BALTIC JOURNAL OF LAW & POLITICS
A Journal of Vytautas Magnus University
VOLUME 19, ISSUE 1 (2026)
ISSN 2029-0454

Cit.: *Baltic Journal of Law & Politics* 19:1 (2026): 87–110
https://reference-global.com/journal/BJLP
DOI: 10.2478/bjlp-2026-0005

TRANSFORMATION OF FORENSICS IN THE DIGITAL AGE: CHALLENGES AND PERSPECTIVES OF ARTIFICIAL INTELLIGENCE

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Received: February 5, 2026; accepted: May 15, 2026.

ABSTRACT

The authors of this article examine the increasingly widespread use of artificial intelligence tools and analyze the essence of their application in forensics. The implementation of AI raises fundamental questions regarding the nature of forensic cognition, the role of the investigator, and the transformation of professional competencies. In assessing the intersection between artificial intelligence and forensics, the article explores whether AI can fully replace human actions and whether it functions merely as an auxiliary tool or fundamentally transforms forensic methodology. The purpose of the article is to evaluate the challenges and prospects associated with the

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use of artificial intelligence in forensics. The authors analyze the main challenges and opportunities of AI application in forensics and assess its impact on forensic didactics, including the development of investigators' (criminalists') competencies.

KEYWORDS

Artificial intelligence, forensics, criminal investigation, investigator competence.

INTRODUCTION

One of the most significant transformations of the modern world is the expanding role of digital processes across all areas of life and professional activity, including forensics. The development of a comprehensive legal framework for artificial intelligence (AI) has occurred gradually at the European Union level, with several key documents marking important milestones. On 19 February 2020, the European Commission published a White Paper[1] outlining guidelines for promoting the broader deployment of AI while simultaneously addressing the risks associated with its use. The European Council conclusions of 1–2 October 2020 further emphasized the importance of digital transformation, including initiatives such as the Digital Services Act and the broader digital strategy, as well as the development of safe, trustworthy, and ethical AI.[2]

In 2021, a proposal for the Artificial Intelligence Act was submitted[3], and in 2024 the first comprehensive regulatory framework on AI was adopted[4]. This framework established fundamental principles governing the development and use of AI and laid the foundation for further regulation and implementation at the national level in specific sectors. In parallel, the Council of the European Union introduced the policy programme "Path to the Digital Decade," which set out concrete digital targets for Member States to achieve by 2030.[5] The programme covers four key areas: digital skills, digital transformation of businesses, digitalization of public services, and digital infrastructure. Its implementation requires close cooperation among Member States to ensure effective digital transformation and the achievement of common objectives.[6]

As AI technologies are increasingly applied alongside traditional working methods—and in some cases partially or fully replace them—the need to address emerging challenges and risks becomes more acute. Managing these developments requires not only specialized expertise, analytical tools, and both theoretical and practical training, but also systematic research and scholarly insight. Given the rapidly accelerating

1 European Commission, *White Paper on Artificial Intelligence: On Artificial Intelligence – A European Approach to Excellence and Trust*, COM(2020) 65 final (Brussels: European Commission, February 19, 2020) // https://commission.europa.eu/document/download/d2ec4039-c5be-423a-81ef-b9e44e79825b_en?filename=commission-white-paper-artificial-intelligence-feb2020_en.pdf

2 Council of the European Union, *Conclusions of the Special European Council* (1–2 October 2020), EUCO 13/20, CO EUR 10 (Brussels: European Council, October 2, 2020), 6, para. 13 // https://www.consilium.europa.eu/media/45910/021020-euco-final-conclusions.pdf

3 European Commission, *Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts*, COM (2021) 206 final, CELEX 52021PC0206 (Brussels: European Commission, April 21, 2021) // https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206

4 Council of the European Union, *Artificial intelligence (AI) act: Council gives final green light to the first worldwide rules on AI*, Press release 409/24 (Brussels: Council of the European Union, May 21, 2024) // https://www.consilium.europa.eu/en/press/press-releases/2024/05/21/artificial-intelligence-ai-act-council-gives-final-green-light-to-the-first-worldwide-rules-on-ai/pdf/

5 European Commission, *Proposal for a Decision of the European Parliament and of the Council establishing the 2030 Policy Programme "Path to the Digital Decade"*, COM (2021) 574 final, 2021/0293(COD) (Brussels: European Commission, September 15, 2021) // https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0574

6 Ibid.

deployment of technological innovations, the relationship between artificial intelligence and specific fields of professional activity is likely to become an increasingly significant subject of both theoretical and practical research. It can therefore be anticipated that the expanding possibilities of AI applications will attract growing attention from domain experts, raising fundamental questions concerning AI-based decision-making, including issues of explainability, reliability, security, ethics, and personal data protection.

