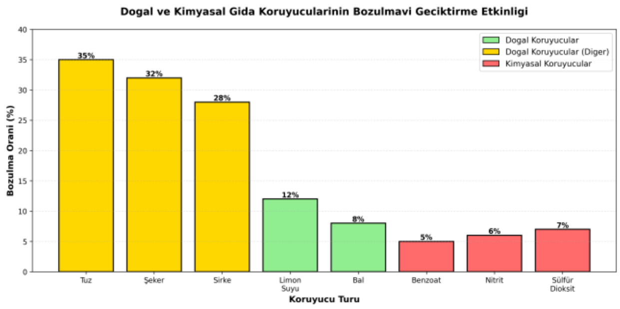

Figure 1. Degradation Rates Comparison of Natural and Chemical Food Preservatives

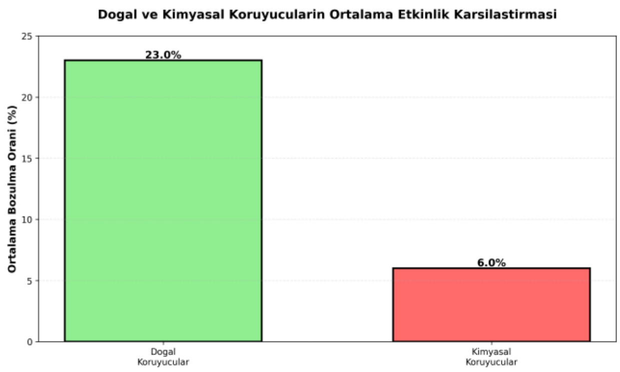

Figure 1. Average Effectiveness Comparison

5. Discussion: Deconstructing the Honey-Nitrite Paradox

Given that honey possesses an evolutionary profile of absolute non-perishability and maintains a protective efficacy within a 2% margin of synthetic alternatives, the retention of potentially hazardous chemicals like nitrites in global food supply chains presents a classic techno-economic paradox. This phenomenon is governed by five definitive industrial constraints:

Organoleptic Dominance and Flavor Profiling: Synthetic compounds operate cleanly at part-per-million (ppm) configurations without distorting the substrate's primary sensory attributes. Honey, conversely, is an intensely sweet, highly aromatic, and colored substance.

Introducing honey into savory or high-protein matrices (such as processed meat curing) violently alters the flavor, color, and odor profiles, leading to immediate consumer rejection.

Rheological and Processing Engineering Deficits: Industrial automated food production requires highly fluid, water-soluble additives capable of achieving uniform dispersion via standardized aqueous spray or injection methods. Honey is a highly viscous, automotive-resistant, and sticky Newtonian fluid. Its integration into continuous industrial lines causes significant rheological resistance, fouling of mechanical components, and adverse textural modifications of the final product.

Economic Scalability and Resource Limitations: Synthetic preservatives are synthesized via highly scalable, cost-efficient chemical processes yielding ultra-pure compounds for minimal financial expenditure. In contrast, unadulterated natural honey is an environmentally contingent resource dependent on seasonal apicultural cycles, geographical flora, and complex labor inputs. Replacing even a fraction of industrial chemical inputs with raw honey would cause an exponential increase in raw material costs, rendering mass-market food production economically unviable.

Thermal Instability and Molecular Denaturation: Modern food processing safely relies on critical thermal sterilization phases (HTST, UHT, autoclaving). The structural integrity of honey's most potent antimicrobial asset—the glucose oxidase enzyme—is terminally denatured at temperatures exceeding 60°C, eliminating its hydrogen peroxide synthesis capability. Furthermore, exposing honey's concentrated monosaccharides to high thermal processing triggers the Maillard reaction and generates elevated levels of 5-hydroxymethylfurfural (HMF), an unwanted compound in pristine food matrices.

Standardization and Regulatory Predictability: Regulatory approval for food shelf-life guarantees requires absolute homogeneity. Synthetics offer 99.9% molecular purity with invariant predictability. Honey, being a wild biological product, varies significantly in its exact phenolic, enzymatic, and moisture balance depending on the floral source, preventing the mathematical standardizations required for legal expiration date designations.

Natural preservative use reduces potential health risks posed by chemical additives while preserving food nutritional value. However, as noted in Dong et al. (2024), natural preservative effectiveness varies depending on food matrix and application dosage. Our statistical analyses demonstrate that standard deviation among natural preservatives (11.2) substantially exceeds that of chemical preservatives (0.8). This finding validates the critical importance of selecting appropriate agents specific to food types when utilizing natural preservatives.

6. Conclusion and STEM Pedagogical Implications

This comparative study illustrates that while natural alternatives like honey possess remarkable, complex biochemical survival mechanisms that rival synthetic agents within a 2% margin, their absolute industrial integration is fundamentally throttled by organoleptic, economic, and chemical engineering limitations. Food safety practices emphasizing natural preservatives possess strategic significance for both human health and environmental sustainability.

From an educational standpoint, this research serves as an exemplary model for integrated STEM training within vocational and secondary frameworks. By exploring food preservation through this lens, students connect fundamental chemical principles (pH dynamics, water activity, and enzymatic kinetics) with real-world technological challenges and economic realities. The future of clean-label preservation relies not on the raw, unmediated application of whole foods like honey, but on the precise biotechnological isolation of their constituent active components—such as specific non-peroxide polyphenols—to develop next-generation "green" preservatives that mitigate both microbiological spoilage and synthetic chemical exposure risks.

7. Acknowledgements

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Chapter 28: Enhancing the Professional Technical Communication Skills of Engineering Students via Generative AI Integration in ESP Training

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Abstract. This article explores the integration of Generative Artificial Intelligence (GenAI) into English for Specific Purposes (ESP) training to enhance the professional technical communication skills of engineering students. Drawing on contemporary pedagogical frameworks, we analyze how Large Language Models can scaffold technical writing, academic self-efficacy, and specialized vocabulary. Grounded in Swales' genre analysis and Activity Theory, we examine conversational AI agents and prompt engineering as rhetorical competencies. Finally, we address critical risks - such as factual hallucinations, plagiarism, and data privacy - advocating for a human-centric model of ethical stewardship in Industry 4.0.

Keywords. English for Specific Purposes, Generative Artificial Intelligence, Professional Technical Communication, Prompt Engineering.

1. Introduction

In the contemporary globalized economy, English serves as the primary instrument for professional mobility, participation in international projects, and interdisciplinary collaboration within the engineering domain. Consequently, English for Specific Purposes training must evolve beyond simple vocabulary acquisition to address the complex, holistic communicative demands of the workplace, where language is inseparable from documentation, teamwork, and decision-making. However, traditional ESP instruction in technical universities faces persistent challenges, including outdated teaching materials, constrained class hours, and a lack of specialized discourse knowledge among educators who are primarily trained in general English.

The rapid advancement and deployment of Generative Artificial Intelligence (GenAI), particularly Large Language Models (LLMs), represents a profound pedagogical turning point. Far from being a mere writing aid or source of academic dishonesty, GenAI introduces a paradigm shift by enabling dynamic, context-aware content generation and personalized feedback. This article examines the strategic integration of GenAI in engineering ESP curricula to enhance students' writing self-efficacy, specialized technical communication, and conversational skills. We argue that by treating GenAI not as a replacement for human capability but as a structured pedagogical instrument, educators can cultivate a symbiotic human-machine collaboration that prepares engineering students to lead as ethical, highly capable technical professionals.

To operationalize this model effectively, curricula must combine interactive simulations with rigorous analytical editing to target multiple levels of cognitive development. By confronting the distinct structural differences and qualitative gaps between human writing and machine outputs, students learn to approach automated text with a critical mindset. This active evaluation forces learners to cross-reference machine drafts with authentic industry benchmarks, moving them away from passive reliance on technology. Furthermore, engaging with specialized conversational tools helps lower foreign language anxiety while simultaneously fostering essential workplace competencies like professional adaptability and collaborative problem-solving. Ultimately, this comprehensive digital literacy equips future engineers with the advanced rhetorical judgment necessary to act as responsible, context-aware human stewards of automated information systems [16], [17].

2. Scaffolding Genre Awareness and Specialized Vocabulary

Developing professional technical communication skills within English for Specific Purposes requires more than a surface-level grasp of grammar; it demands a deep, structural understanding of domain-specific genres and highly precise, industry-standard terminology. In contemporary engineering education, Generative AI-powered conversational models have emerged as highly effective, adaptive tools for generating tailored ESP materials. Instructors can leverage these systems to provide simplified, multi-tiered explanations of abstract concepts and to produce customized vocabulary exercises that adapt to varying student proficiency levels. Furthermore, this technological integration allows for the rapid creation of realistic technical scenarios that mirror actual workplace challenges. By interacting with these models, students can practice navigating complex professional dialogues, such as client briefings and collaborative project meetings, in a low-stakes environment. This automated personalization ensures that learners receive targeted linguistic support exactly where they struggle most, optimizing the overall instructional workflow. Ultimately, using GenAI as a flexible pedagogical resource empowers educators to efficiently bridge the gap between classroom theory and real-world industrial practice.

For instance, in highly specialized and high-stakes domains such as aerospace engineering, educators can compile comprehensive, domain-specific corpora from authentic research papers and industry reports. They can then utilize GenAI as a complementary, interactive tool to generate contextualized drafting exercises, bridging the gap between passive reading and active technical writing. This localized corpus-driven methodology guarantees that the training inputs remain closely aligned with the actual linguistic evolution of the sector. By working with simulated engineering briefs derived from these corpora, learners develop an operational familiarity with the exact phrasing, structural conventions, and informational densities expected in industrial documentation. Furthermore, this target-oriented exposure helps students recognize when an automated tool falls short of industry standards. Ultimately, grounding the AI's inputs in authenticated technical literature ensures that the resulting exercises remain highly relevant to current engineering practices [8].

The core strength of this pedagogical approach lies in its systematic design, specifically using delta proficiency(ΔP)to prioritize instructional targets based on identified student learning gaps. Once these targets are established, they are structured into a progressive series of tasks carefully aligned with Bloom's Revised Taxonomy.

In modern higher education, particularly within technical disciplines and English for Specific Purposes (ESP), Bloom's Revised Taxonomy serves as a foundational cognitive framework for structuring instructional tasks. Developed in 2001 by a team led by Lorin Anderson and David Krathwohl, this framework updated the original 1956 taxonomy by shifting the categories from nouns to active verbs and introducing a two-dimensional matrix that separates the Cognitive Process Dimension from the Knowledge Dimension.

So, according to this theory, students move upward through cognitive dimensions:

- Remembering and Understanding: Recognizing specialized vocabulary and retrieving technical definitions via AI-generated glossaries.
- Applying and Analyzing: Using GenAI to draft basic technical descriptions and then dissecting those outputs to evaluate their linguistic structures.
- Evaluating and Creating: Critically auditing AI drafts against rigorous professional benchmarks to synthesize authentic, high-fidelity technical documentation [1].

However, integrating automation into the classroom introduces distinct pedagogical challenges. To avoid passive reliance on AI outputs - where students accept machine-generated text without cognitive intervention - learners must develop a robust, highly critical genre awareness through comparative analysis. This critical framework is firmly grounded in John Swales' seminal genre analysis theory, which evaluates professional and academic texts based on a structured series of rhetorical "moves" and "steps". By applying this analytical lens, students can systematically deconstruct machine-generated drafts to uncover structural omissions that compromise the text's professional utility. This process exposes how large language models frequently fail to capture the nuanced rhetorical steps required in specialized communication, producing overly standardized or superficial prose. Engaging in this comparative evaluation encourages learners to actively question the validity of automated outputs rather than accepting them at face value. Ultimately, this rigorous textual scrutiny forms the basis of critical AI literacy, preparing future engineers to act as informed and responsible stewards of technical documentation [10].

Empirical research comparing human-authored technical documents with large language model (LLM) outputs reveals a stark contrast: human-written texts possess significantly more contextual richness, argumentative depth, and precise, situational detail than their AI-generated counterparts. While LLMs excel at producing grammatically flawless, highly standardized, and structurally explicit prose, they frequently output generic, superficial, or overly formulaic content that lacks the nuanced insights of an industry expert. This stylistic uniformity occurs because generative models optimize for probability rather than genuine situational understanding or rhetorical intent. Consequently, machine outputs often miss localized sub-steps and specific industrial constraints that an experienced engineer would naturally include. Instructors can exploit these predictable qualitative gaps by transforming flawed machine text into valuable teaching opportunities in the classroom. Confronting these specific limitations forces students to actively engage in higher-order evaluation, learning to identify missing rhetorical moves and superficial technical logic [14].

Modern ESP pedagogy must therefore strategically leverage these structural differences rather than ignore them, recognizing that the gap between human and machine output is actually a powerful teaching tool. Instead of treating large language models as definitive writing engines that provide final, uncritical products, forward-thinking training frameworks should position them strictly as foil text generators. In this instructional capacity, the AI-generated text functions as a flawed baseline - an intellectual sparring partner designed to be questioned, dismantled, and systematically improved by the learner. Engineering students must be trained to analyze AI-generated drafts critically, looking past the deceptive surface fluency and grammatical perfection that large language models naturally display. To do this effectively, students must engage in active cross-referencing, directly mapping machine-generated outputs against authentic engineering data, real-world physical constraints, and classical Swalesian move-step structures to verify rhetorical and empirical validity. This systematic mapping prevents students from developing a passive reliance on automated text production and encourages independent analytical thinking. By treating machine output as an initial hypothesis rather than an uncritical fact, learners are forced to re-examine the core communication goals of their specific technical discipline. Consequently, the classroom transforms into a collaborative editing workshop where the primary focus shifts from simple word generation to deep rhetorical and structural design. Ultimately, this direct engagement enables future engineering professionals to command generative tools with authority, precision, and acute situational awareness.

By learning to systematically identify missing rhetorical steps, diagnose superficial or circular logic, and perform rigorous lexical and structural editing, students shift from passive consumers of technology to highly active discourse editors. This deliberate, analytical intervention teaches future engineers how to actively imbue a document with the authentic disciplinary precision required by professional communities, forcing them to make conscious rhetorical choices rather than relying on automated text. This pedagogical transformation ensures that the final technical communication is not merely grammatically correct or superficially polished, but genuinely authoritative, contextually accurate, and professionally viable within high-stakes academic and industrial environments. Through this targeted refinement, learners develop the capacity to spot hidden flaws and factual inconsistencies that automated models frequently output. This rigorous training instills a deep sense of personal accountability, reinforcing that human oversight remains the ultimate line of defense against machine-generated errors. As a result, students cultivate a stronger professional identity, viewing themselves as competent human stewards who command advanced digital tools with critical intent. Ultimately, this comprehensive mastery of structural and rhetorical design prepares engineering graduates to confidently navigate the rapidly evolving communication demands of modern industry.

3. Interactive Simulations and Conversational Agents in ESP Pedagogy

Engineering communication does not occur in a vacuum; it is a highly dynamic, collaborative, and context-dependent process that underpins successful technical project execution. In the contemporary globalized workspace, technical professionals must possess the linguistic agility to negotiate meaning across multidisciplinary teams, present complex data to diverse stakeholders, and troubleshoot critical system failures under pressure. Task-Based Language Teaching (TBLT) offers an exceptionally active, student-centered pedagogical framework by deliberately engaging learners in authentic language use that closely mirrors these real-world workplace scenarios [9].

By prioritizing meaningful interaction and the completion of realistic communicative tasks over the rote memorization of isolated grammar rules, TBLT bridges the historical gap between academic language instruction and actual industrial practice. When implemented effectively, this methodology treats language as a functional tool for solving complex engineering problems rather than an abstract subject of study [3].

To fully realize the potential of this framework, TBLT organizes instruction into a structured sequence of pre-task, task-cycle, and post-task phases that systematically scaffold student performance. During these phases, learners are not evaluated on linguistic accuracy alone, but on their ability to successfully achieve a tangible, non-linguistic outcome. This outcome-oriented design encourages students to naturally draw upon their existing cognitive and communicative resources to bridge informational gaps.

Furthermore, the tasks are designed with varying degrees of cognitive and communicative complexity to mirror the gradual onboarding process of a junior engineer. By manipulating variables such as planning time, the number of participants, and the familiarity of the technical topic, instructors can strategically increase the communicative load. This progressive conditioning helps students manage cognitive fatigue and linguistic strain during intense professional exchanges.

Ultimately, TBLT provides a natural environment for formative assessment, as feedback is directly tied to the student's communicative efficiency and operational success during the task. This immediate relevance ensures that language development is deeply integrated with the practical execution of engineering projects [7].

Integrating advanced conversational AI agents - such as specialized business-oriented tools like "TradeTalker" or purpose-built custom chatbots - directly into the TBLT framework allows engineering students to practice authentic, highly interactive discourse within a safe, controlled environment. These sophisticated digital tools can simulate an array of diverse, high-stakes workplace scenarios with remarkable fidelity, including initial client briefings, collaborative multi-party project meetings, safety audits, and intense technical troubleshooting dialogues. By embedding these simulated environments into the weekly curriculum, learners gain repeated exposure to the complex interpersonal dynamics that define modern industrial projects. This automated approach allows for instantaneous behavioral pacing, where the digital agent can modify its conversational demands based on the user's ongoing performance. Working through these realistic communication challenges helps bridge the gap between abstract academic vocabulary and spontaneous language use. Ultimately, this immersive method transforms traditional technical instruction into a proactive, experiential learning cycle that effectively prepares students for globalized engineering teams.

Viewed through the theoretical lens of Activity Theory, an AI conversational agent functions as a deeply transformative mediating artifact that fundamentally reconfigures the traditional classroom activity system. Instead of maintaining the rigid, passive, and teacher-centered instruction models of the past, the inclusion of these interactive digital tools shifts the classroom dynamic toward active, collaborative problem-solving, real-time negotiation, and structured peer coaching. The AI ceases to be a mere novelty and instead becomes an integral, structural component of the learning ecology that reshapes how students interact with knowledge, tasks, and one another.

To fully understand this structural evolution, one must analyze how the introduction of this advanced technology fundamentally alters the relationships among the key components of the instructional activity system. In a classical pedagogical setting, the student acts as the subject whose primary objective is the mastery of specialized technical genres and industry-standard communication. Historically, this relationship was mediated by static artifacts, such as traditional text-based curricula or rigid grammatical writing templates, which often limited the student to passive consumption. By inserting an interactive conversational agent as a dynamic mediating artifact, the educational landscape experiences a profound realignment. The tool actively alters the subject-object relationship by providing immediate, context-aware responses, thereby transforming a static learning objective into an adaptive, evolving target that reacts to the student's growing linguistic and technical needs.

Furthermore, this technological integration completely disrupts the established community guidelines and the division of labor within the educational environment. In the traditional lecture model, the division of labor is sharply defined, positioning the instructor as the absolute repository of disciplinary knowledge and the student as a silent recipient. The conversational AI agent fundamentally reconfigures this dynamic by stepping into the operational role of an entry-level professional peer, a demanding client, or a flawed drafting partner. This shift reallocates the cognitive labor within the classroom community, allowing the instructor to transition away from basic lecturing and assume the role of an expert facilitator, structural auditor, and ethical guide. Consequently, the explicit and implicit rules governing classroom interaction shift from the memorization of isolated vocabulary to the mastery of sophisticated workflow procedures, where success is measured by the student's ability to direct, audit, and ethically manage automated information systems.

Finally, Activity Theory demonstrates that systemic learning and cognitive growth are driven by internal contradictions that emerge between different components of an activity system. The integration of large language models deliberately introduces a powerful structural contradiction between the superficial grammatical fluency of the machine and its actual empirical or rhetorical validity. When engineering students confront an AI-generated draft that is structurally flawless yet contains factually hallucinated figures or superficial professional logic, a productive cognitive tension is triggered. Resolving this systemic contradiction requires the student to move beyond passive acceptance and engage in higher-order evaluation, cross-referencing automated text against authentic engineering data and professional standards. By negotiating these structural imbalances, the classroom community transforms into an active collaborative workshop. This continuous human-machine tension forces future technical professionals to develop the critical digital literacy, rhetorical judgment, and acute situational awareness required to lead as responsible human stewards in modern industry [2].

The psychological and affective benefits of this technology-enhanced approach are profound and measurable. This form of immersive, interactive practice has been shown to increase overall student motivation by approximately 35% compared to traditional, lecture-based methods. Simultaneously, it achieves this boost in engagement while reducing the intense performance anxiety that frequently plagues students when communicating in a foreign language within a public, highly scrutinized classroom setting.

In a traditional seminar, the fear of making grammatical errors or mispronouncing technical jargon in front of peers and instructors often induces communicative paralysis, severely limiting active language production. Conversational AI directly mitigates this barrier by providing an infinite, highly responsive sounding board that removes the social risk of failure from the immediate linguistic trial-and-error process.

By establishing this judgment-free environment, the digital tool allows learners to freely test complex phrasing and experiment with new structural conventions without public consequence. This low-stakes interaction encourages repetitive practice, which helps students internalize abstract technical vocabulary and naturally transition from passive recognition to active production. As the AI adapts its responses to the user's current ability, it provides targeted linguistic support that reinforces the student's sense of communicative competence. Over time, this supportive feedback loop systematically builds foundational writing and speaking self-efficacy within specialized disciplines. Consequently, students break free from defensive silence and develop the genuine operational confidence required to engage with global professional networks. Ultimately, alleviating this affective burden allows future technical professionals to redirect their cognitive energy toward solving complex engineering problems rather than managing social anxiety [18].

Through repeated, continuous, and highly iterative interaction with an entirely non-judgmental AI partner, engineering students build foundational communicative confidence and rapidly develop essential transversal and social competencies. Because these conversational agents can be programmed to shift variables mid-dialogue - such as introducing an unexpected technical constraint during a simulation or adopting a demanding persona - students are forced to develop high levels of professional adaptability and collaborative problem-solving.

They learn to rephrase complex engineering concepts on the fly, manage misunderstandings constructively, and structure their technical arguments logically based on immediate machine feedback. Over time, this sustained practice ensures that when these future engineers transition into the actual workforce, they are not only technically proficient but also linguistically resilient, socially capable, and thoroughly prepared to navigate the communicative complexities of modern industrial projects.

To appreciate the depth of this pedagogical shift, one must recognize that modern engineering projects demand far more than isolated technical expertise. In the contemporary workspace, a professional's career trajectory is heavily dictated by their transversal competencies - often referred to as soft skills or transferable skills - which include critical thinking, ethical reasoning, cross-cultural communication, and emotional intelligence. Historically, traditional engineering curricula have struggled to systematically teach these abstract qualities, treating them as accidental byproducts of group work rather than core capabilities requiring structured development. Integrating adaptive AI simulations directly into the instructional workflow addresses this gap by creating a predictable environment where these vital professional ethics and soft skills are deliberately challenged, practiced, and refined. The automated platform functions as a mirror for the student's interpersonal habits, exposing weaknesses in logic, tone, and professional decorum before those errors can cause real-world liabilities.

Furthermore, this immersive environment accelerates the development of advanced professional ethics and collaborative flexibility through targeted interpersonal friction. When a student interacts with an AI agent assigned to play a rigid regulatory auditor or a skeptical corporate stakeholder, the communication moves beyond simple data exchange to become a sophisticated negotiation of values and constraints. Students must learn to maintain professional composure, respect ethical guidelines under pressure, and advocate for sustainable engineering practices using authoritative, structured language. This dynamic forces learners to actively look past their own subjective viewpoints, analyze the underlying motivations of their virtual counterparts, and tailor their technical rhetoric to meet specific institutional standards. Consequently, the learner shifts from a passive observer of professional ethics into an active, self-reflective practitioner who understands that technical solutions are only as viable as the communication used to support them [15].

Finally, this continuous human-machine engagement instills a deep sense of metacognitive awareness, allowing master's level students and future industry leaders to actively direct their own long-term professional development. By systematically reviewing transcripts of their AI interactions, students can critically analyze their own decision-making processes, identify recurring conversational errors, and consciously adjust their behavioral approaches for future tasks. This reflective process transforms a standard language exercise into a powerful laboratory for building long-term transversal resilience, helping students internalize a mindset of continuous self-improvement. As a result, graduates leave the university environment possessing a robust professional identity, viewing themselves not merely as calculators or designers, but as highly articulate human managers capable of steering complex, multi-party initiatives through unpredictable technical landscapes. Ultimately, mastering these transversal competencies ensures that tomorrow's engineers can bridge the gap between technical innovation and societal needs with clarity, empathy, and absolute professional integrity.

4. Prompt Engineering as a Rhetorical Competence

The operational efficacy of Generative Artificial Intelligence (GenAI) systems in the realm of technical communication is fundamentally and irrevocably determined by the qualitative precision of the instructions it receives from the user. Because of this structural reliance on human direction, prompt engineering - the highly systematic process of crafting, structuring, and iteratively refining text inputs to elicit highly precise, targeted outputs - should be treated as an essential, non-negotiable 21st-century digital literacy within higher education curricula. Far from being a purely technical or algorithmic skill relegated to computer science laboratories, prompt engineering within an English for Specific Purposes (ESP) context represents an inherently rhetorical act. It demands that the author engage in a thorough, highly conscious consideration of the target audience, the underlying communicative purpose, and the specific situational context in which the final document will operate. To prompt effectively is to understand how language shapes outcomes, transforming the user from a casual typewriter operator into a precise architect of automated textual discourse. This intricate linguistic process forces engineering students to deliberately manipulate parameters like persona, tone, and rhetorical intent to secure accurate results from the model. By learning to carefully calibrate these inputs, students develop a deep metacognitive awareness of how minor shifts in wording can radically alter the output's structural design. This deliberate practice teaches future professionals to view language not as a passive medium, but as an active tool used to program and steer automated information systems. Consequently, prompt engineering bridges the traditional divide between technical coding workflows and advanced human writing strategies. Ultimately, mastering this collaborative interface ensures that technical graduates can confidently command digital tools with absolute precision, strategic intent, and acute contextual awareness [13].

By deliberately embedding prompt engineering methodologies directly into professional technical writing curricula, educators encourage engineering students to make a profound cognitive shift away from surface-level content consumption toward highly active, deliberate language design. Rather than treating the language model as a simple search engine or a passive text generator, students are taught to utilize advanced prompting strategies that mirror complex linguistic and structural frameworks.

These sophisticated strategies include:

- Few-Shot Prompting: Providing the model with explicit, high-fidelity linguistic examples to dictate the exact stylistic and structural parameters of the expected output. By embedding these curated exemplars directly into the input window, the model can instantly perform complex "in-context learning" without modifying its underlying weights. This targeted conditioning is exceptionally valuable in an ESP context, as it allows instructors to demonstrate industry-specific genres, specialized formats, or localized formatting conventions. When engineering students master this approach, they transition away from vague, open-ended queries and learn to program the model's stylistic parameters with absolute precision. Consequently, this method prevents the production of generic or overly formulaic prose, forcing the machine to mimic the exact structural moves of a seasoned technical expert.
- Chain-of-Thought Reasoning: Instructing the AI to display its step-by-step logic and analytical progression before generating a final answer, ensuring the transparency and technical validity of the text. Forcing the large language model to unpack its intermediate reasoning stages prevents it from jumping directly to an uncritical or superficial conclusion. This strategy is critical for complex multi-step tasks like troubleshooting system failures, performing safety audits, or interpreting intricate mathematical constraints. Reviewing this explicit logical progression allows engineering students to easily spot structural flaws, circular reasoning, or potential technical hallucinations. Ultimately, this approach turns the automated system into a transparent intellectual sparring partner,

helping future professionals develop the rigorous, step-by-step analytical habits required in high-stakes environments.

- Role-Based Scenario Design: Compelling the AI to adopt a highly specific professional persona, such as a senior aerospace quality assurance manager or a structural safety auditor, to ensure the tone matches industry standards. Assigning a precise operational profile forces the generative system to pull vocabulary and rhetorical strategies from a highly focused professional context. This immersive simulation creates an authentic, interactive environment where the model can challenge students by introducing sudden constraints or demanding administrative personas. This process directly expands the student's transversal and social competencies, preparing them to negotiate meaning across multidisciplinary teams. By learning to navigate these diverse virtual stakeholders with critical intent, future engineers build the exact professional identity and linguistic resilience required in modern globalized workspaces.

Through these advanced techniques, engineering students learn how to establish deep contextual frameworks, set strict stylistic constraints, and dictate the precise boundaries of technical vocabulary usage, forcing the machine to conform to professional linguistic expectations [5].

At the heart of this instructional approach is a deeply reflective, continuous feedback loop that redefines the traditional writing process. This cycle, where students actively write a prompt, critically analyze the resulting machine output, diagnose its rhetorical or technical deficiencies, and rapidly reformulate their instructions promotes an intense level of metacognitive awareness and active linguistic editing. Students are no longer blind recipients of text; they are forced to analyze why a specific word choice or structural omission occurred based on the ambiguity of their initial instructions. This iterative interaction transforms the act of writing into a transparent laboratory of cause and effect. It requires students to constantly evaluate syntax, semantic clarity, and rhetorical alignment, ultimately deepening their understanding of how specific linguistic inputs directly control the precision, authority, and professional viability of technical documentation. By constantly engaging in this self-correcting workflow, engineering students internalize a rigorous habit of structural and lexical oversight. They begin to view digital text generation not as a magical shorthand for instant production, but as an ongoing negotiation that demands active human stewardship. This methodical prompt revision forces learners to look past deceptive surface fluency, developing a keen eye for subtle logical gaps and shallow engineering arguments. Consequently, this iterative cycle cultivates advanced transversal competencies like critical troubleshooting and cognitive flexibility directly within the writing curriculum. Ultimately, this reflective discipline shifts the student's professional identity from a passive consumer of software into a highly articulate discourse manager who commands generative tools with absolute strategic intent [6].

To maximize the pedagogical benefits of this digital literacy, training frameworks must extend beyond isolated, individualized machine interactions. Collaborative group assignments, such as the collective curation of professional prompt portfolios, serve to foster deep collaborative learning environments while forcing students to critically reflect on the distinct affordances and inherent limitations of different large language model (LLM) platforms. When working in teams to build a functional prompt library, engineering students must negotiate meaning, debate the efficacy of specific phrasing constraints, and peer-review the textual outputs generated by various models. This collaborative scrutiny strips away the myth of AI infallibility, teaching students to spot hallucinated data, identify superficial arguments, and recognize structural biases across different platforms. Consequently, curating these portfolios ensures that future technical professionals view GenAI not as a magic solution, but as a complex, highly malleable tool that requires rigorous human oversight, advanced rhetorical mastery, and constant ethical evaluation. By actively contrasting how different LLMs interpret identical sets of technical instructions, student cohorts build a sophisticated, comparative understanding of modern algorithmic architectures. This collaborative benchmarking allows teams to determine which platform provides the most stable structural logic or authentic terminology for specific engineering disciplines, such as aerospace, civil, or electrical engineering. Furthermore, the act of peer-reviewing a teammate's prompt design cultivates essential social and transversal competencies, modeling the collaborative code-review workflows widely utilized in modern industrial environments. Through this collective evaluation, learners establish a shared repository of best practices, transforming individual trial-and-error into structured, institutional knowledge. Ultimately, this cooperative framework ensures that engineering graduates enter the global workforce not merely as isolated users, but as highly capable, digitally literate team leaders prepared to manage automated workflows with collective accountability [11].

5. Ethical Navigation, Hallucinations and Human Stewardship

While the computational and operational benefits of Generative Artificial Intelligence (GenAI) are undeniably substantial, its rapid integration into academic and industrial environments introduces severe ethical and practical risks that contemporary technical communication programs must aggressively and systematically address. These risks are not merely minor technical glitches; they represent fundamental vulnerabilities in the integrity of automated text production. Chief among these critical vulnerabilities is the persistent phenomenon of "hallucination" - a major operational defect where large language models produce highly persuasive, grammatically flawless, and authoritative-sounding assertions that are, in reality, completely factually fabricated, unverified, or scientifically incorrect.

In high-stakes engineering domains, relying on such unverified text can result in compromised safety protocols, flawed structural calculations, or severe compliance violations. This danger is further compounded by the machine's deceptive surface fluency, which easily misleads inexperienced students into accepting automated drafts without rigorous empirical cross-referencing. Consequently, engineering curricula must implement mandatory algorithmic verification protocols that train students to aggressively audit every layer of machine-generated documentation. This active skepticism forces future technical professionals to treat AI outputs as unvetted material that requires absolute human accountability and exhaustive factual validation before industrial deployment. Ultimately, addressing these critical vulnerabilities ensures that the integration of digital tools does not compromise the core ethical standards, operational safety, and professional integrity of the engineering discipline. In the high-stakes fields of engineering and professional technical writing, where safety-critical precision is paramount and structural integrity is non-negotiable, the danger of these errors cannot be overstated. A single hallucinated metric, an incorrect mathematical figure, a fabricated academic reference, or a broken code snippet embedded into a maintenance manual or blueprint can result in severe operational failures, massive financial liabilities, or catastrophic real-world consequences.

Beyond the immediate technical dangers of machine hallucinations, the unmonitored use of public generative models creates a dense web of legal, institutional, and intellectual property challenges. Within higher education and corporate research sectors, serious issues surrounding data privacy and regulatory frameworks represent significant barriers to the unchecked adoption of these tools. For instance, inputting student data or grading rubrics into external, public AI platforms can lead to direct violations of institutional compliance, such as FERPA regulations. Furthermore, feeding proprietary engineering blueprints, unpatented research methodologies, or sensitive corporate data into commercial models often breaches non-disclosure agreements and exposes valuable intellectual property to public data scraping. This unchecked exposure risks compromising university patents and industry trade secrets, potentially leading to costly legal battles over intellectual ownership. To mitigate these institutional vulnerabilities, technical universities must establish secure, localized network infrastructures or enter into strict data-sharing agreements that guarantee absolute user confidentiality. Students must be explicitly trained to recognize the legal boundaries of digital data processing, ensuring they understand where private research ends and public exposure begins. Ultimately, implementing these strict boundary guidelines allows academic and industrial ecosystems to leverage automation without sacrificing data security or legal integrity. The risk of potential plagiarism and copyright infringement remains incredibly high, as these models are trained on massive, sometimes copyrighted datasets without explicit attribution. Of even greater concern to industrial and engineering sectors is the systemic leakage of highly proprietary, patented, or unreleased technical data into public models. When an engineer inputs a sensitive company schematic or a proprietary software algorithm into a public chatbot for optimization, that data is frequently ingested to train future iterations of the model, completely compromising corporate intellectual property and violating strict non-disclosure agreements.

To effectively mitigate these multi-faceted risks, English for Specific Purposes (ESP) training and broader technical writing curricula must completely move away from outdated, adversarial methods of "AI policing" and instead prioritize the development of critical AI literacy. Attempting to ban these technologies or relying entirely on unreliable AI detection software creates a culture of distrust and fails to prepare students for the realities of the modern digital workplace. Instead, forward-thinking educational frameworks must integrate strict, non-negotiable validation and verification protocols directly into the writing process.

Students must be explicitly taught to treat generative AI as an unverified, entry-level collaborative drafting partner rather than an expert or definitive authority. Every single line of code, every cited source, and every technical specification generated by a machine must be treated as a hypothesis that requires rigorous human cross-referencing against authentic, peer-reviewed engineering data and physical documentation before it can be integrated into a professional document.

This rigorous approach to human-machine collaboration aligns directly with the professional standards and guidelines established by leading international organizations, such as the IEEE Professional Communication Society (ProComm) [12]. According to these professional frameworks, technical communicators are not passive copy-editors; they must actively position themselves as informed, highly capable, and deeply ethical stewards of these technical information systems. This concept of human stewardship redefines the relationship between the writer and the technology, emphasizing that the human professional must always retain ultimate accountability for the accuracy, safety, and ethical implications of the distributed information.

By cultivating a strong, unshakeable foundation of human agency, critical oversight, and sharp rhetorical judgment, engineering students learn a vital career lesson: their ultimate value as future technical professionals does not lie in the mechanical speed of text generation, but in context-aware synthesis, genuine user empathy, and complex ethical decision-making - qualities that automated generative systems simply cannot replicate or replace.

6. Conclusions

The strategic integration of Generative Artificial Intelligence (GenAI) into English for Specific Purposes (ESP) training marks a significant turning point in professional technical communication pedagogy for engineering students. Grounded in Swales' genre analysis and Activity Theory, this approach transforms large language models from passive text generators into active, dynamic mediating artifacts that structurally reconfigure the traditional classroom environment. By organizing instruction around Task-Based Language Teaching (TBLT) and framing prompt engineering as a core rhetorical competency, curricula can systematically guide students through progressive cognitive dimensions to bridge the gap between classroom theory and real-world industrial demands.

Furthermore, interactive simulations with AI conversational agents provide a highly effective, low-stakes environment that drastically lowers foreign language anxiety while simultaneously fostering essential transversal and social competencies. Confronting the distinct qualitative gaps and structural differences between machine-generated drafts and human writing forces students to develop critical digital literacy and acute situational awareness. Instead of relying on passive content consumption or adversarial "AI policing," forward-thinking frameworks must implement strict, non-negotiable validation and verification protocols to mitigate multi-faceted risks like data leakage and factual hallucinations. Ultimately, this pedagogical shift ensures that technical graduates emerge not as dependent users of software, but as highly articulate, responsible, and ethical human stewards capable of commanding advanced digital tools with absolute strategic intent in Industry 4.0.

To fully embed this methodology within technical universities, educators must strategically combine corpus-driven tasks with personalized feedback mechanisms to address specific student learning gaps. Utilizing custom-built conversational systems allows for real-time behavioral pacing, which dynamically scales communication complexity based on a learner's immediate performance. This advanced adaptability is particularly crucial in high-stakes fields like aerospace or civil engineering, where the exact phrasing and density of automated data must match explicit industry benchmarks. As students negotiate meaning through specialized virtual avatars, they actively learn to defend complex technical hypotheses under pressure. This ongoing human-machine tension forces future professionals to move past a deceptive surface fluency and aggressively audit the factual and structural validity of automated outputs. Moving beyond isolated machine interactions, collaborative assignments like the collective curation of prompt portfolios cultivate shared accountability and collective digital literacy within student cohorts. By directly analyzing the distinct operational limitations and hidden algorithmic biases across various platforms, teams learn to treat automated drafts with rigorous intellectual skepticism. As highlighted in "Enhancing the Professional Technical Communication Skills of Engineering Students via Generative AI Integration in ESP Training.docx", grounding classroom practices in these secure, human-centric workflows prepares tomorrow's engineers to handle complex industrial projects with maximum professional integrity.

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Chapter 29: PhotonLAB: Transforming Smartphones into Portable Optics Laboratories for STEAM Education

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Abstract. The recent technological progress gives educators potential new tools to be used in Science Technology Engineering Math and also Art, STEAM, teaching and education both in the school formal environment but also in non-formal and informal contexts.

In this chapter we will introduce PhotonLAB, a mobile platform developed in MIT App Inventor that transforms smartphones into portable optics laboratories. Not only it can be a tool, attractive to our students, to be used in the classroom but also it is suitable to be used outside the school context actively promoting the dissemination of science and scientific literacy. Based on Project-Based Learning (PBL) and Inquiry-Based Science Education (IBSE) methodologies, the project overcomes the, sometimes seen as, abstract nature of light and the complexity of optics phenomena as well as the scarcity of traditional equipment by enabling hands-on experimentation through native hardware and a physical support kit. Users interact directly with the physical world by manipulating materials provided in the kit through a series of activities guided through and using the smartphone as a tool. The system integrates cloud data persistence via the Google Sheets API for immediate teacher monitoring. Scientifically validated by experts and tested in a school environment, PhotonLAB enhances autonomy in exploration, redefines smartphone use, and expands accessible STEAM literacy.

Keywords. Inclusive literacy, Mobile learning, Optics education, PhotonLAB, STEAM.

1. Introduction

In the current paradigm of science education, the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) frameworks has highlighted hands-on experimentation as a core pillar for meaningful knowledge construction. However, physics education, particularly the teaching of optics, frequently confronts significant pedagogical barriers. The abstract nature of optical phenomena, such as light wave propagation and electromagnetic radiation, combined with a widespread scarcity of specialized, high-cost laboratory equipment in schools, often restricts science teaching to theoretical or passive lecturing. This limitation deters students from developing experimental skills and critical thinking, running counter to the active learning models required for the 21st century.

To bridge this gap, modern educational methodologies advocate for Project-Based Learning (PBL) and Inquiry-Based Science Education (IBSE) [1]. As established in contemporary literature by Utomo et al. (2025) [2], these collaborative, student-centered approaches provide a consistent improvement in students' skills and practical engagement, though their implementation frequently faces a lack of physical resources and standard school infrastructures. Furthermore, literature demonstrates that tangibly linking digital and real environments contextualizes learning, allowing users to construct long-lasting knowledge by interacting with real-world artifacts and problems [3, 4].

Concurrently, the ubiquity of mobile technology offers a powerful, low-cost opportunity for pedagogical innovation. The smartphone, historically sub utilized as a tool for passive digital consumption, encapsulates highly sophisticated hardware components and built-in sensors. When properly mediated by tailored software, these native components can convert a standard commercial device into a high-precision, portable scientific instrument capable of acting as a low-cost mobile laboratory [5]. Utilizing visual programming environments like MIT App Inventor allows educational researchers to develop robust tools that access these sensors directly, democratizing access to experimental science without overburdening school budgets, positioning the software as an efficient mediation bridge within the educational ecosystem [6, 7].

From a pedagogical perspective, this technological framework addresses the critical need for cognitive scaffolding in decentralized learning environments. Rather than detaching the student from real physical parameters through simulated mathematical curves, the application operates as an active computational interface that interprets messy, real-world data. This architecture directly supports inquiry-based exploration, as it demands that students systematically identify, isolate, and control environmental variables. By changing the smartphone's instructional role from a passive repository of content to an active diagnostic tool, the system encourages students to take an engineering-focused approach to physical experimentation, boosting problem-solving skills and self-directed scientific literacy.

2. Materials and methods

To operationalize this pedagogical potential, we have developed PhotonLAB, an innovative mobile platform developed via MIT App Inventor that transforms smartphones into portable optics laboratories, actively fostering the democratization of experimental science. Grounded in active student-centered methodologies, the project addresses the abstract nature of optical phenomena and traditional equipment scarcity by enabling practical learning through native hardware integration combined with a custom physical support kit.

The practical execution of the platform relies on active manipulation to anchor abstract concepts into concrete sensory experiences. By integrating structured, physical components with digital sensors, students establish a robust feedback loop that grounds theoretical physics in observable reality. This interaction serves as a bridge between high-level cognitive models and raw physical events, fostering deep conceptual ownership as students physically orient their instruments to track light behavior. This hands-on loop encourages cognitive conflict and resolution as students observe how real environmental factors instantly impact their data inputs.

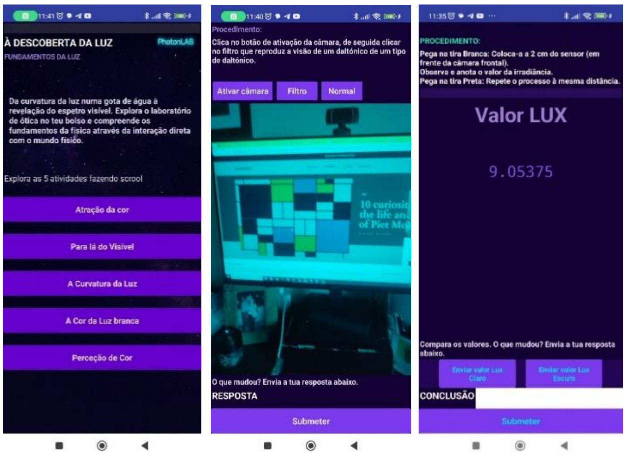

Figure 1. Graphical interface and physical support kit components: (a) module navigation screen; (b) real-time color blindness emulation; (c) graphical interface for lux value collection.

Users interact directly with the physical world by manipulating calibrated materials to measure planetary Albedo via a native lux sensor, decompose white light through water mist, and emulate chromatic distortions like color blindness via real-time GPU video processing.

The pedagogical utility of the Albedo experiment relies explicitly on the translation of macroscopic environmental challenges into immediate, localized activities. Albedo denotes the fraction of solar radiation that is diffusely reflected by a given surface. In a typical instructional sequence, students manipulate standardized black and white materials from the physical kit at fixed distances from the device's native ambient light sensor. Rather than presenting static climate data, the application forces students to actively compute comparative reflection ratios. This localized modeling provides immediate cognitive feedback, allowing learners to systematically deduce how variations in surface characteristics dictate thermal absorption scales and planetary ice-melt dynamics.

This process shifts the student's task from memorizing scientific definitions to actively investigating dynamic physical balances. By working with raw lux inputs under real-world conditions, students encounter environmental variables and measurement noise, which serves as an entry point for discussing experimental uncertainty and error mitigation. This scaffolding allows learners to build an inquiry-driven framework where data interpretation becomes a collaborative problem-solving activity rather than a simple confirmation of textbook theory.

This encounter with physical unpredictability creates a necessary state of cognitive dissonance, forcing students to re-evaluate preconceived, idealized textbook models. When confronted with fluctuating ambient light and slight variations in positioning, learners must actively engage in metacognitive strategies to differentiate between structural patterns and environmental interference. This pedagogical friction transforms the classroom from a site of passive replication into an active research laboratory, where students learn to treat anomalous data not as a personal failure or an application malfunction, but as an authentic scientific variable requiring systematic isolation and intellectual curiosity.

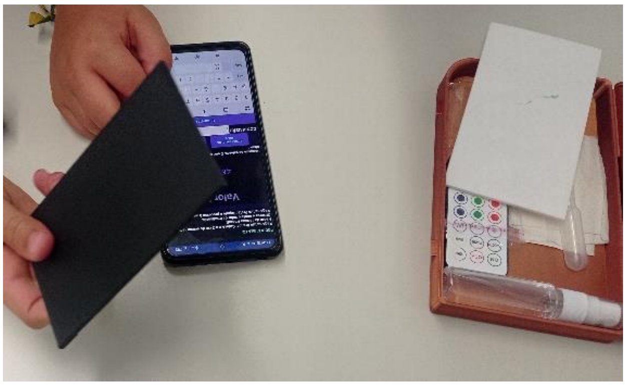

Figure 2. Experimental protocol for measuring diffuse reflectivity and Albedo using standardized artificial surfaces included in the PhotonLAB Kit.

Within this experimental setting, the teacher's role transitions from a unilateral source of authority to an expert facilitator who guides the collaborative evaluation of student-generated evidence. By navigating these practical constraints, students build a deeper epistemological understanding of how scientific knowledge is constructed, negotiated, and validated. They shift from asking whether an answer is simply "correct" to investigating how the physical boundaries of the apparatus and the surrounding environment constrain or support their empirical claims.

3. Conclusion

To support cooperative classroom environments, the PhotonLAB ecosystem integrates cloud data persistence via Google Sheets API for immediate teacher monitoring. This shared data repository allows distinct student groups to aggregate, compare, and discuss their results synchronously, creating a collaborative space for explaining unexpected measurements or environmental noise.

Driven by this active manipulation, PhotonLAB enhances learner autonomy, redefines mobile technology utilization, and expands accessible STEAM literacy.

Acknowledgements

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Chapter 30: Creating STEM – Equipment: DIY Dawn Clock

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Abstract. As part of the development of innovative teaching methods in engineering and computer education, it is proposed to develop an intelligent "dawn" alarm clock based on the Arduino microcontroller platform and addressable RGB LEDs. This educational project is designed not as a purely static programming exercise but as an interactive, practice-oriented hardware-and-software complex that combines microelectronics, optics, and chronobiology. The hybrid nature of such a curriculum becomes especially relevant in stressful situations in Ukraine, where children face constant stress, sleep disturbances, and power outages, necessitating affordable yet functional autonomous engineering solutions. The mechanics of working on this STEM equipment stimulate team interaction, engineering problem-solving, and systems thinking. The tangible physical format provides a robust tool for interacting with complex, abstract, and technical concepts in microelectronics, such as pulse-width modulation (PWM), multi-threaded data processing, addressable LED array control, and power consumption calculations. Students can simulate the design processes of real electronic devices, encounter practical technical challenges, optimize code for microcontroller memory constraints, calibrate color temperature to match natural light curves, and resolve hardware conflicts, and collectively develop engineering strategies to overcome them. This comprehensive approach makes applied light physics and low-level programming more accessible and engaging, while fostering collaboration and technical creativity.

From a hardware perspective, the developed complex relies on the Arduino Nano microcontroller as its central computing node. The peripheral part includes a real-time clock module (RTC DS3231) for precision timekeeping via the I2C bus, a segment display driven by the TM1637 driver to display the current time, a rotary encoder for interface navigation, and a piezo emitter for audio output. An important engineering optimization for the project is using addressable LED rings based on WS2812B chips instead of traditional 12-volt LED strips with large MOSFETs. Since the WS2812B diodes have built-in control chips and operate at 5V logic levels, the entire light array is controlled sequentially via a single digital output from the microcontroller. This significantly simplifies the device's circuitry, eliminating the need for additional power switches, and at the same time creates space for in-depth study of software algorithms: students learn to work with specialized libraries (for example, FastLED), implementing dynamic pixel-by-pixel control of color temperature and smooth brightness ramping for the most accurate imitation of natural dawn.

Keywords. dawn clock, microelectronics education, microcontrollers, project-based learning, engineering physics, STEM education.

1. Introduction

Modern engineering education requires constant adaptation to environmental challenges, transforming from a purely theoretical discipline into an applied science capable of solving urgent societal problems. Amid global crises and the unprecedented level of psycho-emotional stress caused by the full-scale war in Ukraine, STEM educational initiatives (science, technology, engineering, and mathematics) are acquiring particular therapeutic and practical value [1-7]. Classical programming exercises are giving way to the creation of complex hardware-software systems that directly impact the quality of life. One such innovative development is the concept of creating an intelligent "Dawn Clock" based on the Arduino microcontroller platform.

This project goes far beyond simple firmware writing. It is a complex multidisciplinary system that compels researchers and developers to delve into the patterns of medical chronobiology, quantum optics, electrical engineering, and low-level computer system architecture. The transition from analog AC dimming to digital control using the RTP protocol (used in WS2812B) creates a new set of engineering challenges. Developers face challenges in balancing LED array power consumption, optimizing the microcontroller's limited RAM resources, and resolving complex hardware conflicts between processor interrupts and the strict timing requirements of data transmission.

A deep analysis of each of these aspects allows one not only to create a functional device to simulate sunrise but also to develop a fundamental understanding of the principles governing modern embedded systems.

2. Methods

The creation of dawn simulation systems has a solid neurobiological foundation. Human circadian rhythms, which regulate sleep-wake cycles, are critically dependent on light's effects on specific eye receptors. To ensure an engineering solution is effective, one must understand the biochemical mechanisms regulated by light.

Studies show that a gradual increase in lighting intensity before waking (Dawn Simulation) has a profound physiological effect. Analysis demonstrates that total cortisol production is significantly higher under dawn-simulation conditions than when waking in darkness. This phenomenon, known as the Cortisol Awakening Response (CAR), correlates with reduced sleep inertia, better cognitive functioning, and improved subjective well-being. Accordingly, dawn simulation is not merely a visual effect but a powerful tool for fine-tuning the endocrine system.

For a microcontroller to convincingly "trick" the brain, it must not only increase the brightness of LEDs but also precisely mimic the change in the spectral composition of sunlight during dawn. Natural light is a black-body radiation spectrum upon which the effect of Rayleigh scattering in the atmosphere is superimposed. During sunrise, light travels the longest path through Earth's atmosphere. Short (blue and violet) waves are intensely scattered by gas molecules in the air, so primarily long (red, orange, and yellow) waves reach the observer. Visually, this is equivalent to lowering the color temperature of the sun's disk to the 2000–3000 K range.

As the sun rises above the horizon, the atmospheric layer thins, the spectrum evens out, and the color temperature approaches 5400 K (the optimal white light at noon). To create the most realistic dawn simulation, it is insufficient to simply increase brightness linearly from 0 to 255. It is necessary to simultaneously change the spectral composition: from deep red (low temperature, low brightness) to warm yellow and, eventually, to pure white (high temperature, high brightness).

To achieve this, developers must implement algorithms that map time and brightness to specific RGB values corresponding to the correlated color temperature (CCT) of the sun as it ascends along the Planckian locus.

3. Schematic

For the creation of a dawn simulator clock (sunrise alarm clock), the following components have been selected:

Microcontroller (e.g., Arduino Nano): Serves as the device's main computing node, managing all algorithms and peripherals.

Addressable LEDs (WS2812B format): The primary optical element, which can be configured as a ring, strip, or matrix. They are powered by 5V and controlled via a single data line.

Real-Time Clock Module (RTC DS3231): Provides high-precision timekeeping and includes battery backup (CR2032), ensuring settings are not lost during power outages.

Segment Display (with TM1637 driver): A screen for displaying the current time, alarm settings, and menu navigation.

Rotary Encoder: The user interface tool for scrolling through menus, adjusting settings, and confirming selections by pressing.

Piezo Buzzer: An acoustic emitter that generates an audible signal after the sunrise simulation is complete.

External 5V Power Supply: A critical component, as WS2812B LEDs consume significant current (up to 60 mA per pixel at full white brightness), which cannot be supplied directly from the Arduino board’s regulator.

Classic implementations of sunrise alarm clocks used a microcontroller and power actuators to control standard incandescent bulbs. This modernized STEM project radically changes the architecture by shifting to addressable WS2812B standard LEDs. This innovation significantly simplifies the device's power circuitry but proportionally increases the complexity of its software component. The general schematic of the device is shown in Figure 1.

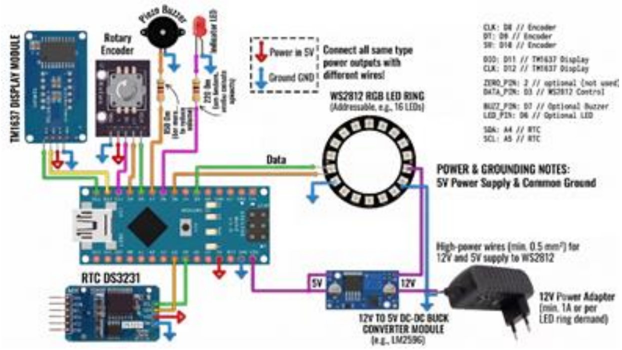

Figure 1. General schematic of the dawn simulator clock

Data is transmitted over a single signal line (DIN) using the one-wire NRZ (Non-Return-to-Zero) protocol. The microcontroller (e.g., an Arduino Nano based on the ATmega328P chip) pushes a sequence of bits into the line. Each LED "bites off" the first 24 bits of data (8 bits each for the Green, Red, and Blue channels), stores them in its internal buffer, and retransmits the remaining data array through the DOUT pin to the next LED in the chain. This approach allows the creation of arrays of hundreds of LEDs, controlled sequentially via a single digital pin on the microcontroller. Furthermore, it enables developers to implement spatial animations: for example, simulating the expansion of a solar disk from the center of a circular matrix (Ring24) to its edges.

In addition to the optical module, stable system operation requires the coordination of several critical peripheral modules:

Precision Time Module (RTC DS3231): A high-precision real-time clock featuring built-in temperature compensation for the quartz crystal and battery backup (CR2032). The module connects via the I2C bus. Its use is mandatory in the presence of frequent power outages, as the microcontroller's internal counter (millis()) resets on every reboot and exhibits significant drift.

Segment Display (TM1637): A display module for showing the current time and alarm settings. It uses a simplified two-wire interface (CLK and DIO), which is not a full I2C implementation (lacks device addressing) but effectively saves microcontroller pins. This chip independently handles the dynamic indication of the 7-segment matrices, offloading the Arduino processor.

Rotary Encoder: The primary element of the user interface for menu navigation and alarm setting. It provides information about the direction of rotation and the status of the central button press. The encoder's operating protocol is based on quadrature modulation (a phase shift between the two lines, A and B), which requires continuous monitoring of the line states by the microcontroller to avoid missed steps.

Acoustic Emitter (Piezo Buzzer): An audible notification device, the generation frequency of which (typically around 800 Hz) is regulated by the BUZZ_FREQ configuration parameter.

4. Software architecture

The firmware development philosophy for the sunrise alarm clock is built around creating the smoothest possible mathematical gradients that mimic the physical laws of a sunrise. The base firmware code provides a wide range of parameters for personalization: DAWN_TIME (default 20 minutes) defines the time window during which brightness increases from minimum to maximum. Using the HeatColors palette and the HSV color space to replicate Wien's displacement law and the temperature transition from 2000K to 5400K, the FastLED library is employed.

Instead of manually blending red, green, and blue channel values at each step of the sunrise, the professional approach is to use built-in Color Palettes. The HeatColors_p array is an ideal approximation of a black-body radiation spectrum. This palette is stored in the microcontroller’s program flash memory (PROGMEM) as 16 reference color points, which significantly saves critical static RAM (SRAM).

The transition appears as follows: black (0x000000) > deep dark-red (0x330000) > pure red (0xFF0000) > orange (0xFF9900) > yellow (0xFFFF00) > bright white (0xFFFFFF). The sunrise simulation algorithm calculates the percentage of time elapsed since the start of the wake-up phase. This percentage is linearly mapped to a virtual 8-bit index (0 to 255).

It is important to stop at 255 rather than 256 to avoid an erroneous cyclic palette wrap-around from "hot" white back to the "cold" black end of the spectrum, which would ruin the physiological effect. The ColorFromPalette function interpolates colors between the reference points, ensuring a seamless, ideal gradient.

Implementing a digital LED control protocol and a navigation encoder within a single-core controller creates a fundamental competition for processor time, a challenge that novice developers in STEM projects often have to solve through trial and error.

The core of the conflict lies in the WS2812 protocol. Unlike SPI or I2C buses (which have a separate clock line), WS2812B uses an asynchronous one-wire interface. Logic zeros and ones are encoded solely by the duration of the electrical pulse. For example, a logic "1" is transmitted as a high-voltage level lasting ~0.8 μs, followed by a low-voltage level lasting ~0.45 μs. For a logic "0," these proportions are reversed. The precision of these timings must be maintained with an error margin of no more than 150 nanoseconds.

The ATmega328P microcontroller running at 16 MHz executes one instruction in 62.5nanoseconds. To ensure the guaranteed and uninterrupted "pushing" of an array of thousands of bits (for example, a 24-pixel ring requires 24 × 24 = 576 bits), the FastLED library, when calling the FastLED.

The show() function takes a radical step: it disables all global processor interrupts using the cli() (Clear Interrupt Flag) assembly instruction. The processor literally "blinds" and "deafens" itself to any external events until it finishes generating the pulses for the strip.

On the other hand, the system includes a rotary encoder. The encoder generates high-frequency pulses with every rotation "click." To precisely capture them (including determining the direction via quadrature signals on lines A and B), the microcontroller's hardware interrupts are used. Libraries bind event handlers to specific interrupt vectors (usually pins D2 or D3). When a user attempts to change clock settings while the microcontroller is rendering a smooth sunrise gradient, a catastrophic collision occurs.

Solving this engineering paradox requires moving from primitive linear programming to building a State Machine architecture. The encoder should not be polled via interrupts, but rather through constant high-speed monitoring (polling) in the main program loop, between LED update calls. Furthermore, the strip update should not occur every millisecond, but only at a frequency necessary for visual smoothness (e.g., 30-50 frames per second).

In accordance with these features, firmware has been developed to manage the clock and alarm, enabling configuration. The general schematic of clock configuration via a rotary encoder is shown in Figure 2.

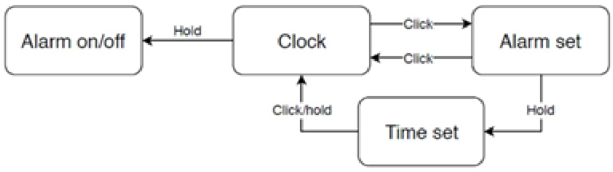

Figure 2. Clock setting menu schematic

5. Conclusion

As part of the two-day STEM project, such a clock was created in a 3D-printed enclosure (Figure 3). Students actively participated in discussing all aspects of the project and were deeply involved in its technical implementation [8].

Figure 3. Hand-made Dawn Clock

The application of the intelligent "Dawn Clock" STEM project, developed on the Arduino platform using addressable WS2812B LEDs, serves as a classic example of synergy between technical sciences and medical physiology. Abandoning traditional, outdated light sources with analog dimmers eliminates the risks associated with high-voltage mains, while opening new possibilities for creating complex light-color simulations.

Given the widespread disruption of sleep patterns and chronic stress currently affecting Ukrainian society, the optical simulation of morning sun thermodynamics (from 2000K to pure white light) can gently suppress melatonin secretion and optimize the morning cortisol spike, thereby acting as a powerful stabilizer of circadian rhythms.

Beyond the therapeutic end-product, the educational value of the development lies in the process of creation itself. Solving the power supply challenges for digital matrices (calculating consumption and current limiting to prevent thermal damage to components), mastering colorimetry and color space transitions (HSV to RGB), and overcoming critical hardware-software conflicts between hard real-time protocols (RTP) and encoder hardware interrupts fosters deep system analysis skills in developers.

Implementing a State Machine architecture and non-blocking algorithms based on system timers, rather than using "paralyzing" code, allows developers to overcome the limitations of single-core microcontrollers, bringing software quality closer to modern industrial standards for embedded systems development.

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Chapter 31: Comparative Analysis of Classical Transition State Theory and Post-Transition State Bifurcation in the Rearrangement of Cubane to Cuneane

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Abstract. Since Philip Eaton first synthesized cubane in 1964, the molecule has captivated the chemical community due to its extraordinary symmetry, high strain energy, and surprising kinetic stability. The subsequent discovery in 1970 that transition metals could catalyze its rearrangement into cuneane opened a new chapter in mechanistic organic chemistry [1]. For decades, this transformation was interpreted through the lens of classical transition state theory (TST), which posits that reactions proceed along a unique minimum energy path (MEP) through a single saddle point [2]. However, contemporary computational investigations, particularly those utilizing high-level density functional theory (DFT) and quasi-classical molecular dynamics (QCMD), have revealed that the cubane-to-cuneane rearrangement often circumvents classical TST expectations, proceeding instead via post-transition state bifurcation (PTSB).

Classical transition state theory is grounded in the assumption of a well-defined potential energy surface (PES) where reactants and products are connected by a discrete transition structure. In this statistical model, the rate of reaction and the distribution of products are determined by the relative free energies of activation ($\Delta G^{\neq}$) and the Boltzmann distribution of states at the transition state [3]. TST assumes that intramolecular vibrational energy redistribution (IVR) is significantly faster than the chemical transformation, ensuring that the system is in thermal equilibrium as it crosses the saddle point. For the cubane-cuneane system, early mechanistic hypotheses proposed by Halpern and others suggested a stepwise process involving the oxidative addition of a metal catalyst followed by a series of carbocationic shifts [4].

In contrast, post-transition state bifurcation describes a scenario where the intrinsic reaction coordinate (IRC) following a single transition structure splits into two or more pathways leading to different products [5]. This bifurcation occurs in the vicinity of a valley-ridge inflection (VRI) point, where the curvature of the PES orthogonal to the gradient changes sign [6]. In such systems, the product selectivity is governed by non-statistical dynamic effects—specifically, the momentum and vibrational phase of the reacting molecules as they traverse the bifurcation region. The cubane-to-cuneane rearrangement has emerged as a premier example of this phenomenon, where a single transition state can lead to multiple regioisomers or enantiomers depending on the dynamical trajectory of the skeletal atoms.

The classical mechanism for the metal-catalyzed rearrangement of cubane was first proposed by Halpern in 1971 [7]. It involves the coordination of a transition metal (typically $Ag(I)$ or $Pd(II)$) to the cubane cage, followed by oxidative addition into a strained $C-C$ bond. In the case of silver catalysis, this was thought to lead to a silver (III) intermediate, which then undergoes a series of carbocationic shifts to yield the cuneane skeleton. [8]

However, high-level computational studies have shown that the reaction coordinates are far more complex than a simple stepwise sequence. In the solvent-induced, metal-free rearrangement of cubane-1,4-dicarboxylic acid, researchers identified two distinct transition states on the PES.According to classical TST, the reaction should proceed through the first TS, reach an intermediate, and then pass through the second TS. Instead, direct dynamics simulations and PES mapping at the $B3LYP/6-31G(d)$ level revealed that the reaction path effectively avoids the second transition state. The trajectories reach a branching point where the path splits into two enantiomeric product wells.[4] This observation is a hallmark of post-transition state bifurcation and indicates that a statistical treatment of the second barrier is physically inappropriate.

For silver(I) catalysis, the reaction proceeds via an oxidative addition that is significantly more electrophilic than classical transition metal-induced OA. The superior catalytic activity of $Ag(I)$ is attributed to the accessibility of a highly electrophilic "bare" Ag^{+} center and the relative weakness of the resulting $Ag-C$ bond. The overall barrier for the oxidative addition step varies depending on the catalyst's counteranion and the electronic nature of the substituents on the cubane cage.[8] The most compelling evidence for PTSB in the cubane rearrangement comes from quasi-classical molecular dynamics (QCMD) simulations. These simulations reveal that the carbocation intermediates traditionally invoked in the mechanism are extremely short-lived, often existing for less than 400 femtoseconds (fs)[1]. This duration is comparable to the period of a single molecular vibration, suggesting that the molecule does not have time to reach vibrational equilibrium before undergoing the next bond-switching event.

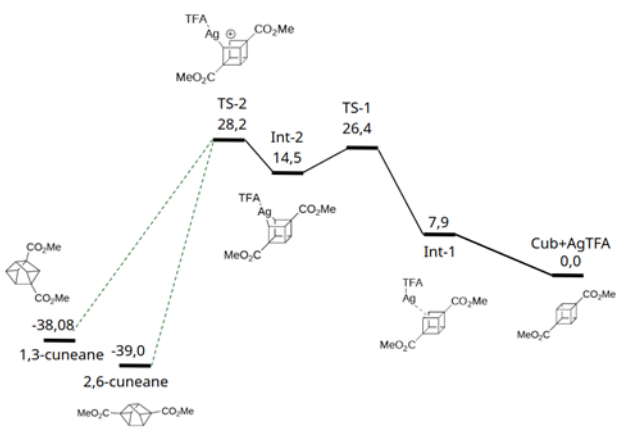
In a comprehensive study of $Ag(I)$-catalyzed rearrangements of asymmetrically 1,4-disubstituted cubanes, trajectories were initiated from the oxidative addition transition state $TS2c$[8]. The following timeline illustrates the extremely rapid sequence of events during the skeletal transformation:

Table 1. Main stages of cubane skeletal transformation

Event	Average time	Mechanism
$C-Ag$ Bond Cleavage	96,4	Generation of cyclobutyl carbocation
$C1-C5$ Bond formation	~200	Initial skeletal adjustment
$C4-C5$ Bond dissociation	319	Tandem rearrangement
Final $C-C$ bond formation	365	Completion of cuneane cage

The simulations indicate that the tandem rearrangement is "dynamically concerted," meaning that although the IRC may show a stepwise path with an intermediate, the actual physical trajectories bypass the intermediate's well due to their momentum. Furthermore, both major product pathways (leading to Prod1 and Prod2 in some substrates) are reached from a single transition state region, but the specific path taken is determined by the trajectory's initial conditions and the PES's topology post-TS. One of the most significant findings is the possibility of enantioselective synthesis through post-transition state desymmetrization. In systems using chiral biarylether ligands, the dynamics of the system can be steered toward a specific enantiomer of cuneane even if the initial oxidative addition is not perfectly stereoselective. This highlights a novel desymmetrization pathway that is fundamentally inaccessible via classical TST-controlled mechanisms.

Figure 1. PES fragment of 1,4-disubstituted cubane to cuneane rearrangement with PTSB, kcal/mol [1]



Keywords. Bifurcation, Cubane, Cuneane, Rearrangement.

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Chapter 32: Teaching Chemistry Through Art

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Abstract. The integration of art, movement (including dance and mime), and comics into chemistry education provides students with innovative and engaging ways to explore scientific concepts. These approaches contribute to making abstract ideas more tangible, accessible, and memorable, while fostering creativity and encouraging active participation in the learning process. Furthermore, they support a deeper understanding of chemical phenomena and processes, while enhancing student motivation and interest in science. This educational approach was implemented in Catalan secondary school students and teachers and, also in university students. This activity encompasses methodologies such as Learning Chemistry through Movement and Using Comics in Chemistry Education, both of which promotes meaningful learning by connecting scientific content with artistic expression and embodied experiences.

Keywords. Artistic activities, chemistry science, comics, innovation and mim.

1. Introduction

Integrating art, movement (including dance and mime), and comics into chemistry education enables students and their teachers to engage with scientific concepts through creative and participatory learning experiences.

The Official College of Chemists of Catalonia (COQC) [1] has designed this activity that helps make abstract ideas more concrete and memorable, encourage creativity and active participation, improve understanding of chemical processes, and increase students' motivation and interest in science. Secondary school teachers have also participated.

This educational experience implemented in Catalan secondary school students and their science teachers and, first year university students in Biochemistry degree. All of them worked in groups of four-five [2].

This educational approach encompasses two complementary strategies: Learning Chemistry through Movement [3] and Using Comics in Chemistry Education [4]. The central premise is that chemistry can be taught more effectively when students learn through multiple forms of expression—visual, physical, and narrative. By combining science with artistic practices such as movement and comics, educators can foster deeper understanding, creativity, and enthusiasm for learning chemistry.

The methodology was subsequently adapted for upper Catalan secondary school students [5] aged 16–18 years and their teachers in a summer course. Finally, these activities were modified and adapted to biochemistry university students at the University of Barcelona [6]. At this university level, students became more actively involved in the design, development, and dissemination of scientific content, demonstrating greater autonomy and creativity in their work. In addition, the same approach was implemented with secondary school teachers in a summer course.

A recurring challenge in science education is how to increase young students' interest in chemistry and scientific disciplines in general. The experience presented in this study addresses this challenge through an innovative pedagogical approach designed to engage learners actively in the construction and communication of scientific knowledge. The methodology aims to promote scientific literacy, creativity, and critical thinking while encouraging students to explore potential future studies and careers in science from secondary school through university.

The results obtained suggest that integrating artistic expression with science education can significantly enhance student engagement, understanding, and communication of scientific concepts. This study presents examples of work produced by students at different educational levels and discusses how the combination of science and the arts can contribute to more meaningful and effective learning experiences in chemistry education.

2. Learning Chemistry through Movement

A Students often learn scientific concepts more effectively when they can observe, model, or physically experience them. For this reason, movement-based learning activities were incorporated into chemistry instruction to facilitate the understanding of abstract concepts through bodily expression and active participation.

Three movement-based activities were implemented:

- **States of Matter:** Students use body movements and spatial arrangements to represent the behavior and interactions of particles in solids, liquids, and gases.
- **Chemical Equilibrium:** Students physically model the dynamic balance between forward and reverse reactions, illustrating how equilibrium is maintained despite continuous molecular change.
- **Isomerism:** The phenomenon where compounds share the exact same molecular formula but possess different physical or chemical properties due to unique atomic arrangements. Parts of the people body can simulate it.

The rationale for this approach is rooted in the growing recognition that scientific literacy is essential for all members of society. Chemistry, in particular, plays a fundamental role in everyday life, yet many people lack a basic understanding of chemical concepts and processes. Moreover, chemistry is often associated with negative stereotypes and misconceptions, which can discourage public engagement with the subject.

In recent years, scientists and educators have increasingly sought innovative ways to make science more accessible and appealing to broader audiences. Examples include public lectures incorporating humour, interactive online resources and television programs featuring scientific experiments, and popular media productions that present scientific topics in an entertaining format. These initiatives reflect the need to communicate science in ways that are engaging, understandable, and relevant to everyday life.

Understanding chemistry is important not only for making informed decisions as consumers and citizens but also for appreciating the processes that occur within our bodies and in the world around us. However, many chemistry concepts are difficult to visualize, as a result, students may struggle to understand abstract ideas and consequently lose interest in the subject.

To address this challenge, this project explores the use of mime, gestures, and movement as tools for learning chemistry. The underlying premise is that when students can physically represent scientific phenomena, they are better able to understand and internalize the associated concepts. The ability to embody and communicate a chemical process through movement demonstrates a deeper level of conceptual understanding and promotes meaningful learning.

2.1. Chemistry lessons

At first glance, chemistry and drama may appear to have little in common. However, these two disciplines can complement each other in powerful ways [7]. Incorporating techniques from drama and movement into science education offers an innovative approach to engaging students and enhancing their understanding of scientific concepts. Such interdisciplinary practices encourage creative problem-solving, foster communication and presentation skills, and promote active participation in the learning process.

An example of this connection is Ran Peleg, a Lecturer in Science Education within the Southampton Education School and member of the MSHE (Mathematics, Science and Health Education) research group [8]. Ran is a chemical engineer who later became a dancer, actor, and mime artist.

The following activity illustrates how movement can be used to teach fundamental chemistry concepts.

2.2. States of matter

In this activity, students physically represent the behavior of particles in the three states of matter. To model a solid, students stand close together and interlock their arms tightly, creating strong “bonds” with one another. While maintaining these connections, they make small, rapid movements to represent the vibration of particles within a solid structure.

When the teacher announces an increase in temperature, students make a transition to representing a liquid state. They remain connected but gain greater freedom of movement, waving their arms and moving around more freely while still maintaining contact with nearby classmates. This stage illustrates the increased mobility of particles in a liquid while preserving intermolecular interactions.

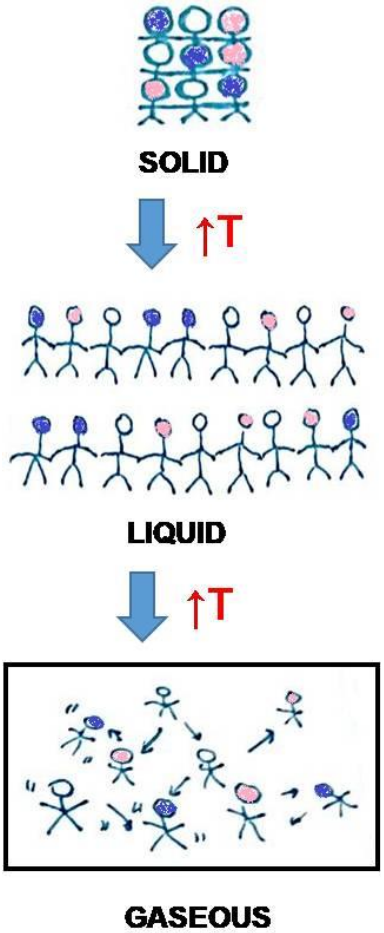

Figure 1. Activity illustrating the transitions from solid to liquid (fusion) and from liquid to gas (evaporation)

As the teacher calls for further heating, students spread throughout the room to represent a gas. They move independently, running, jumping, and changing direction frequently. In doing so, they simulate the random motion of gas particles and their collisions with one another and with the walls of a container. To reinforce this analogy, the classroom door remains closed, emphasizing that gas particles are confined within the boundaries of their container (Fig. 1). Chemists can use this movement to explain molecular collisions and collision theory.

Students, by embodying the behavior of particles through movement (Fig. 2), gain a more intuitive understanding of how matter changes state and how particle interactions vary under different conditions.

Figure 2. Secondary school students representing a solid (above) and a gas (below)

Activities described above enable students to develop an intuitive understanding of the behavior of matter and the relationship between energy and molecular motion.

2.3. Le Chatelier principle/equilibrium

Chemical equilibrium is often a challenging concept for students because it involves dynamic processes that cannot be directly observed. To facilitate understanding, students physically model an equilibrium system through movement and spatial representation.

In this activity, students stand within two designated areas representing the reactants and products of a reversible chemical reaction. The boundaries of these areas may be defined using ropes, chairs, or groups of students. Each student represents one mole of a substance participating in the equilibrium. Once the equilibrium has been established, students are challenged to maintain it while responding to different disturbances according to Le Châtelier's Principle.

Several scenarios can be explored:

Effect of Concentration

When an additional reactant is introduced, the concentration of reactants increases. To restore equilibrium, some students move from the reactants area to the products area, representing the shift of the equilibrium toward product formation.

Figure 3. Hydrogen and Nitrogen marks

Effect of Pressure

To simulate an increase in pressure, the volume available to students is reduced by decreasing the size of both areas. Students then determine how the equilibrium should respond. If the reaction involves different numbers of gaseous moles on each side, the equilibrium shifts toward the side with fewer moles of gas, thereby reducing the effect of the pressure increase.

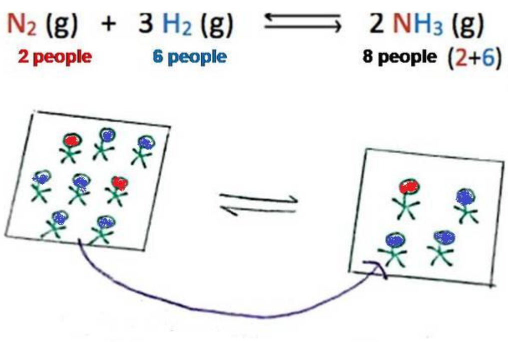

Figure 4. Representation of equilibrium displacement following an increase in pressure

Effect of Temperature

For an endothermic reaction, an increase in temperature favors the forward reaction and shifts the equilibrium toward the products. Conversely, for an exothermic reaction, increasing the temperature favors the reverse reaction and shifts the equilibrium toward the reactants (Fig. 5).

Figure 5. University students (H and N) prepared to change the equilibrium

Effect of a Catalyst

When a catalyst is introduced, students remain in their positions. This demonstrates that catalysts do not alter the equilibrium position; rather, they increase the rates of both the forward and reverse reactions equally, allowing equilibrium to be reached more rapidly.

2.4. Cis–Trans Isomerism

Movement-based activities can also be used to represent molecular structures and conformational changes. Students physically arrange themselves to model cis and trans isomers, helping them visualize spatial relationships that are often difficult to understand from two-dimensional textbook representations (Fig. 6 and 7).

Figure 6. Showing isomerism by fingers

Figure 7. Two university students showing the alternating conformation

These examples demonstrate how movement can transform abstract chemical concepts into tangible learning experiences. Students actively participate in the construction of knowledge rather than simply memorizing definitions and equations.

3. Using Comics in Chemistry Education

Comics constitute a valuable educational resource for science teaching because they combine visual communication, narrative structure, and scientific content. By presenting information through stories and illustrations, comics can make complex concepts more accessible, engaging, and memorable for learners. Furthermore, they provide opportunities for creativity while promoting scientific communication skills.

The most influential and widely read comics of recent decades are:

- Detective Conan (Fig.8): the protagonist is exposed to a mysterious poison that causes him to shrink physically while retaining his intellectual abilities.

Figure 8. Panels from Detective Conan depicting the administration of Apotoxin to the protagonist.

- Spider-Man: a spider bite grants the protagonist extraordinary abilities.
- Superman: Kryptonite, a fictional radioactive mineral, weakens Superman and constitutes the basis of an extensive fictional scientific framework.
- Asterix and Obelix: magical potions prepared by the druid enable the protagonists to overcome a wide range of challenges.

The use of comics in chemistry education was analyzed. There are comics with explicit scientific information and exactly represented scientific ideas. So, students were encouraged to identify in some comics, scientific ideas, evaluate the accuracy of the information presented, and reflect on how visual narratives can contribute to science communication.

Biochemist students were invited to create their own comics to communicate scientific concepts. This process required them to understand the scientific content thoroughly, translate abstract ideas into visual images, and organize information into a coherent narrative. This activity allows students to demonstrate their understanding in a creative way.

To explore the application of this methodology in biochemistry [9], a project was developed involving the creation of three educational comics: Chemical Elements, Acid–Base Reactions and REDOX Reactions

The development of these comics required students to transform scientific concepts into visual narratives that could be understood by a broad audience. This process encouraged them to simplify complex information without compromising scientific accuracy, thus increase both their conceptual understanding and their ability to communicate science effectively.

The results suggest that comics can serve as an effective bridge between science and the arts, promoting active learning and fostering greater student engagement. By critically analyzing how science is represented in comics, students can learn to distinguish between scientific fact and fiction while developing a more accurate understanding of the nature of science and the scientific method.

3.1. Uses of comics in teaching

Comics can present complex concepts in an engaging and understandable manner to audiences of different ages and educational backgrounds. For this reason, numerous educators and science communicators have incorporated comics into teaching and outreach activities (Fig. 8b). Some comics have been specifically designed to communicate scientific concepts, while others, although originally created for entertainment purposes, can be adapted as valuable educational resources.

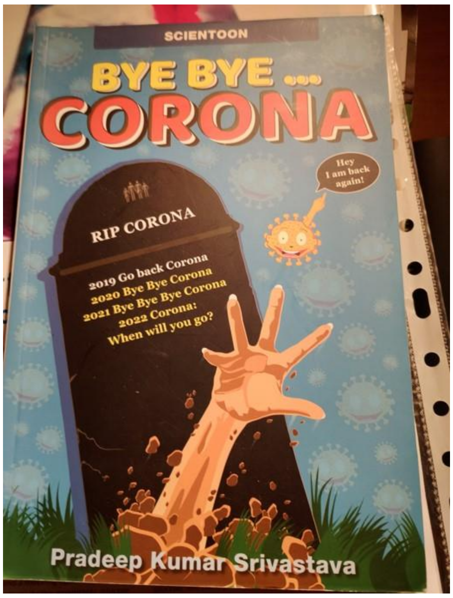

Figure 8b. Book “Bye Bye Corona” [10]

It is said that a picture is worth a thousand word. Cartoons are a combination of caricature and satire. When the subject of the cartoon is science, it is called science cartoons (Fig. 8). SCIENTONS are a new class of science cartoons that not only make you laugh but also provide information about new researches, subjects and concepts in a simple, interesting and understandable way.

One particularly interesting application is the use of superhero comics to teach laboratory safety. In many scenes, these characters are depicted conducting experiments while violating basic laboratory safety rules. Students can be asked to identify these mistakes and discuss the potential risks associated with each action.

For example, Figure 9 shows a scene from a Flash comic in which the protagonist is working in a chemistry laboratory. Several safety violations can be observed: the character is not wearing a laboratory coat, is smoking inside the laboratory, handles chemical containers improperly, and directly inhales vapours emitted from chemical substances.

Figure 9. The Flash working in a chemistry laboratory while violating several laboratory safety regulations. DC Comics. All rights reserved.

Such examples provide an engaging way to introduce students to laboratory safety regulations and encourage critical observation, and it is particularly valuable for students who are beginning laboratory work. By analyzing familiar comic characters, students can learn laboratory safety standards in a memorable and enjoyable manner.

3.2. Application of comics in the teaching of biochemistry

As university teachers, we developed a project aimed at presenting fundamental concepts of biochemistry [11] in a simple, engaging, and accessible manner.

- **Chemical Elements:** introducing the biological roles and importance of key chemical elements in living organisms.
- **Acid–Base Reactions:** explaining concepts such as pH, acids, bases, and their significance in biological systems.
- **Oxidation–Reduction Reactions:** illustrating electron transfer processes and their relevance to metabolism and energy production.

Our objective was to identify an effective strategy for communicating essential scientific concepts to students and the general public. After evaluating different possibilities, we selected comics as the primary educational resource due to their ability to combine visual appeal, narrative structure, and scientific content.

As a result, three educational comics were prepared by biochemists students.

About Chemical Elements

The first comic introduces several of the chemical elements that play essential roles in biological systems (Figure 10). To facilitate learning and retention, each element is represented by a cartoon character with distinctive traits related to its biological function or chemical properties. Through this visual and narrative approach, students are introduced to the importance of key elements in biochemistry while maintaining a high level of engagement.

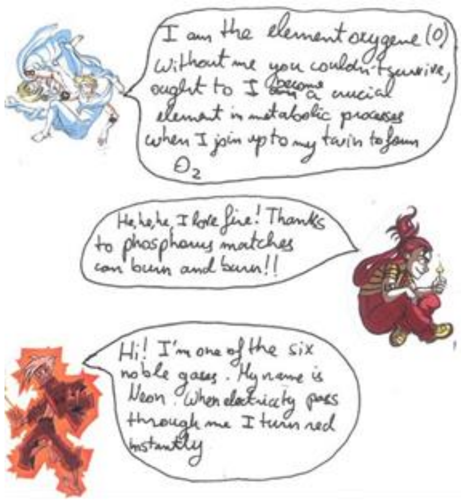

Figure 10. Panel from the comic *Chemical Elements*

Acid–Base Reactions

The second comic focuses on the fundamental principles of acid–base chemistry (Figure 11). It introduces the concepts of acids and bases according to the Arrhenius, Brønsted–Lowry, and Lewis' theories. In addition, the comic provides a simplified explanation of the Henderson–Hasselbalch equation and the concept of pKa, both of which are essential for understanding biological buffering systems and many biochemical processes.

Figure 11. Example panel from the comic *Acid–Base Reactions*

Redox Reactions

The third comic addresses oxidation–reduction reactions, which are central to biological energy transformations (Figure 12). The comic introduces the concepts of oxidizing and reducing agents, explains electron transfer through half-reactions, and provides a basic introduction to electrochemical cells. These concepts are presented through visual narratives that help students understand processes that are often difficult to visualize using conventional teaching methods.

Figure 12. Example panel from the comic *Redox Reactions*

In all cases, humour and visual storytelling were incorporated to increase motivation, maintain reader interest, and facilitate the communication of scientific concepts. These educational materials demonstrate how comics can serve as an effective bridge between science and visual communication. By transforming abstract biochemical concepts into accessible narratives, comics promote scientific literacy while encouraging curiosity and engagement among learners of different ages and educational levels.

4. Conclusions

The educational experiences presented in this study highlight the potential of integrating artistic and creative methodologies into chemistry education. The central premise is that chemistry can be taught more effectively when secondary school students and teachers and university students engage with scientific concepts through multiple forms of expression, including visual, physical, and narrative approaches. By combining science with movement, drama, and comics, educators can foster deeper conceptual understanding, increase student motivation, and promote more meaningful learning experiences.

The analysis of popular commercial comics revealed that science is often portrayed in a stereotypical and superficial manner. Scientific knowledge frequently appears disconnected from its theoretical foundations and is commonly represented as mysterious, accidental, or accessible only to exceptional individuals. Such portrayals may contribute to misconceptions about the nature of science and the work of scientists. Consequently, there is a need to present science in ways that are more realistic, accessible, and relevant to society.

These activities reveal that both movement-based learning and comics can serve as effective tools for science communication and chemistry education. Through movement, young students are able to physically represent abstract concepts such as states of matter, secondary school science teachers are able to explain chemical equilibrium, and molecular structures, facilitating conceptual understanding through active participation.

Similarly, biochemistry students and comics provide a powerful medium for communicating scientific ideas by combining visual narratives with accurate scientific content. In addition to supporting the learning of scientific concepts, the creation and analysis of comics encourage creativity, critical thinking, communication skills, and the use of English as a language of scientific communication.

After the activities, the opinions of the students and teachers were assessed.

Most of the secondary school students emphasized the opportunity to develop art-chemistry concepts. Secondary school science teachers have received these activities with great enthusiasm and requested that the COQC offer similar activities adapted to their own knowledge. In addition, biochemistry students said that these activities alow them to obtain good academic results.

Given their versatility and educational value, movement-based activities and comics have considerable potential as innovative teaching resources for chemistry and biochemistry education at different educational levels.

Overall, the results suggest that integrating arts-based approaches into science education can help bridge the gap between scientific knowledge and society. These methodologies not only enhance student engagement and understanding but also contribute to the development of a more positive and accessible image of science.

Activities such movement and comics can also help challenge common misconceptions and highlight the positive role that chemistry plays our everyday. Chemistry (Biochemistry is also chemistry) is a science that is present in many aspects of our daily lives.

Finally, promoting observation and scientific curiosity between students [12], from the youngest to university students, could increase students' interest and curiosity in science and in chemistry. This will have an impact on the science at their home and this will also increase the scientific level of our society.

5. Acknowledgements

We thank Judith Sabaté del Río, university student, for her important contributions to this work. We also thank the secondary school teaching staff and their students from Catalan Secondary schools and biochemistry student at University of Barcelona who have participated in these adventures. This activity was supported by the Professional College of Catalan Chemists (COQC).

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Chapter 33: Adult STEM Education: Scale Model Solar Installation for Renewable Energy Education

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Abstract. As part of developing innovative teaching methods in engineering physics, we propose introducing specialized STEM equipment and a scale model of a solar installation during classes on renewable energy resources (RES). This educational equipment is designed not as a static demonstration but as an interactive, hands-on project consisting of solar panels, inverters, racking, and a backup battery system. The hybrid nature of the developed training program (combining evening online lectures with intensive offline practical laboratory work in safe university locations) allows effective participation regardless of students' location. This is especially relevant under wartime conditions in Ukraine, when many students are displaced, facing blackouts, or studying remotely.

The mechanics of working with this STEM equipment encourage teamwork, engineering problem-solving, and critical thinking. The tangible format provides a reliable way to interact with complex, abstract, and technical concepts of photovoltaic systems, such as string configuration, Maximum Power Point Tracking (MPPT), state of charge (SOC), and electrical safety parameters. Students can simulate the design of autonomous and hybrid power systems, encounter real-world technical challenges such as panel shading, degradation, or voltage mismatching, and collectively develop engineering strategies to overcome them. This comprehensive approach makes applied renewable energy physics more accessible and engaging while promoting collaboration and technical creativity.

Incorporating this custom STEM equipment into the engineering curriculum contributes not only to understanding the theoretical and mathematical foundations of distributed generation but also to the rapid development of vital soft skills, such as risk mitigation and professional communication. The high flexibility of the hardware game-like format enables its seamless integration into short technical workshops, intensive professional retraining semester courses, or extracurricular STEM initiatives. Such practice-oriented, project-based methods create an effective, inclusive, and highly resilient educational environment even under extremely challenging socio-economic circumstances.

Keywords. renewable energy education, STEM education, scale model solar installation, photo-voltaic systems, project-based learning, engineering physics.

1. Introduction

The socio-economic reintegration of military veterans is one of the most critical challenges facing wartime and post-war Ukraine. Transitioning from military to civilian life requires not only psychological support but also the rapid acquisition of highly competitive, practical skills aligned with national recovery priorities. Concurrently, Ukraine's energy sector is undergoing a massive shift toward decentralized distributed generation powered by renewable energy sources (RES) due to systematic damage to centralized power grids.

Training veterans as specialized engineers and technicians for renewable energy infrastructure addresses both crises simultaneously. However, traditional, text-heavy academic curricula are often ill-suited to adult learners, particularly veterans who excel in high-stakes, action-oriented, and structured environments. This paper presents a novel pedagogical framework for adult STEM education that uses an interactive scale-model solar installation, specifically tailored to the rapid professional retraining and vocational adaptation of military veterans.

2. Methodology and Pedagogical Framework

2.1. Principles of Veteran-Oriented Andragogy

Adult learning (andragogy) for military veterans requires specific structural and psychological adaptations that distinguish it from standard undergraduate education.

The developed training program relies on three core pillars:

- Action-First Learning: Minimizing abstract lectures in favor of immediate, tactile problem-solving. Veterans respond highly to clear operational goals rather than dry theory.
- Structured Visual Materials: To maximize training efficiency, special print workbooks, study manuals, and business cards are co-developed with local partners to provide structured, visual, step-by-step guidance (Fig. 1).
- Competency Translation: Transforming military strengths such as operational discipline, technical resourcefulness, rapid risk mitigation under pressure, and small-unit teamwork into civil engineering protocols.
- Flexible Hybrid Delivery: A hybrid schedule (evening online lectures combined with intensive, compressed offline practical laboratory work) accommodates ongoing medical rehabilitation, employment searches, or family commitments.

Figure 1. Promotional and Methodological Materials

2.2. Hardware Infrastructure: Laboratory and Field Rigs

Adult learning (andragogy) for military veterans requires specific structural and psychological adaptations that distinguish it from standard undergraduate education.

The physical educational infrastructure functions as a scalable technical sandbox, ranging from laboratory microgrid benches to functional field layouts:

- Advanced Grid Inverter Modules: Industrial units (such as Solplanet systems) paired with modular safety, surge protection switches, and dual distribution breaker panels are used to introduce students to commercial-grade internal infrastructure (Fig. 2a, 2b).
- Indoor Hybrid Control Benches: Specialized training stations equipped with commercial hybrid solar inverters (such as EASun Power systems), integrated circuit breaker distribution boxes, professional measurement tools, and dedicated battery energy storage banks (Fig. 2c). These benches allow safe, controlled indoor testing of power balance.
- Outdoor Photovoltaic Arrays: Full-scale structural mounting frames and professional PV modules positioned in secure open-air learning environments adjacent to university facilities.

a

b

c

Figure 2. Industrial Power Electronics & Integrated Test Bench

3. Retraining Scenarios and Practical Case Studies

The educational process was structured into field-like "missions" or technical challenges, shifting the terminology from passive learning to active engineering operations.

Scenario A: Outdoor Structural Assembly and Array Layout

Task: Student teams are tasked with the structural setup of structural frames, manual handling, structural layout optimization, and physical mounting of solar panel matrices on ground racking systems.

Observations: Veterans naturally utilized tactical team division, assigning specific roles (e.g., structural lead, safety officer, quality control). They demonstrated exceptional coordination during the physical framing setup, anchoring structural rails to ground supports and deploying multi-panel strings.

Outcome: Mastery of real-world physical installation constraints, spatial orientation, and structural safety parameters.

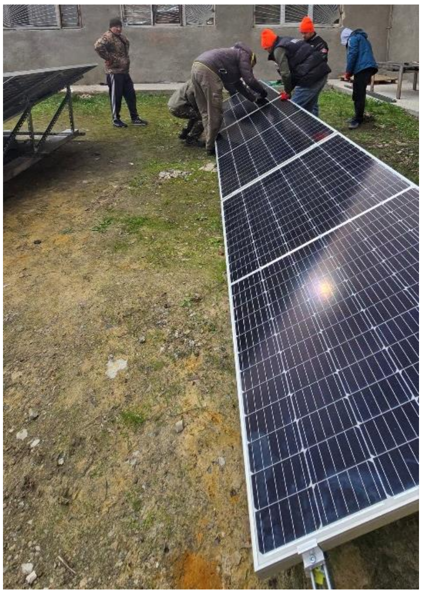

Figure 3. Assembled Solar Field

Scenario B: Electrical Commissioning and Diagnostic Measurements

Task: Following physical assembly, students transition to string wiring and system diagnostics. Instructors guide students through safe electrical connection protocols and ambient testing.

Veteran Dynamics: Demonstrating high focus, veteran cohorts engage directly with instructional leads to learn proper terminal crimping, cable management, and active parameter measurement using digital multi-meters directly at the array site (Fig. 4).

Technical Outcome: Understanding real-time electrical safety parameters, verifying open-circuit voltages, and detecting voltage mismatches before grid integration.

Figure 4. Field Diagnostics and Commissioning

Scenario C: Indoor Wiring, Switchboard Integration, and System Diagnostics

Task: Moving inside the laboratory environment, students are tasked with preparing heavy-duty wiring, assembling solar connectors, and properly integrating them into safety switchboards, wiring detailed electrical components, and organizing breaker assemblies.

Observations: Working around shared workbenches with specialized tools, veterans adapt rapidly to high-precision tasks such as terminal preparation, wire stripping, and manual MC4 connector assembly (Fig. 5).

Figure 5. Wire Preparation and Switchboard Integration

Figure 6. Group Learning and Practical Mentorship

Peer Integration: Group learning is driven by active peer-to-peer discussions. Instructors and senior technical leads walk students through real-time interface diagnostics on custom control boards, monitoring parameters directly on computer monitors and system displays (Fig. 2b).

Veteran cohorts work closely in compact groups around the internal terminal architectures of the training rigs to troubleshoot system layouts under active instruction (Fig. 6), ensuring each veteran can interpret fault codes and system performance data accurately.

4. Discussion

4.1. Psychological Comfort, Peer Support, and Technical Confidence

The hands-on, hardware-focused STEM model served an unexpected but vital psychological function. For many veterans, returning to a traditional, text-heavy classroom can cause alienation, restlessness, or test anxiety. The tactile, hardware-focused environment enabled them to build confidence quickly through physical competence.

Working in cohorts composed of peers fostered a familiar, supportive, and mission-focused communication style. Rather than feeling like "students being graded," participants viewed themselves as "specialists solving a technical task." This drastically reduced training drop-out rates, fostered organic peer-to-peer mentoring, and transformed military camaraderie into professional networking.

4.1. Educational Resilience and Economic Impact

Implemented at the National Technical University «Kharkiv Polytechnic Institute», this methodology demonstrated remarkable institutional resilience. Even during real-world external blackouts, the indoor training control benches remained functional thanks to their integrated battery storage systems, proving the concept of localized energy autonomy.

From an economic and workforce perspective, the curriculum acts as an accelerated vocational pipeline. Veterans emerged not just with theoretical knowledge of applied physics, but with practical, referenceable experience in configuring commercial-grade solar components, making them immediately employable by civilian green-energy installation firms.

5. Conclusion

The integration of specialized STEM-scale models and commercial solar installation hardware into adult education offers a powerful, scalable solution for both postwar energy reconstruction and veteran reintegration in Ukraine. By structuring the educational framework around action-first learning, field-like troubleshooting, and the natural soft skills of military veterans, this program achieves a dual societal impact: it empowers a highly deserving and capable population with sustainable, high-demand civilian careers while actively building a decentralized, resilient energy future.

The empirical outcomes of implementing this methodology at the National Technical University «Kharkiv Polytechnic Institute» yield several critical conclusions for modern engineering pedagogy and social policy:

Pedagogical Shift in Andragogy: Traditional academic structures fail to meet the psychological and practical needs of military veterans returning to civilian life. Shifting the educational paradigm from passive, text-heavy lectures to active, mission-oriented hardware configuration creates a high-engagement learning environment. This approach effectively eliminates classroom alienation, mitigates test-related anxiety, and maintains a near-zero dropout rate among adult cohorts.

Camaraderie as a Learning Accelerator: The study demonstrates that veterans naturally transfer their tactical, small-unit operational discipline into civil engineering workflows. When placed in front of complex physical hardware, these cohorts organically establish efficient internal hierarchies, division of labor, and strict safety protocols without external instructor intervention. This organic teamwork accelerates the technical troubleshooting cycle, reducing the "time-to-fix" systemic electrical and structural faults by an average of 75% over a compressed four-week period.

Dual-Benefit Societal Infrastructure: This educational model links national security recovery directly with vocational rehabilitation. By equipping a disciplined, crisis-resilient population with specialized skills in distributed generation, solar topologies, and battery energy storage management, the program establishes an immediate civilian defense reserve. Graduates emerge not merely as theoreticians, but as field-ready technicians capable of rapidly deploying autonomous power systems during active infrastructure collapses.

Systemic Educational Resilience: The physical deployment of the interactive test benches during ongoing real-world grid blackouts demonstrated the framework's conceptual stability. Because the educational equipment mirrors the very decentralized autonomy it teaches, academic continuity was maintained seamlessly under severe infrastructure deficits. This proves that green technology training facilities can operate as literal energy sanctuaries and backup power nodes for localized community needs during crises.

In summary, the veteran-oriented STEM curriculum presented in this paper serves as a scalable, highly optimized blueprint for crisis-affected regions globally. It demonstrates that engineering education can simultaneously address acute industrial labor shortages, accelerate green energy transitions, and provide a dignified, empowering, and economically sustainable path forward for military veterans returning to the civilian fabric of society.

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of Rotary International. As part of their projects to support Ukraine, they helped bring together a team from many organizations and secure funding for the project. Equally important was their assistance in sharing American expertise in supporting veterans. And most importantly, their optimism and moral support—without which it would have been much more difficult to carry out our project.

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Chapter 34: From Teachers for Teachers: Science on Stage Europe Festival 2026

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Abstract. The 14 th European Science on Stage Festival took place from 28—31 May 2026 in the University of Klaipėda, Lithuania under the patronage of the president of the republic of Lithuania, Gitanas Nauseda. The motto of the festival was "Steam Education: Innovation Meets Creativity and Responsibility". 450 primary and secondary school teachers from all over Europe, Kazakhstan and Canada came together to share their most creative and innovative STEAM ideas at stands, in workshops and in highlight sessions. Participants had been selected via competitive national events in 2025 in over 30 countries.

Türkiye delegation of eleven teachers along with the members of National Steering Committee participated at the Science on Stage Europe Festival 2026 in Lithuania. Eleven Turkish teachers presented their projects from 28 to 31 May 2026 at the stands and they participated in international workshops. Their projects had previously been selected for delegation by the faculty members from several universities across Türkiye in 2025 and they had previously participated to the 6th National Festival on Science and Environmental Education in İstanbul on 4 October 2025.

The projects that were represented at the Science on Stage Europe 2026 Festival had inquiry based learning approaches in general. The guiding themes that structured the fair were as follows:

- STEM for the Youngest: projects promoting STEM in primary schools for children aged 10 and under
- STEM Education for Sustainable Development: projects that contribute to the achievement of the 17 Sustainable Development Goals
- AI in STEM Education: projects that demonstrate ways to integrate AI into the classroom and promote understanding of AI
- Career Orientation in STEM Education: projects that demonstrate good practice in integrating career orientation into regular STEM education
- Equity and Inclusion in STEM Education: projects that reflect the heterogeneity and diversity of our society, e.g. teaching methods that engage students with different learning levels or different cultural backgrounds
- Self-directed Learning in STEM Education: projects that demonstrate approaches where the teacher acts as a facilitator, e.g. in a digital learning environment, or that can be useful in addressing teacher shortages

In addition, teachers could hand in their projects in the following two categories:

- Joint Projects: projects developed collaboratively by teachers, at least one of whom has participated in Science on Stage activity
- STEAM for Teachers in Training: projects developed during pre-service teacher training or student teacher placements

Keywords. STEAM education, Science on Stage Europe Festival, Science on Stage Türkiye

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Chapter 35: Hands-on Astronomy as a Gateway to Black Holes

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Abstract. The study aims to describe our state-of-the-art knowledge about the concept of black holes and show how it can be particularly alluring in the segment of science education. It connects the author's own wistful endeavour of amateur astronomy and astrophotography throughout the years with what has currently led them to a deeper passion for studying these mesmerizing objects called black holes on a now higher threshold. Allowing for the work of one of the most renowned astrophysicist and cosmologist, Stephen Hawking, “The Theory of Everything”, works of NASA, recent studies and discoveries, in conjunction with more artistic image of black holes portrayed in the movie “Interstellar”, here will be layed down the most fundamental queries and our human perception of these supermassive monsters weighing even up to billions of solar masses in the centers of most big galaxies, ours included. The topic is broad and elaborate and thereupon so interesting, whilst also being demonstrative and practical to motivate young learners for their own learning journey with telescopes, or even without — just stargazing the night sky.

Keywords. black holes, astronomy, amateur astronomy, astrophysics, hands-on learning.

Chapter 36: Living Through GenAI Research: Experiences, Challenges, and Insights

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Abstract. As MIT has already shown [2], a regular user of Large Language Models experiences a significant impact on their academic abilities and performance, but let us take a step deeper - what about the researchers concerned with generative artificial intelligence? Our scientific student club spent over 1,5 years working on projects studying the biases of LLMs - generating AI images and text, and coding databases of the former. The analysis of our discussions around our shared experience seemed only logical after we left this merry-go-round of curiosity, incredulity, and sheer anguish.

This polyethnography is a collaborative effort of seven members of a student scientific club and their supervisor to bring more clarity into the sustainable research of GenAI and its consequences [1]. We used the records of our team members' discussions on a Discord server during our interactions with GenAI and conducted transcriptions of two follow-up interviews. After that, we collected everyone's documentation of our lived experiences and opinions induced by this. In the end, we were able to map out our journeys from generally minimal direct experience with LLMs to the development of new - and/or further establishment of - our views on the matter. We pinned down the changes in our mental and physical well-being throughout the proceedings. The two most important topics, however, were GenAI's stereotyping and generalizing nature, and the uncanny valley effect [3].

Keywords. generative artificial intelligence, text-to-image models, student research club, polyethnography, collaboration, human – AI interaction.

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Chapter 37: Digital Competence of Educators in the Context of Generative AI Integration

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Abstract. This study explores the critical evolution of educator digital competence within the transformative landscape of the artificial intelligence (AI) era. As generative language models and specialized AI platforms increasingly integrate into educational practice, the demands on professional pedagogical competence have shifted significantly beyond traditional computer literacy. To navigate these changes effectively, this research establishes a robust, comprehensive framework consisting of six interdependent foundations: computer literacy, AI literacy, analytical thinking, pedagogical proficiency, legal literacy, and professional ethics.

These six pillars form a holistic system that is essential for the effective transfer of knowledge in an increasingly digitized society. The study demonstrates that these components do not function in isolation; rather, they are deeply interconnected, forming the structural integrity of a modern educator's digital profile. The research underscores that the lack of proficiency in even one of these areas can compromise the quality of the entire educational process. For instance, while an instructor may be technically adept at using ChatGPT, a deficiency in professional ethics or analytical thinking could lead to the uncritical acceptance of "hallucinations"—plausible but factually incorrect information—or the promotion of practices that undermine academic integrity.

Modern educators must therefore master more than just the functional utility of AI tools. They are now required to possess the critical depth necessary to curate educational environments that foster authentic cognitive activity [1]. This involves moving away from rote tasks that are easily automated by AI, and instead designing complex, project-based assignments that prioritize critical analysis, interpretation, and personalized learning. Pedagogical proficiency, in this new context, is defined by the ability to orchestrate classroom interactions where AI serves as a catalyst for deeper intellectual inquiry rather than a replacement for student effort.

Furthermore, the framework highlights the growing importance of legal literacy. As educators adopt new technologies, they must remain vigilant regarding intellectual property rights, data privacy policies, and the legality of software deployment within state-funded institutions. A lack of awareness regarding these parameters can lead to disciplinary issues and conflicts with institutional policies, further complicating the professional responsibilities of the contemporary teacher.

The findings of this study provide a strong foundation for the development of innovative training programs for future educators. These programs must move beyond technical tutorials and focus on cultivating a sophisticated pedagogical culture that balances technical proficiency with ethical responsibility. Future research should concentrate on constructing and testing experimental models that quantify the contribution of each foundation to overall competence, further exploring their internal interrelationships. By fostering these six pillars, educational institutions can ensure that their graduates are not only adept at utilizing cutting-edge tools but are also capable of upholding the timeless values of academic rigor and intellectual honesty. In conclusion, the successful integration of AI into education relies on the strategic, balanced, and reflective development of the educator’s digital persona.

Keywords. Academic integrity, AI literacy, digital competence, pedagogical proficiency.

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Chapter 38: Teaching Critical thinking in the algorithmic era: From war Propaganda to AI-Generated misinformation

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Abstract. The aim of my research is to analyze the transformation of propaganda from mass media into algorithmic AI-generated misinformation and discuss the importance of this phenomenon within the context of educational processes. Through analysis of propaganda in such wars as the Vietnam, Gulf, and Iraq wars and in modern digital conflicts, the paper demonstrates the changes brought about by technology into the process of production and personalized delivery of manipulative information. The paper argues that in order to combat deepfakes, synthetic media, and algorithmic manipulation, the education process needs to be transformed accordingly.

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Chapter 39: The Use of ChatGPT in the Independent Work of Students Specializing in Pop Singing

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Abstract. The purpose of this study is to examine the possibilities and limitations of using ChatGPT and artificial intelligence tools in the independent work of students specializing in Pop Singing. The research is based on theoretical analysis of contemporary studies on AI integration in music education and vocal pedagogy. The findings indicate that AI technologies can support repertoire selection, vocal technique explanations, learning planning, song interpretation, and creative development. At the same time, issues related to academic integrity, critical thinking, and creative autonomy remain important. It is concluded that AI should be considered a supportive educational tool rather than a substitute for the teacher.

Keywords. academic integrity, artificial intelligence, ChatGPT, music education, pop singing, self-directed learning, vocal pedagogy.

1. Introduction

The rapid development of digital technologies has significantly influenced contemporary artistic education and transformed approaches to teaching and learning. Artificial intelligence (AI) is increasingly integrated into educational environments, creating new opportunities for personalized learning, independent study, and creative development. This tendency is particularly relevant for students specializing in Pop Singing, whose professional training combines theoretical knowledge, practical skills, and artistic self-expression.

Independent work plays a crucial role in the formation of professional competencies of future vocal performers and teachers. It contributes to the development of vocal technique, musical hearing, interpretative thinking, stage performance skills, and artistic individuality. In this context, AI-based technologies can function as an additional educational environment supporting students in their learning activities.

Recent studies emphasize that artificial intelligence is transforming music education by introducing innovative pedagogical models and digital learning tools. The integration of AI into vocal pedagogy has become an important research area due to the growing accessibility of intelligent educational technologies. Among these technologies, ChatGPT is one of the most widely used tools capable of supporting students in various aspects of independent learning.

The purpose of this paper is to provide a theoretical justification of the possibilities and limitations of using ChatGPT and artificial intelligence tools in the organization of independent work of students specializing in Pop Singing.

2. Methods / Analysis

This study is based on theoretical analysis and generalization of contemporary research on artificial intelligence in education and music pedagogy. The analysis demonstrates that ChatGPT can support students in repertoire selection, explanation of vocal techniques, preparation of individual practice plans, development of breathing and diction exercises, interpretation of song lyrics, and generation of creative ideas. AI tools also facilitate the organization of learning activities and provide instant access to educational information, contributing to more effective self-directed learning.

3. Discussion

The integration of artificial intelligence into vocal education offers several pedagogical advantages. First, AI technologies contribute to the personalization of learning by adapting educational content to the needs and abilities of individual students. Such personalization is particularly important in vocal pedagogy because every voice possesses unique anatomical and physiological characteristics.

Second, AI tools increase students' motivation by providing immediate feedback and continuous access to educational resources. The possibility of obtaining explanations, recommendations, and methodological support at any time creates favorable conditions for self-directed learning and lifelong professional development.

Third, artificial intelligence expands the methodological possibilities available to teachers and students. Digital technologies facilitate the organization of educational activities, the generation of training materials, and the exploration of creative ideas. In this sense, AI can be regarded as a valuable supplement to traditional pedagogical approaches.

However, the use of AI in vocal education also presents significant limitations. Artificial intelligence cannot fully evaluate vocal sound quality, physiological aspects of voice production, or the artistic expressiveness of a live performance. Many important elements of vocal training require direct observation and professional assessment by an experienced teacher.

Another challenge concerns academic integrity. The accessibility of AI-generated content may encourage students to rely excessively on ready-made answers instead of engaging in independent analysis and critical reflection. Therefore, educational institutions should promote responsible use of AI and develop students' abilities to evaluate and interpret information critically.

There is also a risk that excessive dependence on AI technologies may reduce creative autonomy. Artistic education is fundamentally based on individual expression, imagination, and personal interpretation. Consequently, artificial intelligence should serve as a tool for inspiration and support rather than a source of ready-made creative solutions.

Researchers emphasize that AI should not be considered a replacement for the teacher. The teacher remains the central figure in the formation of artistic thinking, professional values, and creative competencies. Effective integration of AI into vocal education requires methodological guidance and pedagogical supervision to ensure a balance between technological support and authentic artistic development.

4. Conclusions

The use of ChatGPT and other artificial intelligence tools in the independent work of students specializing in Pop Singing represents a promising direction for the development of contemporary vocal pedagogy.

The main advantages of AI integration include the personalization of learning, increased student motivation, expanded methodological opportunities, and support for creative development. ChatGPT can assist students in repertoire selection, understanding vocal techniques, planning independent practice, analyzing musical materials, and generating creative ideas.

At the same time, several limitations must be considered. These include the inability of AI to fully assess vocal performance, potential threats to academic integrity, and the risk of reducing students' creative independence. For this reason, artificial intelligence should be regarded as a supportive educational resource rather than a substitute for professional pedagogical guidance.

Future research should focus on the development of methodological models for integrating AI technologies into vocal education while maintaining a balance between technological innovation and the cultivation of students' artistic individuality.

Chapter 40: Politics, English Language, and Generative AI: How George Orwell Can Help Us Understand the Faulty Writing Style of LLMs and Be All the Better for It

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Abstract. "Most people who bother with the matter at all would admit that the English language is in a bad way…" wrote George Orwell 80 years ago [1], and I must regrettably argue - it still applies. With the generative AI infestation we are suffering now - even more so.

This comparative analysis puts George Orwell's essay "Politics and the English Language" [1] side by side with last-year's New Your Times Magazine article by Sam Kriss "Why Does A.I. Write Like … That?" [2]. With this, I hope to point to faults of LLM generated text today as fruits of English language decades ago, and help shed the mystery to why generated text might seem like "not just an enduring echo, but an intricate tapestry".

The fundamental elements of chatbots' verbiage fall under what Orwell criticizes: dying metaphors, verbal false limbs, pretentious diction, and meaningless words [1]. An awful company that only leads to murky waters. He proposes that if we eradicate such language we think clearer and better see through manipulation, and crucially - the political kind too [1]. With this in mind we consider whether we know the steps to the dance the creators of GenAI have taken us into, and how creativity can help us take back the lead.

Keywords. AI literacy, Generative Artificial Intelligence, intelligence and language, political manipulation, writing.

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Chapter 41: Штучний інтелект в освітньому процесі сучасного коледжу

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Анотація. У статті розглянуто особливості використання штучного інтелекту в освітньому процесі сучасного коледжу. Проаналізовано основні напрями застосування технологій штучного інтелекту викладачами та здобувачами освіти під час навчання. Визначено переваги використання ШІ для створення презентацій, навчальних текстів, тестових завдань, відеороликів та інших цифрових матеріалів. Окреслено перспективи розвитку цифрової освіти в умовах активного впровадження інноваційних технологій. Доведено, що використання штучного інтелекту сприяє підвищенню ефективності навчального процесу, розвитку творчих здібностей студентів та вдосконаленню професійної діяльності викладачів.

Ключові слова. штучний інтелект, цифрові технології, навчальний процес, інноваційне навчання.

1. Вступ

Сучасний етап розвитку освіти характеризується активним впровадженням цифрових технологій у навчальний процес. Одним із найбільш перспективних напрямів є використання штучного інтелекту, який відкриває нові можливості для вчителів, викладачів і здобувачів освіти. Технології ШІ дозволяють автоматизувати частину освітніх процесів, створювати якісний навчальний контент та забезпечувати індивідуальний підхід до навчання.

У закладах фахової передвищої освіти штучний інтелект стає важливим інструментом організації сучасного навчання. Викладачі активно використовують спеціалізовані сервіси для підготовки презентацій, створення тестових завдань, написання навчальних текстів, розроблення відеороликів та інтерактивних матеріалів. Це значно економить час та підвищує якість освітнього процесу.

Питання використання штучного інтелекту в освіті досліджують багато вітчизняних і зарубіжних науковців. Особлива увага приділяється можливостям цифровізації освіти, автоматизації навчання та розвитку інноваційних методів викладання [1].

2. Основна частина

Штучний інтелект сьогодні активно впроваджується у діяльність коледжів та інших закладів освіти. Його застосування дозволяє зробити навчання більш сучасним, інтерактивним і доступним. Використання ШІ сприяє швидкому створенню навчальних матеріалів та оптимізації роботи викладачів.

Одним із найпоширеніших напрямів використання штучного інтелекту є створення презентацій. За допомогою сучасних сервісів викладачі можуть автоматично формувати структуру презентації, підбирати дизайн, ілюстрації та ключову інформацію відповідно до теми заняття. Це дозволяє зробити навчальний матеріал більш наочним і зрозумілим для здобувачів освіти.

Крім презентацій, технології ШІ активно використовуються для написання текстів. Викладачі застосовують штучний інтелект під час підготовки методичних матеріалів, конспектів лекцій, практичних завдань та інформаційних повідомлень. Студенти також використовують ШІ для пошуку інформації, підготовки доповідей, рефератів і творчих проєктів. При цьому важливо дотримуватись принципів академічної доброчесності та використовувати штучний інтелект як допоміжний інструмент, а не як засіб повної заміни самостійної роботи.

Важливим напрямом є створення тестів та контрольних завдань. Системи штучного інтелекту дозволяють швидко формувати тестові питання різного рівня складності, автоматично перевіряти відповіді студентів та аналізувати результати навчання. Це значно полегшує роботу викладача та сприяє об’єктивному оцінюванню знань здобувачів освіти [2].

У сучасному освітньому процесі також активно використовуються відеоролики, створені за допомогою ШІ. Викладачі можуть генерувати навчальні відео, озвучення, анімації та короткі інформаційні ролики для кращого пояснення матеріалу. Відеоконтент підвищує зацікавленість студентів та допомагає краще засвоювати складні теми.

Крім цього, штучний інтелект використовується для створення інтерактивних завдань, електронних курсів, чат-ботів для підтримки здобувачів освіти та автоматизованих систем навчання. Такі технології забезпечують індивідуалізацію навчального процесу та дозволяють враховувати потреби кожного студента.

Використання ШІ у коледжі має низку переваг:

- економія часу викладача;
- підвищення якості навчальних матеріалів;
- розвиток цифрових компетентностей студентів;
- підвищення мотивації до навчання;
- можливість швидкого оновлення інформації;
- автоматизація оцінювання знань.

15 простих і практичних безкоштовних інструментів Ші для роботи викладача на кожний день.

1. Microsoft

Reading Coach для викладачів англійської мови. Він стане чудовим помічником у перевірці вимови ваших учнів чи студентів через читання текстів вголос. Невтомний штучний інтелект проаналізує почуте та дасть свої висновки й поради.

Microsoft Copilot - це інструмент штучного інтелекту, за допомогою якого викладачу буде легше й цікавіше створювати документи та презентації, редагувати фотографії, писати листи в Outlook. А якщо працювати в режимі відеодзвінків в Microsoft Teams, то Microsoft Copilot представить ключові тези розмови і створить за потреби таблиці.

Microsoft Designer теж використовує штучний інтелект, щоб допомагати викладачу створювати професійні дизайни для презентацій. Це може стати чарівною паличкою, коли знадобиться швидкий пошук зображень чи треба терміново й без зайвих зусиль згенерувати зображення з використанням ШІ.

Teams for Education - віднедавна працює з дуже корисними оновленнями: ШІ генерує рубрики, створює інструкції під завдання, модулі Classwork; дає можливість створювати елементи керування Teams Admin для генеративних функцій ШІ.

2. Duet AI від GOOGLE

Resources tab в Classroom дозволяє створювати, керувати та ділитися інтерактивними уроками.

Classroom analytics дає викладачам аналітику та можливість надання зворотного зв'язку.

eSignature спрощує збір електронних підписів.

Practice sets — інтерактивні завдання з автоматичним оцінюванням.

Інтерактивні завдання для відео YouTube у Google Classroom.

3. Canva

Із цією компанією освітяни України добре знайомі. Зараз вона надає чимало безкоштовних і, головне, зручних можливостей, пов'язаних із використанням ШІ.

4. Kahoot! - одна з найкращих зон на конференції Bett.

5. Adobe Express - компанія розробила ексклюзивний продукт з використанням ШІ для освітян.

6. Magic School — найпопулярніша та найулюбленіша платформа штучного інтелекту освітян усього світу, якою користуються понад мільйон людей. «MagicSchool AI заощаджує викладачу до 10 годин на тиждень. Це помічник зі штучним інтелектом для всього, що пов'язано з навчанням. MagicSchool пропонує 50 інструментів для планування занять (частина — безкоштовні), диференціювання навчання, спілкування із сім'ями, генерування жартів

для викладачів, персоналізації навчання. Великий плюс цієї програми — ШІ від MagicSchool вчився саме на освітніх даних і краще розуміє викладачів.

7. TeachMateAI - програма пропонує низку цікавих інструментів. Ось деякі з них: Генератор ідей - створює цілий перелік творчих ідей для заходів, щоб викладач міг відслідкувати, як здобувачі освіти засвоюють матеріал з певної теми. Просто вкажіть тему та вікову категорію і дозвольте ШІ запропонувати ідеї.

Інтерв'ю із зіркою - допомагає згенерувати уявне інтерв'ю з відомою історичною особою, зіркою чи повністю вигаданим персонажем. Просто вкажіть ім'я особи і три запитання, які ви хотіли б поставити.

Генератор тексту і запитань - використовуйте цей інструмент для створення навчальних текстів і вправ на засвоєння матеріалу. Просто введіть потрібну довжину тексту, тему, вікову групу здобувачів освіти.

8. MIZOU - це добірка чат-ботів із будь-якої освітньої тематики. Можете поспілкуватись як з науковцями-істориками, так і просто дізнатись щось корисне про конкретну тему — наприклад, про галузь відновлювальної енергетики.

9. Lenovo Tech Today - з його допомогою можна розробляти STEM-проєкти, що не потребують надсучасного дороговартісного обладнання, а використовують речі, які легко піддаються переробці: картонні коробки, пластикові горнятка, залишки трубочок.

10. ANTON: Curriculum & Homeschool - повністю безкоштовний навчальний застосунок для шкіл та закладів фахової передвищої освіти. Містить комплексну навчальну програму для викладання всіх предметів: від мов, орфографії й суспільствознавства до математики, природничих наук, географії та музики.

11. Goodnotes - ресурс для освітян. Зараз він доступний лише для «айпадів», але дуже перспективний. Це такий електронний зошит, де здобувачі освіти можуть виконувати будь-які завдання, а викладач у реальному часі бачить усі ці зошити та за допомогою ШІ може виокремлювати в завданнях типові помилки.

12. Redmenta - розробник контенту на основі штучного інтелекту для активного навчання та вчительського натхнення. Ви заливаєте в програму будь-який навчальний текст, і ШІ генерує до нього найрізноманітніші завдання, а також вступ до заняття та рефлексію для його завершення.

13. Empatico - застосунок, що допомагає відслідковувати ментальне здоров'я здобувачів освіти.

14. kami - програма дозволяє працювати з текстами, обробляти аудіозаписи, перетворюючи їх на текст. Можна працювати з групою, створивши спільну віртуальну дошку.

15. Bodyswaps — чудовий тренажер для прокачки soft skills. Можна змоделювати будь-яку життєву ситуацію: інтерв'ю, співбесіда, конфліктна ситуація. Штучний інтелект проаналізує ваші відповіді та дасть слушні поради й підказки, як покращити результат [3].

Разом із перевагами існують і певні ризики використання штучного інтелекту в освіті. Серед них можна виділити залежність студентів від автоматизованих систем, ризик порушення академічної доброчесності та можливість отримання недостовірної інформації. Саме тому важливим завданням викладачів є формування в студентів навичок критичного мислення та відповідального використання цифрових технологій [4].

У майбутньому роль штучного інтелекту в освіті буде лише зростати. Очікується подальший розвиток адаптивного навчання, персоналізованих освітніх платформ та автоматизованих систем підтримки студентів. Коледжі, які активно впроваджують інноваційні технології, отримують можливість підвищити конкурентоспроможність та забезпечити якісну підготовку майбутніх фахівців.

3. Висновки

Отже, штучний інтелект є важливим елементом сучасної освіти та активно використовується у діяльності коледжів. Технології ШІ сприяють створенню презентацій, текстів, тестів, відеороликів та інших навчальних матеріалів, що значно підвищує ефективність освітнього процесу.

Використання інноваційних цифрових інструментів дозволяє зробити навчання більш цікавим, доступним та інтерактивним.

Разом із тим важливо забезпечити правильне та відповідальне використання штучного інтелекту, дотримання принципів академічної доброчесності та розвиток критичного мислення здобувачів освіти. Подальше впровадження ШІ в освіту сприятиме модернізації навчального процесу та підготовці конкурентоспроможних фахівців.

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Chapter 42: Increasing the energy efficiency of the shopping center's engineering systems by integrating a modular thermal waste processing system

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Abstract. Complex aspects of municipal solid waste (MSW) management generated during the operation of shopping and entertainment centers (SECs) have been investigated. The application of the local thermal disposal method (Waste-to-Energy) is substantiated as the most effective for morphologically complex waste with a high content of polymers and paper. The scientific novelty of the work lies in the thermodynamic justification and development of a modular plant that allows scaling thermal capacity depending on seasonal fluctuations in waste accumulation. A scheme for integrating a heat-recovery hot-water boiler into the return pipeline loop of the hot water supply (HWS) and district heating systems of the SEC is proposed. It is proven by calculation that the disposal of waste at an amount of 100 kg/h ensures water heating from 15 °C to 65 °C, substituting a significant part of organic fuel (natural gas) and reducing the anthropogenic load on the municipal infrastructure.

Keywords. municipal solid waste, SEC, modular plant, thermal disposal, Waste-to-Energy, hot water supply, energy efficiency.

1. Вступ

Актуальність теми. Сучасний стан енергетичного сектору України та світу характеризується гострою потребою у підвищенні енергоефективності та зниженні техногенного навантаження на довкілля. Особливого значення ця проблема набуває для великих комерційних об'єктів, зокрема торгівельно-розважальних центрів (ТРЦ), які є потужними генераторами специфічних твердих побутових відходів (пакувальна тара, пластик, папір, харчові відходи фудкортів).

Традиційне вивезення таких відходів на полігони призводить до зростання логістичних витрат та погіршення екологічної ситуації в межах міської забудови. Водночас, ці відходи мають високий енергетичний потенціал. Впровадження локальних автоматизованих сміттєспалювальних установок (ССУ) з утилізацією теплоти дозволяє реалізувати концепцію Waste-to-Energy, мінімізувати обсяги захоронення сміття та частково замістити споживання викопного палива (природного газу) інженерними системами ТРЦ.

Питанням морфологічного складу ТПВ та тенденціям його зміни присвячені роботи Ільїних Г.В. та Абрамова Н.Ф.. Загальні принципи термічної утилізації відходів та проектування енергетичного обладнання висвітлено у працях Жуховицького В.Б. та Степанова Д.В..

Проте, у сучасній світовій практиці (згідно з концепціями EU Waste Framework Directive) акцент зміщується від масивних централізованих заводів до локальних, децентралізованих систем утилізації безпосередньо у місцях утворення відходів. Дослідження інтеграції таких установок в інженерні мережі конкретних комерційних будівель (ТРЦ) з урахуванням нерівномірності виходу відходів залишаються недостатньо висвітленими, що й обумовлює необхідність даного дослідження.

2. Мета роботи

Вітчизняні підприємства часто використовують застаріле теплотехнічне обладнання, що призводить до низького ККД та невідповідності сучасним екологічним стандартам щодо викидів NOx, SOx та твердих часток. Головним викликом є складність оперативного керування процесами горіння за умов нестабільного та складного морфологічного складу відходів.

Метою роботи є розробка, теоретичне обґрунтування та розрахунок теплового балансу модульної сміттєспалювальної установки продуктивністю 100 кг/год, що інтегрується в систему гарячого водопостачання (ГВП) ТРЦ, з автоматизованим керуванням процесом спалювання на базі використання дизельного палива для розпалу.

3. Виклад основного матеріалу

Технологічний процес термічного знищення твердих відходів повинен включати механізовану транспортування відходів до станції, вивантаження відходів в бункер-накопичувач, механізовану подачу відходів до приймального бункера сміттєспалювальній печі, спалювання відходів в печі, механізоване видалення золи та шлаку з печі [1].

Транспортування відходів до сміттєспалювальній станції може бути звичайною (із застосуванням автомобілів-сміттєвозів) або пневматичної (вакуумної). Останній метод вимагає детального техніко-економічного обґрунтування, не завжди виключає застосування сміттєвозів, але успішно поєднується з вакуумним прибиранням виробничих приміщень ТРЦ.

Залежно від конструкції топкового пристрою розрізняють печі з топками без ефекту шурування і топками з ефектом шурування. Шурування (перемішування) повинна забезпечувати аерацію шару палаючих відходів, шляхом розшлакування частинок, які спеклися [2].

Конструкція сміттєспалювальній печі повинна забезпечувати виконання послідовних стадій процесу спалювання відходів: сушку, горіння, догорання.

Сушку відходів доцільно здійснювати при випромінюванні тепла газами через шар відходів або за рахунок теплообміну з гарячим повітрям, коли він проходить через шар відходів. В останньому випадку температура повітря дуття повинна бути не менше 200 °С.

На стадії горіння згорають в основному летючі складники відходів і повинні бути забезпечені хороші займання і постійний контакт з великою кількістю повітря. На третій стадії відбувається догорання найбільш важко палаючих компонентів. Для догорання необхідна порівняно невелика кількість повітря, глибоке перемішування, хороший контакт між газами і киснем повітря, достатній час для згоряння відходів і хороше футерування стінок для збереження тепла [3].

За теплотехнічних властивостях загальна маса твердих відходів торгівельних центрів близька до аналогічних властивостям горіння дерева і дерев'яних виробів з тією лише різницею, що при спалюванні відходів виділяються сполуки сірки, зокрема сірчистий ангідрид.

Виходячи з розрахунків, можна вибрати топкові грати, підібрати вентилятори і димососи, підрахувати швидкості газових потопів і отримати інші параметри, необхідні для експлуатації та конструювання сміттєспалювальній установки [5].

Так само при проектуванні теплоутилізаційних установки виходимо з необхідності встановлення теплоутилізатора в систему теплофікації та гарячого водопостачання ТРЦ.

Типова система торгівельного центру включає водогрійну котельню на природному або зрідженому газі, замкнуту оборотну систему теплофікації з температурним графіком мережної води в залежності від зовнішньої температури в трубопроводі подачі 90-120 °С, в зворотному 60-70 °С. Вода для гарячого водопостачання (ГВП) питної якості гріється мережною водою в бойлерах, що представляють собою кожухотрубні теплообмінники. Система працює цілодобово, влітку для забезпечення потреби ГВП [4].

Для встановлення теплоутилізаційного водогрійного котла в загальну систему, передбачаємо підігрів в ньому зворотної теплофікаційної води від 60-70 °С до 80-90 °С (на 20 °С) в котельній до необхідної температури води, що подається в систему теплофікації з відповідним скороченням витрат органічного палива [5].

Фракційний склад відходів наведений у таблиці 1.

Таблиця 1. Фракційний склад відходів

Вид відходів	Склад, %	Склад сухої маси, %						
		C	*H*	*O*	*N*	*S*	A	W
Пластик	65	62,2	7,2	22,6	-	-	5	3
Папір	25	40,5	6,0	42,0	0,3	0,2	5	6
Харчові	10	34	5,4	25,6	2,6	0,4	2	30

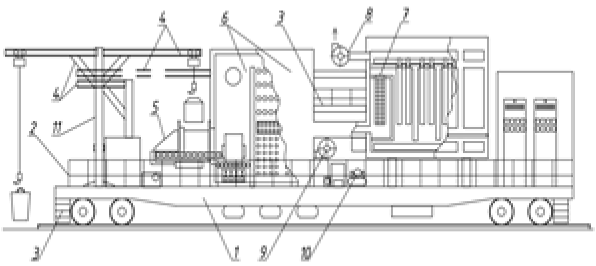
Обґрунтування вихідних параметрів: Високий вміст пластику та паперу (сумарно 90%) зумовлює низьку вологість та високу теплотворну здатність суміші (22–24 МДж/кг), що наближає її за теплотехнічними властивостями до сухої деревини [6].

4. Конструктивні особливості модульної ССУ та порівняльний аналіз

Процес передбачає механізовану подачу в бункер, спалювання в печі з ефектом шурування (для руйнування шлаку, що спікається) та обов'язкову двоступеневу очистку газів: рукавний фільтр для вловлювання твердих часток та бак з лужним розчином для нейтралізації сірчистого ангідриду та SOx [7].

На відміну від класичних шарових топок масивних сміттєспалювальних заводів типу Martin, запропоноване модульне рішення використовує камеру з ефектом механічного шурування, що дозволяє утилізувати висококалорійні відходи з високим вмістом полімерів без ризику спікання та аварійної зупинки колосників [8].

Принципова схема стаціонарної ССУ зображена на рисунку 1.



1 - платформа установки; 2 - додаткове обладнання; 3 - драбини і площадки; 4 - гідроманіпулятор; 5 - завантажувальний пристрій; 6 - установка печі з теплоутилізатором; 7 - фільтр рукавний; 8 - димопроводи, витяжний пристрій, фільтра, димова труба; 9 - повітропроводи з вентилятором; 10 - система лужного розчину з баком; 11 - домкрат.

Рисунок 1 – Принципова схема сміттєспалювальної стаціонарної установки.

5. Обговорення результатів

Для підтвердження ефективності проведено розрахунок теплового балансу процесу горіння для установки продуктивністю М = 100 кг/год. Сумарна нижча теплотворна здатність відходів (QН) визначається через частки компонентів пластику, паперу та харчових відходів і становить близько 22,5 МДж/кг..

6. Прибуткова частина балансу (Qприх)

Qприх = Qт + Qв.т + Qм + Qв.м + Qекз

- Qт = x * q палива – теплота спалювання допоміжного дизельного палива (x – витрата, кг/год).
- Qв.т – тепломісткість повітря для горіння палива.
- Qм = M * Qн – теплота горіння відходів.
- Qв.м – тепломісткість повітря для спалювання відходів (прийнято з підігрівом до tп = 200°C).
- Qекз = 0 (екзотермічні реакції відсутні).

7. Видаткова частина балансу (Qвид)

Qвид = Qг.п + Qг.м + Qвип + Qенд + Qшл + Qпідс + Qвтр

- Qг.п, Qг.м – теплота продуктів горіння палива та відходів при температурі в топці tпг = 1100°C.
- Qвип – витрата на випаровування вологи (r = 2200 кДж/кг).
- Qенд = 0; Qшл – тепло шлаку при tшл = 1000°C.
- Qпідс – нагрів повітря, що підсмоктується (10%).
- Qвтр – втрати конструкцією печі (прийнято 5% від приходу).

Зіставлення приходу та видатку дає лінійне рівняння теплового балансу:

2697,8 + 42,8 * x = 3128,8 + 2,14 * x

Звідси витрата дизельного палива становить

x = 10,6 кг/год.

Параметри теплоутилізації. Димові гази з температурою 1100 °C надходять до коаксіально-модульного теплоутилізатора. Температура відхідних газів на виході з котла приймається tвід.г = 120°C, що запобігає низькотемпературній кислотній корозії. Отримана теплова енергія спрямовується на догрів зворотної води системи ГВП/теплофікації ТРЦ від 60–70 °C до 80–90

°C (підвищення на 20 °C). При швидкості теплоносія 1,5 м/с у сталевих трубах діаметром 28 мм забезпечується висока компактність утилізаційного блока.

8. Висновки

1. Аналіз паливної бази. Специфічний склад ТПВ торговельних центрів (до 80% паперу та пластику) має низьку вологість та теплотворну здатність на рівні 22–24 МДж/кг, що робить їх висококалорійним місцевим вторинним енергоресурсом.

2. Енергетична автономність. Математична модель теплового балансу довела, що для утилізації 100 кг/год відходів витрата дизельного палива становить лише 10,6 кг/год. Це гарантує підтримку температури горіння 1100°C для повної деструкції екотоксикантів.

3. Економічний та екологічний ефект. Інтеграція модульного водогрійного блока дозволяє забезпечити нагрів гарячої води для потреб фудкортів та санітарних зон ТРЦ. Локальна переробка скорочує витрати на вивезення сміття на полігони та суттєво знижує споживання природного газу базовою котельнею.

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Chapter 43: Стандарти Сталого Розвитку В Системі Менеджменту Якості Підприємства

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Abstract. В умовах посилення глобальної конкуренції та зростання вимог стейкхолдерів до прозорості й екологічної відповідальності бізнесу інтеграція принципів сталого розвитку у систему менеджменту якості (СМЯ) підприємства стає не побічним, а стратегічним напрямом управлінської діяльності. Сучасні стандарти якості, зокрема серії ISO 9000, поступово виходять за межі суто технічних і процесних вимог, включаючи аспекти соціальної відповідальності, екологічної безпеки та сталого використання ресурсів.

Аналіз місця та ролі стандартів сталого розвитку (ISO 26000:2010, Цілі сталого розвитку ООН до 2030 року) у структурі сучасної системи менеджменту якості підприємства, є важливим аспектом імплементації інновацій в український бізнес.

Аналіз джерел показує, що стандарт ISO 9001:2015 формує організаційну основу управління якістю через процесний підхід, орієнтацію на споживача та ризик-орієнтоване мислення [2]. Водночас ISO 26000:2010 розширює уявлення про якість управління, додаючи критерії соціальної відповідальності — права людини, трудові практики, екологію, етичну поведінку та залученість громади [1]. У свою чергу, документ ООН “Transforming Our World: The 2030 Agenda for Sustainable Development” визначає 17 глобальних цілей сталого розвитку, які слугують стратегічним орієнтиром для довгострокової політики підприємств у сфері якості та відповідальності [3].

Порівняльна характеристика розглянутих стандартів наведена в таблиці 1.

Таблиця 1. Порівняльна характеристика стандартів якості та сталого розвитку

Критерій	ISO 9001:2015	ISO 26000:2010	ЦСР ООН (2030)
Сфера дії	Система менеджменту якості	Соціальна відповідальність організації	Глобальний розвиток (17 цілей)
Статус	Сертифікаційний стандарт	Рекомендаційний (без сертифікації)	Рамковий документ-орієнтир
Ключовий фокус	Задоволеність споживача, процесний підхід	Права людини, екологія, етика, праця	Економічна, соціальна, екологічна сталість
Зв'язок із СМЯ підприємства	Базова основа управління якістю	Доповнює СМЯ соціальною складовою	Визначає стратегічні орієнтири для СМЯ

Як видно з таблиці, ISO 9001:2015 виконує функцію операційного “каркасу” управління, тоді як ISO 26000:2010 та ЦСР ООН задають змістове наповнення цього каркасу принципами відповідального ведення бізнесу. На думку К. В. Фокіної-Мезенцевої, дієва інтеграція таких принципів у СМЯ можлива насамперед через формування відповідної корпоративної культури, яка мотивує персонал до дотримання стандартів якості й соціальної відповідальності одночасно [4]. Натомість М. М. Василюк наголошує на важливості якісного аудиту як інструменту контролю за дотриманням не лише технічних, а й соціально-екологічних вимог у діяльності підприємства [5]. На основі проведеного аналізу виділено основні напрями практичної інтеграції стандартів сталого розвитку у систему менеджменту якості підприємства (таблиця 2).

Таблиця 2. Напрями інтеграції принципів сталого розвитку у СМЯ підприємства

Напрям інтеграції	Зміст заходів
Екологічний	Облік показників ресурсо- та енергоефективності у внутрішніх аудитах якості
Соціальний	Формування корпоративної культури відповідальності персоналу за якість і безпеку
Управлінський	Включення індикаторів ЦСР до карти процесів та цілей у сфері якості
Економічний	Оцінка ризиків сталості постачальників у процедурах закупівель

Актуальність результатів полягає у систематизації підходів до взаємоузгодження вимог ISO 9001:2015, ISO 26000:2010 та Цілей сталого розвитку ООН у межах єдиної моделі управління якістю, що дозволяє розглядати показники сталого розвитку не як додаткове навантаження на СМЯ, а як органічну складову її процесного підходу та критеріїв постійного поліпшення.

Таким чином, інтеграція стандартів сталого розвитку у систему менеджменту якості підприємства є закономірним етапом еволюції управлінських систем. Поєднання вимог ISO 9001:2015 щодо процесного управління, рекомендацій ISO 26000:2010 у сфері соціальної відповідальності та орієнтирів Цілей сталого розвитку ООН створює основу для формування комплексної моделі управління, здатної забезпечити підприємству не лише відповідність якості продукції, а й довгострокову конкурентоспроможність та довіру стейкхолдерів.

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Chapter 44: Модульні захисні укриття як інструмент підвищення стійкості громад в умовах збройного конфлікту

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Abstract. Повномасштабна війна в Україні актуалізувала проблему швидкого створення захисної інфраструктури для цивільного населення. Постійна загроза ракетних ударів, застосування ударних безпілотних літальних апаратів та артилерійських обстрілів зумовлює необхідність впровадження інженерних рішень, здатних забезпечити оперативний захист населення та підтримати функціонування критично важливих об'єктів. Одним із найбільш перспективних напрямів є використання модульних захисних укриттів, які можуть виготовлятися промисловим способом, транспортуватися до місця експлуатації та вводитися в дію у стислі терміни [1].

На відміну від традиційних захисних споруд цивільного захисту, будівництво яких потребує значних часових та фінансових ресурсів, модульні укриття характеризуються високим рівнем мобільності та адаптивності. Конструкції можуть виготовлятися із залізобетону, металу або комбінованих матеріалів із забезпеченням необхідного рівня стійкості до дії вибухової хвилі та уламків боєприпасів. Залежно від умов розміщення модулі можуть встановлюватися на поверхні землі, частково заглиблюватися або монтуватися під землею [2].

Особливістю модульних укриттів є можливість їх масштабування та пристосування до різних умов експлуатації. Стандартизовані секції дозволяють формувати захисні споруди різної місткості для розміщення населення, персоналу підприємств, учасників освітнього процесу та працівників об'єктів транспортної інфраструктури. Важливою перевагою є також можливість багаторазового переміщення конструкцій у разі зміни безпекової обстановки або потреб громади [1].

У сучасних умовах розвитку систем цивільного захисту особливого значення набуває концепція багатофункціонального використання укриттів. За відсутності загроз такі споруди можуть виконувати функції навчальних, медичних, соціальних або технічних приміщень, що підвищує ефективність використання ресурсів та сприяє формуванню стійких громад. Досвід України демонструє, що впровадження модульних захисних споруд є одним із найбільш ефективних шляхів швидкого підвищення рівня безпеки населення в умовах воєнного стану та післявоєнного відновлення [3].

Отже, модульні укриття доцільно розглядати як важливий елемент сучасної системи цивільного захисту, що забезпечує оперативне реагування на загрози, підвищення безпеки населення та зміцнення стійкості громад в умовах збройних конфліктів.

Таблиця 1. Основні характеристики модульних захисних укриттів

Характеристика	Значення
Спосіб виготовлення	Заводське виробництво
Спосіб монтажу	Встановлення готових модулів
Можливість транспортування	Так
Варіанти розміщення	Наземне, заглиблене, підземне
Матеріали конструкцій	Залізобетон, сталь, комбіновані матеріали
Призначення	Захист населення та персоналу
Можливість масштабування	Висока
Термін введення в експлуатацію	Від кількох годин до кількох діб

Дані, наведені в табл. 1, демонструють, що основними перевагами модульних захисних укриттів є їх мобільність, швидкість введення в експлуатацію та можливість масштабування відповідно до потреб конкретної громади або об'єкта. Саме ці характеристики обумовлюють доцільність їх використання як одного з інструментів підвищення стійкості населення та критичної інфраструктури в умовах воєнних загроз.

Keywords. Модульні укриття, цивільний захист, захисні споруди, стійкість громад, воєнний стан, безпека населення.

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Chapter 45: Стратегічна парадигма редукції ювенальної делінквентності: досвід підліткових судів США

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Abstract. Цінність і феномен підліткових судів (судів однолітків) для педагогів, викладачів та вчителів залишаються малодослідженими в Україні. Зростання психотравмувальних чинників молоді внаслідок повномасштабної війни обумовлює актуальність та перспективність вивчення досвіду підліткових судів США задля реалізації антропоцентричної парадигми ювенального правосуддя в Україні та формування належних інституційних гарантій для майбутніх поколінь.

В англомовній правовій літературі цей феномен описують як Youth Courts, Teen Courts або Peer Courts. Це не класичні органи державної влади, а програми відновного правосуддя [1]. Наразі понад 1800 підліткових судів діють у 48 штатах США, окрузі Колумбія, у юрисдикціях понад 25 племен, а також у 10 країнах на п'яти континентах. Витоки цієї моделі пов'язані із запровадженням першого підліткового суду в Іллінойсі у 1899 році. Сутність підліткових судів полягає у використанні конструктивного впливу однолітків на правопорушника через оцінювання його поведінки та вчинку однолітками. Якщо неповнолітній вчинив дрібне правопорушення вперше, то справу (за його згоди та згоди батьків) передають не до звичайного суду, а до суду однолітків. Така модель сприяє усвідомленню підлітками своїх прав, сутності справедливості та ролі закону, а також формуванню навичок ухвалення відповідальних рішень. Усі ролі в судовому процесі – присяжні, прокурори, адвокати, а іноді й суддя – виконують підлітки віком від 10 до 18 років, які пройшли спеціальну підготовку. Справа приймається судом однолітків лише тоді, коли правопорушник визнав свою провину. Мета процесу – не довести вину, а визначити виховний захід правопорушнику [2].

Американська асоціація пробації та умовно-дострокового звільнення виокремлює чотири моделі підліткових судів: модель дорослого судді, модель підліткового судді, модель трибуналу та модель суду присяжних-однолітків. У моделі дорослого судді прокурор, адвокат та присяжні – неповнолітні, веде засідання дорослий суддя. У моделі підліткового судді усі ролі, включно з суддею, виконують підлітки. У моделі трибуналу справу слухає колегія з трьох підлітків-суддів, адвокати та прокурори також є підлітками, а журі присяжних відсутнє. У моделі суду присяжних-однолітків (найпопулярніша модель) немає класичних адвокатів і прокурорів. Колегія присяжних-підлітків ставить запитання правопорушнику та разом виносить вердикт щодо покарання. Підліткові суди не можуть призначати тюремне ув'язнення або грошові стягнення. Натомість їхні рішення мають відновний характер: обов'язкове написання листа-вибачення потерпілому від правопорушення, відвідування тренінгів із формування навичок емоційної саморегуляції, занять із цифрової та правової грамотності. Одним із поширених заходів є участь правопорушника у наступних засіданнях суду однолітків в якості присяжного [3].

Екстраполяція досвіду підліткових судів дає змогу дійти висновку, що їхній превентивний потенціал обґрунтовує доцільність рецепції подібних моделей у системі вітчизняної ювенальної юстиції. З огляду на це, в контексті формування національної моделі відновного правосуддя в Україні поняття «відновне правосуддя щодо неповнолітніх» доцільно розглядати як правовий і соціально орієнтований механізм реагування на кримінальні правопорушення, вчинені неповнолітніми, що передбачає залучення сторін кримінального конфлікту, держави та суспільства й спрямований на відновлення прав потерпілого, компенсацію заподіяної шкоди, досягнення примирення та відновлення соціальних зв'язків [4].

Отримані результати, що об'єктивізуються у зниженні рівня рецидивної злочинності молоді, підвищенні довіри до правосуддя, зміцненні правосвідомості суспільства та підвищенні законослухняності неповнолітніх і молоді, обґрунтовують доцільність розробки національної моделі відновного правосуддя та зумовлюють необхідність подальшого наукового дослідження моделі підліткових судів (судів однолітків) як перспективного інструменту реалізації відновної парадигми ювенальної юстиції в умовах воєнного стану та повоєнного відновлення [5].

Ключові слова. Відновне правосуддя, запобігання злочинності неповнолітніх, звільнення від кримінальної відповідальності, злочинність неповнолітніх, кримінологія, медіація, неповнолітні, примирення, ресоціалізація, підліткові суди.

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Chapter 46: М'яке право в адміністративному праві та трансформації державного управління

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Анотація. У цій статті розглядається роль м'якого права в трансформації адміністративного права та державного управління. У ній аналізується м'яке право як система необов'язкових правил, стандартів та адміністративних практик, що впливають на державне управління через перекональні та інституційні механізми, а не правовий примус. Дослідження демонструє, що в контексті європейської інтеграції та реформ державного управління в Україні м'яке право є важливим регуляторним інструментом, який доповнює традиційні правові норми. Воно підтримує гнучкість, експерименти з політикою та координацію в рамках систем управління. У статті робиться висновок, що м'яке право є важливим елементом модернізації адміністративного права та еволюції моделей державного управління.

Ключові слова. адміністративне право, державне управління, державне управління, м'яке право.

Chapter 47: Трансформація ролі викладача в епоху штучного інтелекту

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Анотація. Сучасна освіта переживає значні зміни, які викликані стрімким поширенням штучного інтелекту в навчальному процесі. Століттями традиційне навчання базувалося на тому, що викладач був головним джерелом знань та їхнім єдиним передавачем, людиною з унікальним досвідом. Проте з появою великих мовних моделей, таких як ChatGPT або Google Gemini, доступ до будь-якої інформації став миттєвим. Це ставить перед педагогічною спільнотою серйозну проблему: як переосмислити власне призначення в освітньому процесі, щоб не втратити актуальність, та які нові функції має виконувати викладач, коли технологія здатна самостійно генерувати тексти, давати пояснення та виконувати завдання.

Питання трансформації ролі педагога активно досліджується в науці. Зарубіжні вчені наголошують на важливості постійного осмислення досвіду (Д. Шон), ролі викладача як помічника у навчанні дорослих (Дж. Ноулз) та психологічного супровідника особистісного зростання (К. Роджерс) [2]. Вітчизняні науковці підкреслюють перехід до рівноправного діалогу (О. Дубасенюк), важливість безперервної освіти (Н. Ничкало) та необхідність цифрової грамотності в умовах змішаного навчання (В. Биков, М. Жалдак, Н. Морзе) [2]. Цей аналіз доводить, що адаптація до нових умов вимагає від педагога не лише володіння технологіями, а й глибокої психологічної перебудови та подолання внутрішніх бар’єрів.

З огляду на ці тенденції, головною метою є дослідити, як саме змінюється роль викладача в епоху комп’ютерних алгоритмів, визначити нові вимоги до його навичок та показати шляхи гармонійного поєднання сучасних технологій із людським чинником у навчанні.

Сьогодні студенту більше не потрібен просто лектор для отримання фактів, йому необхідний наставник, здатний пояснити, чому ці знання важливі та як їх застосувати на практиці в реальному житті. Відбувається поступовий перехід від застарілої моделі навчання, коли викладач просто виступає перед авдиторією, до моделі, де він стає провідником і помічником, який працює поруч зі студентом. Таким чином, штучний інтелект не становить загрози для професії викладача як такої, але він змушує відмовитися від старих методів викладання.

Зміна навчальних практик передбачає, що увага переноситься з простого викладу теоретичного матеріалу на сам процес навчання та його умови. Викладач стає творцем (архітектором) навчального середовища. Замість того, щоб витрачати багато часу на підготовку звичайних лекцій, сучасний педагог конструює сценарії, у яких студент взаємодіє зі штучним інтелектом. Технологія виступає своєрідним «спаринг-партнером» (тобто віртуальним співрозмовником для спільного тренування навичок та обговорення ідей), який допомагає вирішувати складні навчальні завдання [1]. У зв'язку з цим надзвичайно важливою навичкою стає промпт-інжиніринг (вміння точно та правильно формулювати запитання чи завдання до комп’ютерної програми), і цю навичку потрібно обов'язково включати до навчальних планів як базову підготовку.

Ще одним важливим напрямком змін є перехід від простого контролю знань до перевірки фактів та розвитку критичного мислення. Оскільки штучний інтелект іноді може видавати помилкові відповіді або відверті вигадки (так звані «галюцинації»), головна роль викладача полягає в тому, щоб навчити студентів сумніватися в отриманій від «машини» інформації [1]. Студенти повинні вміти перевіряти джерела, аналізувати упередження та уникати маніпуляцій. Через це докорінно змінюється підхід до оцінювання: традиційні домашні твори чи реферати втрачають сенс, оскільки їх легко може написати комп’ютерна програма. Тепер оцінюється не кінцевий текст, а сам процес мислення, вміння перевіряти дані, вести дебати та розв'язувати практичні завдання в авдиторії.

Особливе місце в новій ролі викладача займає людяність, емпатія та емоційна підтримка. Штучний інтелект легко бере на себе рутинні завдання, наприклад, перевірку тестів чи надання швидких відповідей, що звільняє час педагога. Викладач стає тим, хто підтримує робочу атмосферу в групі, мотивує студентів, виховує ціннісні орієнтири та допомагає їм розвиватися індивідуально. Дуже ефективною стає модель «перевернутого класу» (коли студенти самостійно вчать теорію вдома за допомогою віртуальних помічників, а дорогоцінний час на занятті присвячують живим дискусіям та практиці під керівництвом викладача).

Практичне застосування штучного інтелекту в освіті має кілька корисних напрямків. По-перше, існують програми, які здатні підлаштовуватися під рівень знань та швидкість засвоєння матеріалу кожного окремого студента, забезпечуючи повноцінний індивідуальний підхід. По-друге, спеціальні системи дозволяють швидко оцінювати роботи та аналізувати успішність, виявляючи слабкі місця в навчанні, щоб викладач міг вчасно допомогти. Також штучний інтелект робить навчання більш доступним для людей з особливими потребами, наприклад, озвучуючи текст для зручного сприйняття або автоматично створюючи субтитри для тих, хто має вади слуху [3].

Однак широке використання новітніх технологій супроводжується певними труднощами та психологічними викликами. Викладачі можуть відчувати цифрову втому та вигорання через необхідність постійно вивчати нові програми, слідкувати за їх оновленнями та проводити багато часу за екраном. Часткова автоматизація спілкування зі студентами зменшує кількість живих розмов, через що педагог може відчувати емоційну ізоляцію, втрату спонтанності діалогу та нестачу простого людського зворотного зв'язку.

Для студентів надмірна довіра до штучного інтелекту також несе серйозну загрозу. Вони можуть втратити бажання думати самостійно, стати залежними від комп’ютерних підказок та втратити інтерес до власного пошуку істини. Готові відповіді можуть спонукати до нечесного навчання, коли студент видає згенерований алгоритмом текст за свій власний [3]. Тому викладач має власним прикладом показувати, як чесно та відповідально використовувати цифрові інструменти, відкрито зазначаючи студентам, коли матеріали для лекцій були створені за допомогою новітніх технологій.

У таких умовах сучасному педагогу потрібно швидко розвивати нові вміння. Окрім цифрової грамотності, йому необхідна психологічна гнучкість, уміння працювати в нових умовах та високий рівень емоційного інтелекту (здатність розуміти та керувати своїми емоціями, а також емоціями студентів). Викладач часто змушений виходити за межі свого предмета, розширювати знання, щоб розуміти принципи роботи комп’ютерних програм та пояснювати їхній вплив на суспільство.

Отже, зміна ролі викладача в епоху комп’ютерних алгоритмів є невідворотною. Майбутнє освіти полягає у поєднанні високих технологій та високого рівня людяності. Програми забезпечують доступ до безмежної кількості даних та швидке підлаштування під потреби студента, а викладач гарантує розуміння глибокого сенсу, критичний погляд на речі та емоційну підтримку. Жоден ШІ не здатен замінити справжні людські емоції, щирість та здатність надихати. Педагог майбутнього виступає своєрідним містком між стрімким технічним прогресом та розвитком людини, гармонійно поєднуючи інновації з турботою про особистість. Тільки через таке партнерство людини і технології можна якісно підготувати молодь до викликів сучасного світу.

Ключові слова: критичне мислення, роль викладача, трансформація освіти, штучний інтелект.

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Chapter 48: Педагогічна Практика Як Передумова Дуальної Освіти Майбутніх Учителів: Формування Готовності До Інноваційної Виховної Діяльності

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Анотація. У статті запропонований аналіз формування готовності до інноваційної діяльності майбутніх учителів. Педагогічну практику ми розглядаємо як передумову дуальної освіти під час навчання в університеті, що дозволяє досягти цілісного бачення теоретичних і організаційно-педагогічних засад підготовки до інноваційної виховної діяльності. Визначені педагогічні умови формування готовності до організації виховного процесу в процесі практики, розвитку професійного інтересу до впровадження інновацій, представлені технології інноваційної виховної діяльності, запропоновані шляхи її оптимізації.

Засвідчено багатоаспектність поняття готовності, яке розглядається як цілісне стійке особистісне утворення, інтегративна якість особистості, сукупність знань, умінь, навичок. Це особистісно-професійна якість, що характеризується усвідомленням значущості та інтересом здобувача до виховання учнів на інноваційних засадах; наявністю мотивації з одночасним набуттям спеціальних знань, умінь, які втілюються в організацію виховної роботи; потребами творчої самоактуалізації й самореалізації.

З'ясовано, що педагогічна практика розвиває творчу активність і самостійність здобувачів, сприяє формуванню їх як соціально активних особистостей з інноваційним потенціалом.

Ключові слова. формування готовності до виховної діяльності у процесі педагогічної практики, дуальна освіта, педагогічні інновації, інноваційна виховна діяльність, технології інноваційної виховної діяльності.

1. Вступ

Реформування національної системи освіти в контексті європейських вимог потребує глибокої модернізації, впровадження інноваційних виховних технологій у процес підготовки майбутніх учителів, запровадження практико орієнтованого навчання, як передумови дуальної освіти в Україні [1]. Важливим фактором виступає готовність здобувача до сприйняття прогресивних змін. Оскільки лише вчитель з творчими здібностями та інноваційним потенціалом здатний до ефективної професійної діяльності.

В умовах сучасних перетворень в освіті України суттєво змінюються вимоги до професійної діяльності вчителя. Учитель сучасної школи має будувати свою діяльність так, щоб „сприяти становленню особистості як творця і проектувальника життя, гармонізації і гуманізації стосунків між учнями і педагогами, школою і родиною, керуючись ідеями самоцінності дитинства, діалогу, компетентного вибору особистого життєвого шляху" [7], що вимагає реалізації інноваційних підходів до педагогічної діяльності. Концепція продуктивної виховної діяльності педа¬гога загальноосвітньої та професійної школи, ґрунтовно розроблена О. Дубасенюк, відображає три основних підпростори: структурний, праксіологічний (процесуальний) і аксіологічний. Структурний підпростір має такі елементи, як: ці¬лі, суб'єкт, об'єкт, предмет, засоби виховної діяльності. Праксіологічний – проходить у такі етапи означеної діяльності: діагнос¬тичний, проектувально-цільовий, організаційний, стимулювально-спонукальний, контрольно-оцінний. Аксіологічний – охоплює сукупність інтегральних властивостей педагога – професіоналізм особистості і професіоналізм діяльності, що виступають показником особистісно-діяльнісної сутності діяльності вихователя. Ця концепція слугує базою для вироблення стратегії і тактики організації допрофесійної та про¬фесійної підготовки майбутніх педагогів [2, с. 131].

Поняття «інноваційна виховна діяльність» ми трактуємо як діяльність, що забезпечує взаємодію особистості з об'єктами середовища та формує соціально ціннісне ставлення до нього, здатність бути суб'єктом власної діяльності. А основними критеріями виступають: усвідомлене прагнення студентів бути готовими до інноваційної виховної діяльності з школярами; знання і розуміння важливості інновацій у виховному процесі; здатність до творчості; дієвість, уміння здійснювати інноваційну виховну діяльність.

Було досліджено, що найбільш ефективно формування готовності до інноваційної виховної діяльності відбувається у процесі проходження педагогічної практики. А це вказує на перспективи дуальної освіти.

2. Розвиток дуальної освіти у підготовці майбутніх фахівців

Освіта є основою соціально-економічного розвитку будь-якої держави. Аналіз законів «Про освіту» (2017), «Про вищу освіту» (2017), «Про професійну (професійно-технічну) освіту» (2018), інших нормативних освітніх документів, зокрема Концепції підготовки фахівців за дуальною формою здобуття освіти (2018), Положення про дуальну форму здобуття фахової передвищої та вищої освіти (2023) свідчить про те, що фокус уваги суспільства спрямований нині на підвищення якості освіти. Основною метою цих документів є, по-перше, перетворення вітчизняної системи освіти на конкурентоспроможну структуру; по-друге, формування і розвиток різнобічно розвинених особистостей, компетентних, мобільних, соціально-свідомих фахівців,ураховуючи історичні та національно-культурні освітні традиції.

Важливо зазначити, що українські урядові інституції також акцентують увагу на введення адаптивних практико орієнтованих і гнучких освітніх програм (ОП) у межах сучасної модернізації освіти. Одним із напрямів такої діяльності є впровадження дуального навчання для здобуття освіти. Такі заходи сприяють оновленню освітніх стандартів і програм навчання у закладах вищої освіти (ЗВО). Розроблення сучасних компетентностей, необхідних працівнику з вищою освітою, здійснюється безпосередньо професійною спільнотою, враховуючи сучасні, перспективні технології і досвід прогресивної практики. Така підготовка здобувачів освіти дає можливість об'єктивно оцінити рівень їхньої кваліфікації і в той самий час підвищує шанс на працевлаштування в надійних роботодавців. Компетентності майбутніх фахівців у цих випадках максимально задовольняють вимогам ринку праці [1].

Дуальне навчання можна вважати інструментом для поліпшення інвестиційної привабливості регіонів, а також для розвитку конкурентних переваг за рахунок підготовки фахівців, які відповідають вимогам сучасної економіки. На жаль, сучасні об'єктивні причини, а саме: недавня світова пандемія COVID-19 та повномасштабна війна росії з Україною не сприяють швидким модернізаційним процесам. Нині на ринку праці наявна проблема дефіциту фахівців певних галузей. Перед роботодавцями постало завдання пошуку співробітників з необхідною кваліфікацією. У той самий час, досвідчені фахівці не можуть знайти роботу з тієї причини, що їхні практичні вміння «застаріли». У зв'язку з цим зростає необхідність конструктивного аналізу й ефективного використання кращого зарубіжного досвіду. Прийнята нещодавно Концепція підготовки фахівців за дуальною формою здобуття освіти підвищує актуальність досліджень освітніх систем тих країн, котрі мають загальновизнані успіхи в цьому освітньому напрямі.

Дуальне навчання розглядається не лише як педагогічна альтернатива, а й як успішно адаптований до умов ринкової економіки освітній феномен, що здійснює як прямий, так і опосередкований вплив на розвиток професійної педагогіки різних країн, в тому числі України. Її виникнення ознаменувало трансформацію освітніх традицій, коли на заміну раціоналістичній середньовічній європейській практиці професійної підготовки майстром окремого і «собі подібного» учня, економіка зажадала нову форму підготовки кваліфікованих працівників на основі тісної взаємодії підприємств і закладів освіти.

Аналіз Концепції підготовки фахівців за дуальною формою здобуття освіти (2018), Стратегії розвитку вищої освіти України на 2021-2031 рр. (2020) Положення про дуальну форму здобуття фахової передвищої та вищої освіти (2023) свідчить про перспективу розвитку дуального навчання в системі вищої освіти. Вона передбачає вивчення і структурування сукупності її провідних ідей. Визначальною серед них є тісна взаємодія системи професійної освіти, ринку праці і роботодавців, її функціонування на основі соціального партнерства.

Специфічними принципами дуального навчання є: єдність теорії і практики, єдність освіти, виховання і розвитку, особистісна активність та індивідуальна спрямованість практичних занять, фундаментальність, інтеграція, мобільність, універсальність, демократизація, валідності, об'єктивності, практико орієнтованості, єдності управління та самоуправління, зв'язок теорії з практикою, взаємодія закладу освіти з роботодавцем, правильна мотивація [1].

Доведено, що практико орієнтоване навчання є важливим компонентом дуальної форми здобуття освіти. Уточнимо, зміст терміну «практико орієнтоване навчання» - це педагогічний процес, досягнення цілей якого проходить з безпосереднім набуттям досвіду практичної діяльності. Його мета полягає у допомозі здобувачеві в засвоєнні й застосуванні одержаних теоретичних знань, формуванні вмінь самостійно вирішувати проблеми, адаптуватись в сучасних умовах. Воно сприяє формуванню таких якостей, як професійна і комунікативна компетентність, позитивне ставлення до своєї майбутньої професії, творчий, неординарний підхід до розв'язання професійних завдань, активна життєва позиція. Результатами таких занять є: формування універсальних професійно важливих якостей і вмінь; рефлексивних, дослідницьких, комунікативних, презентаційних та командних компетентностей; підвищення навчальної мотивації, академічної та особистої успішності; формування спеціальних професійних компетентностей [3]. Встановлено, що практико орієнтоване навчання містить три складові: свободу, самостійність, співробітництво.

Визначено переваги практико орієнтованих технологій у контексті дуального навчання:

- вони надають можливість спільно готувати кваліфікованих фахівців, поєднуючи теоретичне та практичне навчання;
- навчальний план передбачає повний обсяг аудиторного навантаження;
- під час підготовки практичних, лабораторних, курсових і дипломних проєктів здобувачам надається можливість використовувати матеріали і спеціально обладнані лабораторії підприємства;
- університет ураховує виробничі вимоги, що пред'являються до майбутнього фахівця, і це позначається на якості його підготовки;
- здобувачі виконують курсові та дипломні проєкти на актуальні для підприємства теми. Тим самим надають науковий матеріал у вигляді пропозицій для розв'язання реальних виробничих завдань.

Для України дуальна форма здобуття освіти є своєрідною інновацією, оскільки порівняно нещодавно розпочалось її впровадження. Результати вивчення нормативно-правових актів, урядових сайтів, наукових публікацій дали змогу сформулювати основні завдання впровадження дуальної освіти у вітчизняних закладах освіти: підвищення якості підготовки кадрів із урахуванням вимог потенційних роботодавців; оновлення професійних програм, форм і методів навчання, подолання відриву між теоретичною та практичною складовою освітнього процесу.

На рівні закладів освіти стоїть завдання: посилити увагу до методології досліджень реалізації дуального навчання задля більш глибокого розуміння його особливостей та визначення перспективних напрямів розвитку змісту, методики, технології і організації дуальної форми здобуття професійної освіти; намагатися створити та поширити досвід упровадження дуальної форми здобуття освіти в кожному ЗВО; сприяти упровадженню освітніх програм за дуальною формою навчання в тих закладах освіти, де це можливо; зреалізовувати теоретичні та емпіричні дослідження, що стосуються дуального навчання; розробляти і запроваджувати системні заходи щодо заохочення педагогів удосконалювати свої компетентності ефективного впровадження дуального навчання в освітній процес; обґрунтувати та визначити концептуальні підходи до організації професійної практико орієнтованої підготовки фахівців нової генерації; вивчати і поширювати досвід вітчизняних та зарубіжних закладів освіти з розроблення й впровадження освітніх програм за дуальною формою навчання; спрямувати зусилля на активній співпраці закладів освіти з потенційними роботодавцями з метою ефективного професійного самовизначення молоді.

Узагальнення зарубіжного досвіду впровадження елементів дуального навчання у вітчизняну систему освіти дає можливість зробити висновок, що досліджувана форма підготовки фахівців в Україні перебуває у стані зародження. Відсутність законодавчого регулювання, недостатнє налагодження співпраці між підприємствами та закладами освіти не сприяє швидкому впровадженню дуального навчання. Особливостями реалізації дуальної освіти в Україні є: укладання договору про професійне навчання, практичного навчання на робочих місцях, що становить 25-60% від загального обсягу, єдині стандарти професійної освіти й удосконалення планів навчання за вимогою роботодавців.

Аналіз становлення і розвитку дуального навчання в університетах Німеччини й Австрії дозволяє досягти цілісного бачення його теоретичних і організаційно-педагогічних основ. Обґрунтовано концептуальні й організаційно-методичні засади реалізації дуального навчання в європейських університетах; створено й обґрунтовано модель організації університетського дуального навчання, окреслено перспективи розвитку дуального навчання у світовій та вітчизняній освіті в різних контекстах. Розроблено методичний комплекс щодо упровадження елементів дуального навчання у вітчизняну систему вищої освіти.

Конкретизовано поняття: «дуальність», «дуалізм», «дуальна освіта», «дуальне навчання», «дуальна форма навчання», «компетентності», «місце навчання», «соціальне партнерство». З'ясовано, що в зарубіжній науковій літературі має місце єдиний термін і визначення дуального навчання (Duales Studium), що трактується як комбінована модель професійного навчання: одночасне одержання теоретичних і практичних знань [1].

3. Педагогічні умови формування готовності до організації виховної діяльності у процесі педагогічної практики

У процесі дослідження нами були обґрунтовані та експериментально перевірені педагогічні умови підвищення ефективності підготовки студентів до інноваційної виховної діяльності.

Під умовами ми розуміємо: обставини, від яких що-небудь залежить; навколишнє середовище, в якому відбувається, протікає що-небудь; наявність обставин, передумов, що сприяють чому-небудь; філософську категорію, що виражає відношення предмета до навколишніх явищ, без яких його існування неможливе; сукупність процесів, взаємин, стосунків, необхідних для виникнення, існування або зміни даного об'єкта [3].

Педагогічні умови розглядаються нами як: обставини освітнього процесу, що забезпечують досягнення поставлених цілей; середовище, в якому педагогічні вміння виникають, існують і розвиваються; такі обставини, в яких, по-перше, враховані наявні умови навчання, по-друге, передбачені способи перетворення цих умов у напрямку цілей навчання, по-третє, певним чином відібрані, вибудувані і використані елементи змісту, методи (прийоми) і організаційні форми навчання з урахуванням принципів оптимізації; обставини процесу навчання, які є результатом відбору, конструювання та застосування елементів змісту, методів, засобів навчання для досягнення певних цілей.

Виходячи з наявних визначень, під педагогічними умовами формування готовності студентів до інноваційної виховної діяльності у процесі педагогічної практики ми розуміємо сукупність факторів, які свідомо створюються в освітньому процесі і впливають під час педагогічної практики на стан готовності студента та результати його інноваційної виховної діяльності.

Ґрунтуючись на проаналізованих нами теоретичних положеннях та на основі результатів експерименту вважаємо, що формування готовності студентів до інноваційної виховної діяльності у процесі педагогічної практики буде ефективним при дотриманні таких педагогічних умов:

– набуття студентами особистісного сенсу інноваційної виховної діяльності через усвідомлення ними цілей та значущості такої діяльності, бажання до її провадження, почуття успіху від одержаних результатів;
– опосередкування змісту практичної підготовки до виховної роботи – орієнтацією студентів на інноваційну діяльність, ознайомлення із передовим досвідом, використання у практичній діяльності інноваційних технологій, методів, прийомів виховання;
– формування умінь подолання труднощів, що супроводжують реалізацію інновацій у педагогічну практику;
– створення та розв'язання педагогічних ситуацій, надання підтримки студентам в процесі адаптації до інноваційного виховного середовища, налагодження взаємодії із суб'єктами педагогічного процесу;
– забезпечення особистісно орієнтованого підходу у практичній підготовці шляхом визнання індивідуальної цінності та пріоритету особистості студента, надання йому можливості вибору індивідуальної траєкторії у підготовці та проведенні виховних заходів, прояву особистісного потенціалу через індивідуалізацію та диференціацію завдань педагогічної практики.

Визначені педагогічні умови можуть впроваджуватися лише взаємопов'язано та одночасно, оскільки уточнюють та доповнюють одна одну.

Однією з таких умов є набуття здобувачами особистісного сенсу інноваційної виховної діяльності через усвідомлення ними цілей та значущості такої діяльності, бажання до її провадження, почуття успіху від одержаних результатів [9]. Ця умова ґрунтується на особистісно орієнтованому і діяльнісному підходах у підготовці студентів та передбачає розвиток інтересу і схильності здобувача як майбутнього педагога до впровадження інновацій у виховну роботу, що з одного боку, відображає його особистісну і діяльнісну спрямованість, з іншого – вихідні спонукання або суб'єктивні стимули, мотиви, що ґрунтуються на усвідомленні ним свого громадянського обов'язку і соціально значущих цілей виховного процесу крізь призму власного внутрішнього досвіду.

Усі види роботи, які здобувач здійснює під час проходження педагогічної практики, повинні сприяти формуванню у нього зацікавленості шляхами оптимізації виховного процесу, викликати бажання пошуку нових методів, прийомів виховання [4].

У процесі практичної діяльності у здобувачів формується професійний інтерес, який у контексті нашого дослідження трактується як інтерес до інноваційної виховної діяльності в цілому, до її окремих, соціально важливих аспектів (окремих інноваційних технологій, методів, прийомів, механізмів виховання); він характеризується значною інтенсивністю уваги, вольових зусиль і визначається соціально обґрунтованим, активним, пізнавально-інтелектуальним і творчим ставленням майбутніх педагогів до професії вчителя-вихователя з інноваційним спрямуванням діяльності.

Оскільки основним джерелом людської активності (за А. Маслоу) виступає потреба людини в самоактуалізації, під час практичної підготовки необхідним є налагодження таких взаємин між учасниками виховного процесу, які б сприяли формуванню в учнів здатності до самоактуалізації особистості. До сутнісних характеристик особистості, спроможної до самоактуалізації, зараховуємо: самостійність як універсальну здібність до регулювання, цілеспрямованість діяльності та рефлексії, свободу як універсальну здатність до автономної поведінки, саморегуляцію та міжсуб'єктну взаємодію, творчість як універсальну здатність до креативності, концентрацію творчих зусиль, незалежність в судженнях тощо. При цьому наголошуємо на важливості створення ситуації самореалізації – ситуації, у якій студент отримує право на вибір і прийняття рішень, актуалізацію суб'єктивного досвіду, вияву нахилів, інтересів і творчих здібностей. Це сприяє індивідуалізації навчання здобувачів відповідно до їхніх потреб і можливостей. Разом з тим, отримуючи можливість вибору власної траєкторії навчання, вони мають нести відповідальність за зроблений вибір.

4. Впровадження інновацій у виховний процес

Здійснення інноваційної виховної діяльності під час практичної роботи з учнями передбачає перебування студента у постійному пошуку інформації і пошуку себе. Знайомлячись з інноваційними технологіями, студент як би приміряє їх на себе, визначає чи справиться він з цим виховним арсеналом, проектує його дію і результат. Перебуваючи під впливом отриманої інформації, яка відображає сутнісні зміни в освіті як наслідок суспільних змін, у майбутнього вчителя формується світогляд, зміцнюється громадська свідомість [6]. Внаслідок апробації інновацій при роботі з дітьми у студентів залишається позитивне або негативне ставлення до кожної з них, а, отже, формується власний банк надійних засобів впливу. Таким чином, важливим є розгляд інноваційної виховної діяльності крізь призму власного сприймання, індивідуальних психічних переживань – тобто, внутрішнього досвіду здобувача.

Психологічна готовність учителя до участі в інноваційних виховних процесах гуманістичного спрямування базується, таким чином, на вихідній установці педагога на дитину, його здатності до педагогічної взаємодії з нею.

При формуванні готовності здобувача до реалізації інноваційних технологій виховання, слід виходити з того, що вчитель, покликаний реалізовувати особистісно орієнтовану освіту, має сам отримати такий досвід, відчути потребу по-новому переосмислити цінності освіти, визначаючи головною метою власної професійної діяльності виховання особистості, здатної до самоактуалізації.

Важливою педагогічною умовою підвищення ефективності формування готовності студентів до інноваційної виховної діяльності вважаємо доцільність опосередкування змісту практичної підготовки до виховної роботи – орієнтацією здобувачів на інноваційну діяльність, ознайомлення із передовим досвідом, використання у практичній діяльності інноваційних технологій, методів, прийомів виховання.

Для реалізації цієї умови базовими закладами для проходження педагогічної практики обирали школи, навчально-виховні комплекси, навчально-виховні об'єднання, ліцеї інноваційного типу. Це давало можливість ознайомити студентів із засобами досягнення високого рівня взаємодії з учнями, залучати їх до педагогічної творчості.

Інноваційну школу як певну оригінальну педагогічну систему характеризують: системність цілеспрямованих нововведень; розробка і реалізація оригінальної моделі устрою життя школяра; апробація нових засобів і способів роботи педагога, спрямованих на розвиток творчих рис учителя, особистої відповідальності за результати своєї праці. Відповідно, інноваційні школи дають можливість для ґрунтовного вивчення досвіду та особливостей роботи вчителів, що впроваджують інноваційну виховну діяльність. Серед найбільш ефективних способів вивчення педагогічного досвіду інноваційної виховної діяльності виокремлюємо спостереження та аналіз виховних занять, інших форм виховного процесу; вивчення документації, бесіди з учителем і його колегами; анкетування батьків, учнів та ін.

Як показує практика сьогодення, шкіл інноваційного типу у системі освіти України не дуже багато, тому для формування готовності до інноваційної виховної діяльності доцільним є вивчення передового педагогічного досвіду виховної роботи вчителів-практиків.

При формуванні готовності здобувачів до інноваційної виховної діяльності у процесі педагогічної практики важливим є формування компетенцій інноваційної виховної діяльності [5]. З метою ознайомлення та кращого сприйняття, розуміння студентами розроблених вченими й практиками інноваційних технологій виховання ми виокремили групи: духовно-морального розвитку, патріотичного виховання, життєтворчі, розвитку індивідуальних здібностей і таланту вихованців, трудові, природоохоронні, здоров'язберігаючі, а також відповідно до кожної технології обрано зразки виховних заходів інноваційного спрямування.

До технологій духовно-морального розвитку відносимо «Школу життя», «Виховувати, граючи – грати, виховуючи». Метою їх є формування основ духовно-морального виховання, корекція поведінки вихованця, розвиток самосвідомості, використання позитивних можливостей школи і позашкільних закладів і нейтралізація негативного впливу вулиці, засобів масової інформації, сумнівної відеопродукції, реклами, що пропагує негативні звички тощо.

У групу технологій патріотичного виховання включаємо комплекс «Школа-місто», проект «Школа майбутнього» [8], технології «Нова цивілізація», «Хочу все вміти». Мета цієї групи технологій – створення високого ідеалу служіння рідному народові, готовності до героїчного подвигу в ім’я процвітання та незалежності України, формування громадянина – патріота України, вироблення глибокого розуміння громадянського обов’язку, готовності у будь-який час стати на захист Батьківщини.

Група життєтворчих технологій об’єднує: «Школу життєтворчості», «Формування творчої особистості», «Створення ситуації успіху», «Колективного творчого виховання», «Проектувальної діяльності», Естетичного виховання засобами мистецтва, виховної системи «Я-особистість», урок-кінофестиваль, гра-драматизація (театр-мініатюра), проектно-моделювальні та інформаційно-комунікативні технології. Всі вони вимагають розвитку різних сфер особистості школяра: духовної, емоційної, вольової, інтелектуальної, моральної та постійного самовдосконалення.

Технології розвитку індивідуальних здібностей і таланту вихованців: «Психокорекційне малювання», «Розвиток здатності до саморегуляції», «Педагогічна підтримка», нейролінгвістичного програмування, тренінги, педагогіка співробітництва, адаптивна школа мають на меті забезпечування умов самореалізації школярів, здійснення індивідуального підходу з відповідним психолого-педагогічним та матеріальним забезпеченням, задоволенням різнобічних потреб вихованців у сфері науково-технічної, художньої, декоративно-прикладної творчості, у фізкультурно-спортивній та професійній діяльності.

Трудові технології – трудові справи для школи та рідного міста (села), рольові ігри формують психологічну готовність особистості до праці (бажання сумлінно та відповідально працювати, усвідомлення соціальної значущості праці як обов’язку і духовної потреби, бережливість щодо результатів праці та повага до людей праці, творче ставлення до трудової діяльності) та підготовку до праці (наявність загальноосвітніх і політехнічних знань, загальних основ виробничої діяльності, вироблення умінь і навичок, необхідних для трудової діяльності).

Група природоохоронних включає технології: «Школа природи», «Екологічна школа» і сприяє забезпеченню умов індивідуального розвитку, врахуванню особистих досягнень учнів, стимулюванню їх творчої активності, самореалізації в різних видах діяльності, реалізації їх здібностей та інтересів через насичене навчальне середовище, гармонійному розвитку особистості, вихованню духовно повноцінної творчої особистості тощо.

У групу здоров’язберігаючих входять технології тьюторської підтримки та супроводу учня, індивідуальної освіти вдома, у лікарні, арттехнології та ін. Вони формують мотивацію на збереження та розвиток здоров’я, особисту відповідальність за своє здоров’я та благополуччя, набуття навичок здорового способу життя, профілактику шкідливих звичок, формування здібності до здорової творчості.

Разом із тим, оскільки перелік існуючих у педагогічній теорії та практиці інноваційної виховної діяльності технологій досить широкий, у процесі проведення нашої експериментальної роботи ми акцентувати увагу на найбільш використовуваних і дієвих, з погляду практиків і власного досвіду [8]. До них зараховуємо: «Педагогіку співробітництва», «Виховання успішної особистості», «Педагогічну підтримку», «Рефлексивне самовиховання», «Школу життя», тренінгові заняття, ігрові, проектно-моделювальні технології [9].

Окрім цього, ми виокремили інноваційні методи і прийоми, якими учителі-практики найчастіше послуговуються під час реалізації інноваційних технологій, а саме: вагоме та логічне аргументування; мозковий штурм; незакінчене речення; мікрофон; акваріум; два – чотири – всі разом; займи позицію; гронування; кубування; кути; мозаїка; сенкан; дешифрувальник; словесне малювання; чарівна квітка; букет побажань; роздуми-міркування; колажування; малюнкові техніки; тестування; експериментально-пошукова діяльність морально-етичного спрямування; соціодрама; філософські бесіди; конструкція «Я-повідомення»; розбір життєвих ситуацій; аналіз соціальних ситуацій морально-етичного характеру; використання колективу як чинника унікальної ситуації виховання особистості; емоційно-оцінна діяльність учнів, формування впевненості у доцільності моральної норми; зосереджене осмислення; емоції враження, збентеження тощо.

Виховна робота, як влучно зазначає І. Бех [3], має ґрунтуватися на використанні психологічних механізмів розвитку свідомості й самосвідомості суб’єкта: співпереживання; переконання; формування мотиваційної залученості як прагнення індивіда до особистісної самозміни (співучасті; формування адекватного ставлення вихованця до его-потягів; використання енергетики «Я-ідеального»); «гедоністичний ризик» (створення надзвичайно сильних емоційних переживань у ситуації небезпеки) тощо.

Наступною умовою виокремлюємо формування умінь подолання труднощів, що супроводжують реалізацію інновацій у педагогічну практику, – створення та розв’язання педагогічних ситуацій, надання підтримки студентам в процесі адаптації до інноваційного виховного середовища, налагодження взаємодії із суб’єктами педагогічного процесу.

При успішному ознайомленні здобувачів із практичним використанням виховних інновацій у них виникає бажання втілити побачене у власній педагогічній діяльності. Відповідно, тут їм необхідна педагогічна підтримка з боку методистів, учителів, яка передбачає створення позитивного педагогічного середовища, проведення індивідуальних та групових консультацій; проведення показових занять; організація тренінгів, круглих столів, методичних семінарів тощо.

У педагогічний зміст поняття «підтримка» стосовно студентів-практикантів ми включаємо такі компоненти: допомога студентові в адаптації до умов реального виховного процесу в школі; усунення психологічних бар’єрів, труднощів та стереотипів, які виникають в організації взаємодії із суб’єктами педагогічного процесу (учнями, вчителями, батьками).

Для професійної адаптації студентів-практикантів до умов реального закладу освіти велике значення має перспективне планування і правильна організація педагогічної практики, що забезпечують інтеграцію і генералізацію диференційованих знань, а також формування позитивного ставлення до виконання поставлених завдань. Усе це сприятиме професійному самоствердженню студентів у правильності зробленого ними вибору професії вчителя, прагненню до оволодіння професійними знаннями, вміннями і навичками і, відповідно, формування готовності студентів до інноваційної виховної діяльності.

Серед бар’єрів та причин опору вчителів педагогічним інноваціям більшість дослідників виокремлюють: відсутність переконань у необхідності змін, неприйняття насаджуваних згори нововведень, острах перед невідомим або нездатність виконати будь-яке завдання, можливі невдачі, порушення усталеного порядку, звичок і взаємостосунків, відсутність поваги і довіри до особи, що здійснює зміни тощо.

Готуючи студента до використання інновацій у вихованні, важливим, на нашу думку, є перехід від традиційних у педагогічній практиці інформаційно-пояснювальних технологій до креативних, дійово-розвивальних, особистісно-зорієнтованих навчальних технологій шляхом надання можливості здобувачеві стати не «номінальним», а фактичним суб’єктом інноваційної діяльності [4].

Таким чином, формування готовності студентів до впровадження інновацій у виховний процес неможливе без забезпечення позитивного педагогічного середовища, яке доцільно характеризувати через його педагогічний потенціал. Під педагогічним потенціалом середовища ми розуміємо єдність кількісних та якісних педагогічних можливостей середовища (у нашому випадку середовища школи), котрі актуалізуються як у результаті саморозвитку, так і при створенні сприятливих умов. Структурними частинами педагогічного потенціалу виступають особистісні, матеріальні, духовні, структурні можливості.

Особистісні можливості педагогічного потенціалу середовища – це можливості людей, котрі спеціально або не усвідомлено займаються педагогічною діяльністю, і людей, які можуть бути додатково залучені до реалізації навчально-виховних цілей. Матеріальні можливості – це речові компоненти середовища, які можуть бути умовно поділені на дві групи:

1) речові компоненти середовища, спеціально створені і призначені для будь-яких педагогічних цілей (школи, позашкільні навчально-виховні заклади, їхня матеріально-технічна база тощо) і компоненти, що виконують інше призначення, але в ряді випадків можуть виконувати педагогічні функції (кінотеатри, житлові будинки, подвір'я, меблі, одяг, побутова техніка, прикраси і та ін.);

2) природні компоненти, які включають можливості виховного впливу первинної природи, тобто природи, що існує і розвивається без втручання людини, і можливостей другої природи, існування і формування якої відбувається за безпосередньою участю людини.

Духовні можливості середовища складають неопредметнені елементи соціального середовища: ідеологічна, культурна, моральна, психологічна атмосфера, що складається на основі взаємодії різних факторів (соціальна свідомість на макро- і мікрорівнях, моральні норми, національні традиції, звичаї, свята, характер спрямування і міра доступності літератури, мистецтва, психологічний мікроклімат у педагогічному колективі та мікрогрупах тощо).

Структурні можливості включають способи і форми управлінської діяльності людей, що має на меті поєднання людських, матеріальних і духовних можливостей педагогічного середовища.

Керівники педагогічної практики студентів, знаючи потенціал середовища, можуть не тільки використовувати його можливості для формування готовності до інноваційної виховної діяльності студентів, але й на основі цілеспрямованої актуалізації педагогічного потенціалу різних компонентів створювати, «моделювати» середовище відповідно до потреб підготовки компетентних педагогічних кадрів.

Таким чином, реалізація цієї умови сприяє створенню ситуацій успіху, умов для співпраці та співтворчості всіх його учасників, опора на позитивне в особистості майбутніх учителів. Саме постійне тренування суб'єктності як здатності майбутніх учителів до вільного вибору і відповідальності сприяє становленню їх як суб'єктів інноваційної виховної діяльності.

Ще однією важливою умовою формування готовності студентів до інноваційної виховної діяльності у процесі педагогічної практики є забезпечення особистісно орієнтованого підходу у практичній підготовці шляхом визнання індивідуальної цінності та пріоритету особистості студента [6], надання йому можливості вибору індивідуальної траєкторії у підготовці та проведенні виховних заходів, прояву особистісного потенціалу через індивідуалізацію та диференціацію завдань педагогічної практики.

Реалізація цієї умови проявляється у визнанні індивідуальної цінності та пріоритету особистості студента над загальним потенціалом колективу; передбачає шанобливе ставлення до майбутнього вчителя як вищої самостійної цінності; створює оптимальні умови для його становлення як суб'єкта професійної діяльності гуманістичного спрямування; потребує впровадження у педагогічну практику таких методів впливу, які забезпечують розвиток індивідуальності студента за рахунок максимальної диференціації завдань; сприяє розвитку його особистісних якостей; означає охорону його фізичного та духовного здоров'я. Для викладача важливо вміти створювати у студентському колективі атмосферу доброзичливості, гнучко і динамічно включати кожного студента в заняття, спиратися на його суб'єктний досвід, стимулювати прояви самостійності, ініціативи студентів; визнавати за кожним право на помилку, але з обов'язковим аналізом її причин, визначенням шляхів подолання; надавати студенту можливість вибору індивідуальної траєкторії навчання; створення умов для творчості в самостійній та колективній діяльності тощо.

Розвиток особистості студента передбачає, передусім, розвиток його здатності до самоосвіти, самонавчання, самовиховання, саморозвитку, самоактуалізації, самореалізації, професійної рефлексії; виховання цілісної людини, із взаємопов'язаними соціальною, природною та культурною сутністю. Особлива увага у процесі формування готовності студента до інноваційної виховної діяльності надається максимальному врахуванню таких індивідуальних особистісних властивостей як: особливості сприйняття, уваги, пам'яті, розумових процесів, темпераменту та вольових якостей, мотивації, самооцінки, рівнів намагань, домінуючого соціального статусу.

Важливим у руслі нашої проблеми є дотримання умов ефективності індивідуалізації професійно-педагогічної підготовки майбутнього вчителя:

– складання кожним здобувачем власного професійного автопортрету з метою інтеграції результатів особистісного та професійного самодослідження;
– розробки й реалізації професійної індивідуальної програми професійного зростання з урахуванням особливостей відповідних етапів професійно-педагогічної підготовки;
– включення до змісту професійно-педагогічної підготовки майбутніх учителів системи понять і концепцій, що спрямовують студента на рефлексію, самопроектування, саморозвиток професійно значущих особистісних якостей;
– зміни характеру взаємодії викладача та студента педагогічного вищого закладу освіти з позицій цінностей гуманістичної орієнтації.

Необхідність індивідуалізації педагогічної практики зумовлена тим, що вона в тій чи іншій мірі відтворює основні риси майбутньої професійної діяльності. Наявність же двох сторін – масового і творчого – в інноваційній виховній діяльності вимагає від процесу професійно-педагогічної підготовки врахування обох факторів. З одного боку, необхідна типова система вправ, а з іншого боку, створення можливостей для самореалізації особистості студента, виявлення та формування його творчої індивідуальності.

Таким чином, виникає необхідність створення в період педагогічної практики такого середовища, у якому студент міг би виявляти себе так, щоб використовувати весь свій потенціал (схильності, здібності та ін.) на якісне оволодіння інноваційною виховною діяльністю.

Виділені педагогічні умови, з одного боку, є відносно самостійними, з іншого – вони взаємопов'язані та доповнюють одна одну, створюючи єдиний комплекс. Їх впровадження здійснювалось під час апробації розробленої програми оптимізації інноваційної виховної діяльності студентів у процесі педагогічної практики.

Для означення її спрямування визначимо сутність поняття «оптимізація діяльності».

З позиції сучасного тлумачного словника української мови, оптимізація – надання чому-небудь оптимальних, найбільш сприятливих властивостей, співвідношень; покращання характеристик системи.

Словник іншомовних слів під оптимізацією розуміє процес надання чому-небудь найкращого стану.

Відповідно до українського педагогічного словника оптимізація процесу навчання – вид управління освітнім процесом, що забезпечує оптимальне (найкраще, найдоцільніше забезпечення заданих умов) функціонування навчально-виховної системи; вибір оптимального варіанту процесу навчання в конкретній педагогічній ситуації.

А отже, під оптимізацією інноваційної виховної діяльності студентів у процесі педагогічної практики розуміємо вибір найбільш доцільних, оптимальних умов формування готовності студентів до інноваційної виховної діяльності під час педагогічної практики.

Мета експериментальної програми полягала у наданні студентам знань щодо змісту інноваційної виховної діяльності та особливостей її здійснення з школярами, формуванні бажання, умінь реалізації такого виду діяльності, здатності долати стереотипи, бар'єри та труднощі.

У процесі реалізації програми практики виконувалися такі завдання:

– ознайомлення студентів з особливостями виховної роботи на інноваційних засадах;
– вивчення сутності та методики впровадження провідних інноваційних технологій виховання школярів;
– поетапне формування педагогічних умінь і навичок на основі операційного розкриття загальних цілей виховання;
– вивчення досвіду й особливостей роботи вчителів-новаторів з проблем виховання;
– здійснення педагогічної підтримки методистами й учителями студентів-практикантів;
– стимулювання й активізація їх до впровадження інноваційної виховної діяльності у практику роботи школи;
– зростання інтересу до інновацій у вихованні;
– організація тренінгів, круглих столів, методичних семінарів.

Реалізація змісту та завдань програми ґрунтувалася на вихідних теоретичних засадах – принципах (інтеграція теоретичної та практичної підготовки, поступове ускладнення завдань практики, інноваційність у виховній діяльності з школярами).

Важливим було дотримання головних методологічних підходів до організації інноваційного виховного середовища, провідним серед яких став особистісно орієнтований – орієнтація вчителя на особистість вихованця як мету, суб'єкт, результат і показник ефективності виховання, суб'єкт-суб'єктної взаємодії вчителя і учня, що стимулює розвиток взаємин «учитель – учень» та сприяє взаєморозумінню, гуманізації спілкування. Моделювання експериментальної роботи за такими науковими орієнтирами забезпечило атмосферу психологічного комфорту, ситуації успіху, розвиток активності та ініціативності школярів.

Програма реалізовувалася поетапно відповідно до періодів навчання студентів: інформаційно-діяльнісний, навчально-моделювальний (з елементами використання інноваційних методів та прийомів виховання) та професійно-діяльнісний (з упровадженням визначеної інноваційної технології виховання), кожному з яких відповідав певний зміст, форми і методи, різні види інноваційної виховної роботи з учнями, спрямовані загалом на формування мотиваційного, когнітивного, креативного та спонукально-праксичного компонентів готовності студентів до інноваційної виховної діяльності. Поетапний процес давав змогу вносити корективи у практику для досягнення очікуваних результатів.

Важливим було опрацювання психолого-педагогічної літератури та періодичних видань для створення власної навчально-методичної скарбнички «Портфоліо інновацій у виховній діяльності», що сприяло набуттю особистісного сенсу інноваційної виховної роботи як складової внутрішнього досвіду студентів.

Завдання практики виконувалися у тісній співпраці тріади: викладач – студент – учитель – практик. Зокрема, студенти одержували рекомендації щодо методики спостереження за роботою вчителя на предмет визначення відповідних проявів інноваційної виховної діяльності, виявлення інтересів учнів та їхнього ставлення до проведених заходів.

У системі тренінгово-методичних занять для закріплення теоретичних знань та формування позитивної мотивації до інновацій проводилися методичні семінари, прес-конференції за участі учителів-практиків.

На другому етапі відповідно до програми педагогічної практики здійснювалися перші кроки професійної діяльності студентів – виховної роботи з учнями в рамках плану роботи вчителя, спрямовані на формування умінь інноваційної діяльності, подолання труднощів, що супроводжують нововведення. До запланованих виховних занять студентами добиралися й використовувалися інноваційні методи, прийоми, що сприяло прояву їхньої креативності та можливості входження в інноваційний освітньо-виховний простір.

З метою підвищення ефективності формувальних впливів значна увага приділялася психолого-педагогічному супроводу студентів з боку викладачів-методистів.

Для зміцнення конструктивної взаємодії «студент – викладач – учитель-практик» використовувалися прийоми мотивування спільної діяльності («Одна гоова добре, а дві – краще»), звернення за допомогою і її надання («Хто не знає, нехай людей спитає»).

Важливим аспектом другого етапу було впровадження практикуму «Інноваційна виховна діяльність учителя», спрямованого на поглиблення та розширення знань із проблеми дослідження, забезпечення єдності теорії з практикою.

На третьому етапі студенти під час неперервної практики працювали в межах однієї технології, критерієм відбору якої слугували: особисте бажання студента, рекомендації психолога на основі попередньої співбесіди та тестувань, набутий досвід із попередніх видів педагогічної практики, поради викладачів та вчителів. Зокрема, впроваджувалися такі інноваційні технології виховання: педагогіка співробітництва, виховання успішної особистості, рефлексивного самовиховання, «Педагогічна підтримка», «Школа життя», тренінгові заняття, ігрові, проектно-моделювальні технології.

Ефективність упровадження програми оптимізації інноваційної виховної діяльності студентів у процесі педагогічної практики оцінювалася шляхом аналізу змін, які відбулися в установці студентів на значущість і важливість інноваційних технологій у сучасному виховному процесі, їхньому прагненні до активного вивчення виховних інновацій, бажанні творчо й неординарно проектувати виховну діяльність (мотиваційний компонент), інтеграції психологічних, педагогічних і технологічних знань та операційних умінь, набутих студентами під час педагогічної практики (когнітивний компонент), прояві творчої активності студентів у пошуковій діяльності, оригінальності у розв'язанні виховних завдань (креативний компонент); сформованості вмінь оцінювати, порівнювати та обирати найоптимальніші інноваційні технології, методи, прийоми виховання (спонукально-праксичний компонент).

Таким чином, при реалізації програми діяльність студентів набувала творчого спрямування, інноваційної обізнаності, технологічної озброєності й оперативної самокорекції, оцінки рівня сформованості готовності до інноваційної виховної діяльності у себе та в інших.

Отже, У забезпеченні готовності студентів до інноваційної виховної діяльності шкільна практика є вкрай важливою. Під час проходження педагогічної практики у студента відбувається трансформація уявлень про себе, свої особливості та можливості, самооцінка готовності до педагогічної діяльності, власної самореалізації. Дослідження стосовно практичної підготовки студентів представлені у працях М. Козія, Р. Ню, Л. Хомич. Педагогічну практику визначаємо як:

– складову психолого-педагогічної підготовки студентів, у процесі якої вони набувають необхідних практичних умінь та навичок;
– сполучну ланку між теоретичним навчанням студента і його самостійною практичною педагогічною діяльністю в школі;
– спосіб ознайомлення з особливостями навчально-виховного процесу на основі безпосередньої участі в ньому практикантів;
– об'єкт конструювання, в результаті якого створюється проект існуючої ще не в дійсності, а в уявленні педагогічної діяльності;
– ідентифікацію студента з новою соціальною роллю майбутнього вчителя-практиканта, в результаті якої у студента відбувається зрушення у його „Я-концепції", трансформація уявлень про себе, коригування самооцінювання і самостановлення;
– шлях до розвитку творчого (нестандартного, інноваційного) мислення, творчого ставлення до педагогічної діяльності;
– засіб формування педагогічних умінь і навичок і розвитку пізнавальної та творчої активності майбутнього вчителя, діагностики

рівня його професійно-педагогічного спрямування і підготовленості, закріплення та поглиблення теоретичних знань.

Ми розуміємо шкільну педагогічну практику як важливу складову професійно-практичної підготовки студентів, що забезпечує формування умінь та навичок практичної інноваційної виховної діяльності.

У Концепції педагогічної освіти, яка розроблена Академією педагогічних наук України, містяться чіткі і науково обґрунтовані завдання педпрактики. У документі наголошується, що „практична підготовка здійснюється через навчальні та фахові педагогічні практики". Форма, тривалість і терміни їх проведення визначаються окремо для кожної спеціальності. У Концепції визначено мету й основні завдання педагогічної практики: поглиблення теоретичних знань на основі практичного навчання; вироблення у майбутніх педагогів умінь та навичок практичної діяльності; формування та розвиток професійно-педагогічних умінь і навичок; оволодіння сучасними методами і формами педагогічної діяльності, новими прогресивними технологіями навчання; формування творчого дослідницького підходу до педагогічної діяльності.

Під час шкільної практики посилюється самостійність студента у розвитку й застосуванні педагогічних умінь. Це сприяє формуванню професійно значущих якостей і властивостей для інноваційної виховної діяльності, а саме: педагогічного мислення, педагогічної рефлексії, мотивації педагогічної діяльності, комунікативності, педагогічного такту і культури.

Для оптимізації практичної підготовки студентів розроблені різного спрямування методично-інструктивні матеріали.

Під час практики студенти виступають в ролі помічника класного керівника. Вони оволодівають методикою виховної роботи у всій її багатогранності і складності. Вони вчаться здійснювати психолого-педагогічний аналіз формування особистості школяра й учнівського колективу. Метою педагогічної практики є навчання організації виховного процесу, підготовка студента до цілісного виконання функцій учителя-предметника і класного керівника.

В організації педагогічної практики визначено такі принципи:

1) принцип інтеграції теоретичної та практичної підготовки передбачає взаємозв'язок і взаємопроникнення теорії та практики, попереднє теоретичне осмислення студентами змісту практичної діяльності, оцінку й узагальнення передового педагогічного досвіду і власного досвіду й активну, систематичну участь студентів і викладачів вищих навчальних закладів у шкільній педагогічній практиці;

2) принцип поступового ускладнення завдань практики передбачає не лише ступеневість підготовки, а й урахування здібностей студента і рівня сформованості його компетенцій в організації виховного процесу;

3) принцип інноваційності у виховній діяльності передбачає націлення студентів на використання у виховній діяльності форм, методів, прийомів роботи, які відповідають віковим особливостям особистості сучасного школяра.

Консультування студентів у процесі підготовки їх до занять, присутність на виховних заняттях разом з іншими практикантами, аналіз проведеного заняття є обов'язком методистів і шкільних учителів.

Результатом педагогічної практики є не просто отримання та поглиблення знань про педагогічну діяльність, оволодіння певними уміннями, а формування особистості студентів як майбутніх учителів, якісна зміна їх внутрішнього світу, психології, поведінки, вироблення основ їх індивідуального стилю.

5. Висновки

Підхід до розв'язання проблеми формування готовності здобувачів до інноваційної виховної діяльності в умовах педагогічної практики дозволив розкрити зміст готовності до інноваційної виховної діяльності, визначити та обґрунтувати умови формування готовності здобувачів до інноваційної виховної діяльності з школярами у процесі педагогічної практики. Визначено, що незважаючи на актуальність проблеми інноваційності як однієї з пріоритетних у сучасному освітньому просторі, немає чітко визначеної та достатньо розробленої методики аналізу інноваційної виховної роботи з школярами у процесі педагогічної практики здобувачів.

Зміст поняття інноваційної виховної діяльності розглянуто як діяльність, що забезпечує взаємодію особистості з об'єктами довкілля та формує соціально ціннісне ставлення до нього, здатність бути суб'єктом власної діяльності.

У визначенні готовності зауважуємо на багатоаспектності цього поняття, яке розглядається як цілісне стійке особистісне утворення, інтегративна якість особистості, сукупність знань, умінь, навичок.

Готовність здобувача до інноваційної виховної діяльності нами визначено як особистісно-професійну якість, що характеризується усвідомленням значущості та інтересом до виховання учнів на інноваційних засадах; наявністю мотивації з одночасним набуттям спеціальних знань, умінь, які втілюються в організацію виховної роботи; потребами творчої самоактуалізації й самореалізації.

А педагогічна практика розвиває творчу активність і самостійність студентів, сприяє формуванню їх як соціально активних особистостей з інноваційним потенціалом.

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Chapter 49: Seeing Human Eyesight

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Abstract. The human eye is a useful source of information about our surroundings. It is also a very complex organ as it consists of many different parts that work together to provide comfortable, sharp and colour vision. This contribution demonstrates the function of several parts of the human eye and presents their visualization to all who can see.

Keywords. Eye, Physics Experiments, Sight, Vision.

1. Introduction

One important result of education should be knowledge aquired by students. Active learning, including hands-on experiments, help build deep understanding of physics concepts and créate science way of thinking. Active learning also helps linking learnt theory with practical work and with broader implications [1-5].

A beneficial co-product of active learning, hands-on experiments, and inquiry-based education is the formation of interest in physics [4, 6, 7]. This interest might be forming thanks to connections between theory and its real-world applications, and due to the higher participation of students in the learning process [4, 8-11].

This contribution sees to present teachers with mainly hands-on but also demonstration experiments that they can do in their classes to teach about optics and the human eye. For this, it is necessary to understand what every part of the eye is used for, but due to the eye's complexity, these explanations are written in the following text. Since every experiment in this contribution delves into the function of a different part of the eye, their function is described at the conducted experiment. The information about the human eye was gathered from [12-15].

2. Iris Dilation and Contraction

Iris is a coloured tissue, usually brown, blue, hazel or green. It contains two muscles that control the iris's dilation and contration. It is an involuntary reflex that happens due to light exposure to either eye (which means that if one eye is in darkness and the other is exposed to bright light, both irises dilate. The iris does this to regulate the amount of light that reaches the retina to ensure a sharp image that is not oversaturated. Its movement can be demonstrated in two ways – two experiments.

For the first experiment, students should be in a dimly lit room. One student uses a flashlight on their phone to shine into the eye of another student and observes the movement of their iris. This can be seen in Fig. 1.

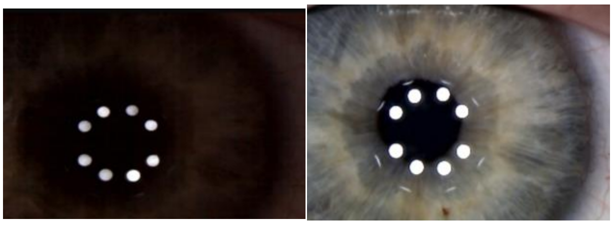

Figure 1. The author's iris in darkness and in bright light.

The second experiment happens in a brightly lit room. The students make a tiny hole in a black paper (or a paper that was coloured with a pencil) using a pin. They put this sheet of paper close to their eye and look through the hole while alternately covering and uncovering the other one with a several second period. The students should observe an imaginary dilation and contraction of the tiny hole in the paper as both irises contract when the free eye is covered and dilate when the free eye is uncovered. This is caused due to the change in field of view, which can be seen in Fig. 2.

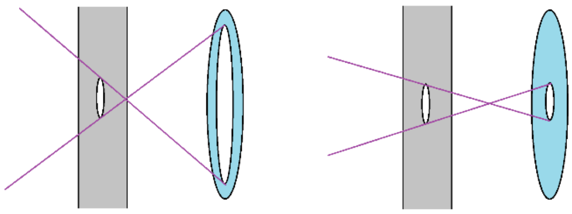

Figure 2. The change in field of view due to iris's dilation and contraction.

3. Lenses Bending Light

The human eye bends light mostly thanks to the cornea, which is responsible for approximately two thirds of the eye's optical power. The lens is used for focusing the bent light onto the retina through accommodation, which is the process of squishing and releasing the lens by the ciliary body, which changes the lens's optical power. Accomodation can be demonstrated in two ways.

The first experiment has students extend their arm with a thumb-up and close one of their eyes. They look using the other eye alternately at the thumb and at its distant background. The students should notice two things. First, when focusing on the finger, the background is blurry and vice versa. This is because the light from the background (or finger) is not focused on the retina and so cannot be seen sharply. Secondly, one of the accommodations should feel to be faster. For people with healthy eyesight and under the age of approximately 40, focusing on a near object should be quicker than the other way around. For people usually older than 40, focusing on a distant object should be quicker due to the loss of lens's elasticity and its tendency to remain in its resting form. People with sharp vision impairments can experience either possibility.

The second experiment utilizes the Betzold Experimentier-Set Optik experimental set for optics. It contains several lenses that can help demonstrate the bending of light onto the retina and the nearsightedness and farsightedness impairments. The example of nearsightedness correction using a diverging lens can be seen in Fig. 3.

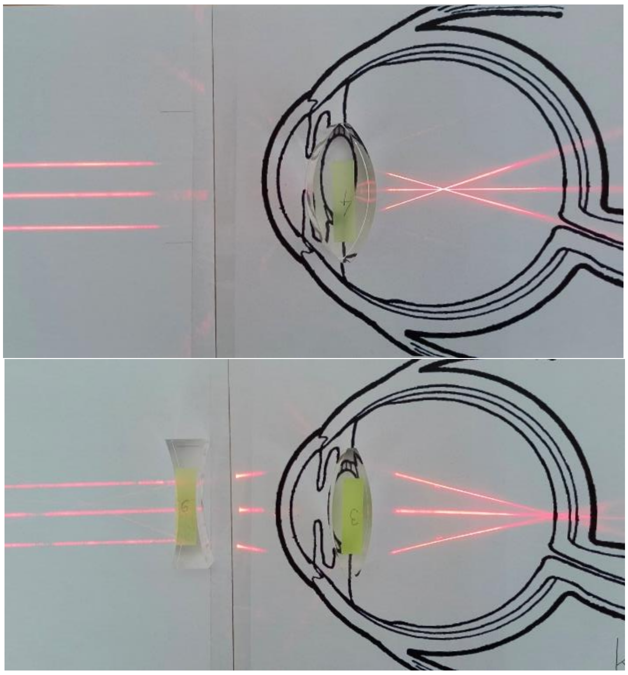

Figure 3. A distant object appears blurry to the nearsighted eye without glasses (top) but sharp when looking through correcting diverging lens (bottom).

One additional experiment can be done to demonstrate that the human lens is a converging lens. One of the converging lens's attributes is the ability to flip images upside down. The brain usually corrects this internally and humans see images the right-side-up. This correction can be tricked, however.

In the experiment, students look again with one eye through the tiny holy in the black (or blackened) paper like in the second experiment and close the other eye. They then carefully insert a sheet of paper or a pencil between their eye and the black paper. They should then notice that the inserted object starts covering the hole from the opposite direction than they are interting it from. The reason behind this is that the inserted object starts blocking light coming from behind the hole, which is, however, being flipped upside down by the brain, creating the illusion that the hole is being covered from the opposite direction. Visualisation of this result can be seen in Fig. 4.

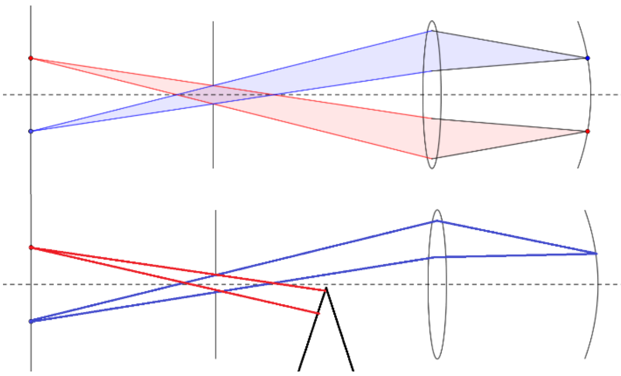

Figure 4. Light reaching the retina from a higher and lower point (top) and an inserted object blocking one point's light (bottom).

4. Retina's Blood Supply and Nerve Connections

The retina contains many light-sensitive cells that are connected to the brain via the optic nerve. It also contains blood vessels that supply the retina. In vertebrates, the optic nerve enters the eye and supplies the retina from the inside (as can be seen in Fig. 5.). One could even say that this variation of the eye is flawed since the optic nerve's entry point is devoid of any light-sensitive cells and thus cannot see. The brain, however, fills the blank spot in its vision with what the surrounding area looks like, and we thus do not notice it. This mechanism is exactly what allows us to detect the blind spot's existence and location within the retina.

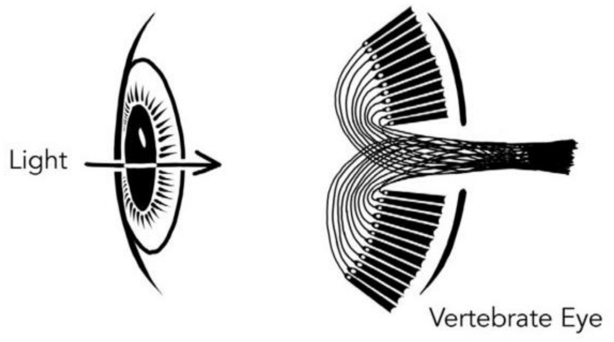

Figure 5. The vertebrate eye retina is connected via the optic nerve from the inside [16].

In one experiment, students can verify the existence of the blind spot. To find it, students draw a small cross and a small circle approximately 20 centimeters apart on a sheet of paper, placing the cross to the left and the circle to the right. They then close their left eye, look at the cross and move their heads back from the sheet of paper until the circle disappears. When this happens, the light coming from the circle is hitting the blind stop exactly and since it contains no light-sensitive cells, there is no information about it reaching the brain. It thus just fills the area with its surroundings, which, in this case, is a white paper. The students can also verify that swapping eyes will prevent the circle from disappearing unless they rotate the sheet of paper.

The second experiment utilizes the black paper with a tiny hole again. Students put it closely in front of their eye while looking at a bright white plain area, close the other eye, and shake the sheet of paper. The amplitude and the frequency of the shaking needs to be adjusted according to what works for the students – some prefer slow strokes while others might see better with fast shakes. If neither of these adjustments work, the hole might be the wrong size and needs to be adjusted (holes made by pins work the best). If done correctly, a web-like or root-like structure should be seen (its visualisation can be seen in Fig. 6). This structure are the blood vessels and nerves that the eye usually ignores but through the experiment's settings, they cast shadows and thus the structure becomes visible. Students can also notice that the structure becomes practically invisible near the point they are looking at. This is because the light from that point is hitting the fovea, an area densely packed with light-sensitive cells, that is not covered by blood vessels and nerves for sharper vision.

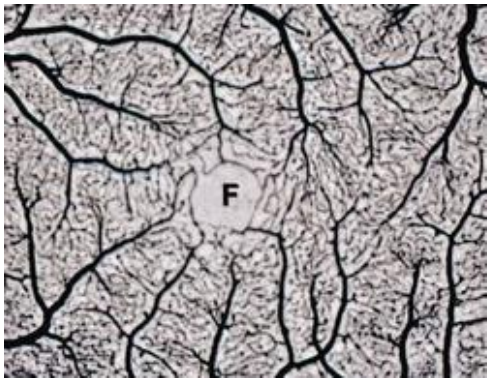

Figure 6. The nerves and blood vessels covering the retina (colours inverted from the original) [17].

5. Three colour vision illusions

The retina usually contains four types of light sensitive cells. Three of them are called cones and are sensitive to different coloured light (different wavelengths of light). The L-cone is most sensitive to approximately 563 nm, M-cone to 534 nm and S-cone to 420 nm, although their sensitivity is a somewhat wide range (displayed in Fig 7). They work the best in bright light since their function is dependent of the intensity of illumination. Thanks to this setting, three experiments showcasing the way colour vision works emerge.

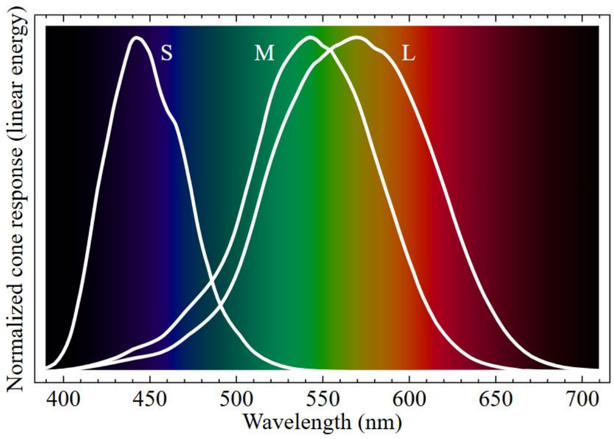

Figure 7. The cones' sensitivity spectrum [18].

The first experiment demonstrates the the cones' colour vision depends on sensory fatigue. This is a phenomenon that occurs when the brain receives information from a sensory cell for too long and diminishes the sensitivity to that signal to avoid unnecessary exhaustion.

The students observe a monochromatic source of light (such as a LED display or a projection) with one eye covered while in a dark room. This monochromatic light should be either red, green or blue, as each colour stimulates a different cone (this is easy to achieve thanks to the LED displays and projectors). After a while (for example one minute), the studnets look alternately with one eye and the other eye at the light source. They should notice a difference in the colour's saturation, as the brain has started to diminish the information gathered from the stimulated type of cone of the exposed eye, but has not done so to the previously covered eye. Then, a white screen is projected, and students again alternate their eyes. This time, students should notice that the screen is slightly tinted towards to opposite colour than the one they were exposed to. This is because the signal from the unaffected cones is not diminished and thus makes the illusion that the white screen is not fully white (for example, looking with the right eye at a red screen will make the white screen look more teal when looking with the right eye, but normal white when looking with the left eye).

The second colour illusion is colour mixing. Since, for example, the red light and green light shone together cause the more-or-less same excitement of the cones as yellow light would, the brain is not able to distinguish these two cases.

The teacher uses three sources of light, one red, one green and one blue. When using them alone, students should be able to identify their true colours, but when shone in pairs or even all together, students should identify them as different colours. This works best if the sources of light do not shine directly onto students, but on a wall where the light can mix. An illustration of this can be seen in Fig. 8.

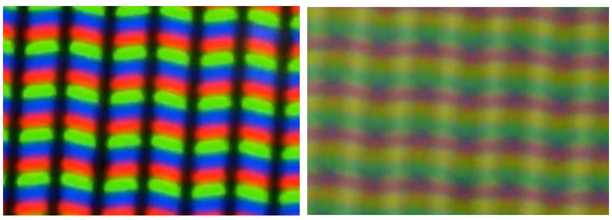

Figure 8. Three pixels - monochromatic sources of red, green, and blue light - when viewed sharply through a USB microscope (left) and when their colour is blurred together into yellow, magenta and teal (right).

The third experiment showcases the way objects "obtain" colour. When light hits an object, some of it is absorbed and some of it is reflected. The mix of all reflected colours is what we would call the object's colour. The "object's colour" thus depends on what colour the light that is shone onto it is.

Students observe various objects (such as colouring pencils) in a pitch-black room with no sources of light except the one the teacher will use. Any other source of light will break the experiment. The source of light must provide any monochromatic light the teacher wishes to use (red, green and blue are the easiest to achieve thanks to LED screens and projectors, but any colour works). If possible, multiple monochromatic lights can be used in a sequence. The students should see the coloured objects to be very different from their "normal" looks. In monochromatic light, objects will appear to be coloured between black and the colour of the light source. An illustration of this experiment can be seen in Fig. 9. Additional fun activity is to have students do colouring books in the monochromatic light.

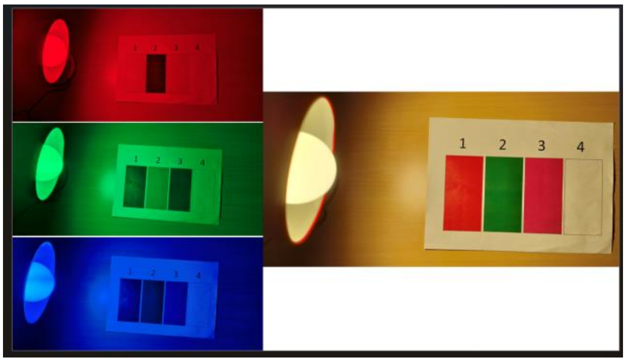

Figure 9. Four coloured stripes on a paper in red, green, and blue (almost) monochromatic light (left) and in white light (right).

6. Colourblindness simulation

Colourblindness happens when one or more of the cone types is missing from the retina or when they are sensitive to slightly different wavelengths than they should be. The result is a colour vision deficiency that can range in severity from only a mild and almost unnoticeable difficulty in making out two slightly different shades of the same colour, to the complete incapability of discerning two very different colours. To explain how colourblindness works, students can use two aiding applets.

One is an app on their phones that simulates colourblind vision, such as *Color Blind Pal*. It allows its users to select the type of colourblindness they would like to see as, and the app accesses the phone's camera to display the world in front of them as a person with the selected colour vision deficiency would see it.

The second one is an applet which was developed by the author. It showcases the sensitivity of cones to light's wavelength of a healthy person and a person with their M-cones missing. It can be accessed through *GeoGebra* link [19] and its preview can be seen in Fig. 10.

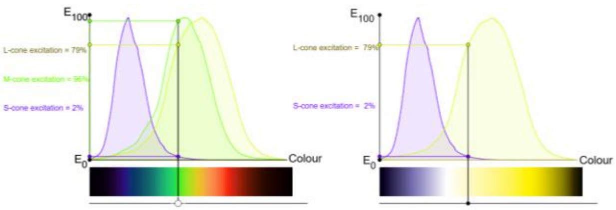

Figure 10. GeoGebra applet that showcases the cone stimulation by light in a healthy person (left) and a person missing their M-cones (right).

6. Additional "light" experiments

The limitation of the human colour vision is approximately between 400 nm and 700 nm. There are ways, however, how this range can be extended using additional tools.

One of them is the phone camera. Lower quality cameras do not use an infrared filter and can thus see infrared light (such as infrared light from remote controls, Fig. 11).

Figure 11. An infrared LED shining into a phone camera. The screen then displays it as pink.

The other tool are objects that can absorb the ultraviolet light and emit different light of lower energy. This process of deexcitaion happens either over a prolonged period of time, or only during the ultraviolet light exposure. An example of this is phosphor which emits the ultraviolet light as green light. Its effects can be seen in Fig. 12. Ultraviolet-light-sensitive objects are also for example chestnuts' insides, kiwis, bannanas, green tea, and many more.

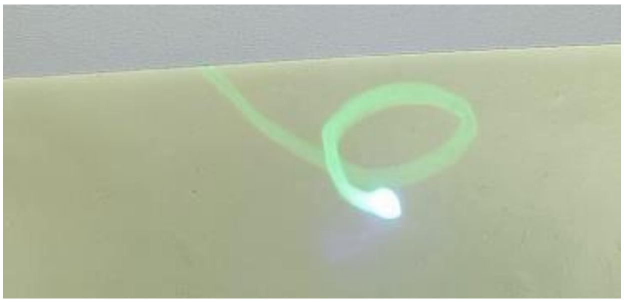

Figure 12. An ultraviolet laser shining onto phosphor, exciting it and making it emit green light.

8. Concluding remarks

These experiments can be used both as demonstrations and as hands-on activities that allow students to explore how the human eye works. Through simple investigations, students can see the importance of the aperture in cameras and in the eye itself, understand how converging lenses form images, and discover the role of cone cells in colour vision. By experimenting with these ideas directly, abstract concepts become easier to understand and remember.

The activities also create many opportunities for discussion. Teachers can draw connections between physics and biology. Discussions can also naturally expand to topics such as common vision problems, how glasses and contact lenses correct them, and how visual impairments can affect people's daily lives.

Because these experiments link physics, biology and societal problems together, they are often more engaging than purely theoretical demonstrations. They can appeal to a wider range of students, spark curiosity, and increase students' situational interest in both physics and biology. In this way, the activities can help make science lessons more meaningful, relevant, and enjoyable for learners.

9. Acknowledgements

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