In this context, the authors of this article consider whether AI can serve not only as a tool to support scientific inquiry but also as a system capable of substantially transforming—or even assuming—certain stages of the scientific process itself. This prompts further reflection on whether autonomous systems could operate without meaningful human intervention and whether algorithms and robotic systems might eventually replace professional processes in specific fields entirely, or whether inherent limitations will necessitate continued human oversight.

Digitalization has also significantly affected forensics and the practical activities of law enforcement institutions. The increasing deployment of advanced technologies assists law enforcement authorities in collecting, processing, and systematizing data; generating activity reports; algorithmizing investigative actions in the course of criminal investigations; producing targeted data and analytical reports for crime prevention purposes; addressing managerial challenges in cooperation with other institutions; facilitating cross-border information exchange; analyzing strategically significant information; and developing mechanisms for managing high-risk threats.

The broad scope of artificial intelligence applications has also been acknowledged by national courts. For example, Lithuanian courts have identified several potential uses of AI, including support in searching for legal sources, locating relevant document templates and forms, allocating judicial workloads, forecasting possible dispute outcomes, and providing consultative assistance.[7]

The advancement of digitalization in forensics is a relatively new and relevant field of scientific research, but it is gradually gaining momentum. In foreign countries, the insights of scientists in this area are associated with the establishment of digital forensics and the formation of digital forensics as an independent branch. For example, Ukrainian scientists have noted that

> digital forensics has been developing into three main branches: 1) a separate scientific field formation, in criminalistics; 2) special knowledge application when working with digital evidence; 3) forensic examination conducting (in particular, computer-technical expertise).[8]

It is therefore undeniable that, along with the development of digitalization, artificial intelligence has also entered the field of forensics. However, scientific discussions must focus on the scope of the use of artificial intelligence in forensics, the reliability of data obtained with the help of artificial intelligence, the explainability of decisions, the competence of responsible entities required to work with artificial intelligence, and

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[7] Agnė Limantė, Monika Šukytė and Neringa Gaubienė, *Dirbtinis intelektas teismuose: teorija, praktika ir teisinis reguliavimas* (Artificial Intelligence in Courts: Theory, Practice, and Legal Regulation) (Vilnius: Lietuvos socialinių mokslų centro Teisės institutas, 2025), 37 // https://teise.org/wp-content/uploads/2025/06/DI_teismuose.pdf

[8] Kateryna Latysh, "*Concept of Digital Forensics and Open Data Source Information in the Investigation Process*," in *Kriminalistika ir teismo ekspertologija: mokslas, studijos, praktika* (Forensics and Forensic Expertology: Science, Studies, and Practice) 19 (Vilnius: Lietuvos teismo ekspertizės centras, 2023), quoting V. Shepitko and M. Shepitko, "Doktryna kriminalistyky ta sudovoyi ekspertyzy: formuvannya, suchasnyi stan i rozvytok v Ukrayini," (Forensics and forensic expertise: formation, current state and development in Ukraine) *Pravo Ukrayiny* 8 (2021): 21.

other related issues. The premises for these discussions arise from an assessment of the nature and character of forensics. Traditional forensics has historically been based on the experience of a human researcher, analytical thinking, and the application of empirical methods.[9] Such pre-trial investigation actions as inspection of the crime scene or interrogation were fully performed by a person, and the results of these actions were determined by the professionalism of the person performing them. However, the insights of scholars allow us to reassess the essence of the use of artificial intelligence in forensics, namely, its current implementation raises fundamental questions regarding the nature of forensic cognition, the role of the investigator, and changes in professional competencies.[10] When assessing the points of contact between artificial intelligence and forensics, the question arises whether AI can truly replace the actions performed by a person. Other scholars assess this aspect in a similar way – thus, in this context, it is relevant to analyze whether artificial intelligence becomes merely an auxiliary tool or fundamentally transforms the methodology of forensics.[11]

The main research problem is broad and is therefore divided into logically related parts (sub-problems) in accordance with methodological principles.[12] Each part constitutes a separate research problem, the resolution of which contributes to answering the overarching question, while the uncertainty inherent in the broad problem is transformed into distinct research questions. Accordingly, the need for a multi-problem analysis was reasonably identified in this study. The formation and justification of the study's methodological framework are closely related to the complexity of the research problem under analysis. The study applies and develops a complex analytical approach based on a single logical line of inquiry while maintaining the focus of the unified research. The research problem itself is multifaceted, consisting of three main elements: legal, procedural, and educational. By applying a multi-problem analysis, the study seeks to highlight the relevance of the use of AI in forensic science across three dimensions of the analyzed topic: first, legal regulation; second, the assessment of the AI reliability dilemma in practical application; and third, the educational dimension, encompassing the development of the competencies necessary for the use of AI in forensic science. The decomposition of these three components enables a more detailed understanding of the research topic and demonstrates that the relevance of AI use, the search for solutions, and process improvements cannot be limited to the refinement of a single element. Rather, it is necessary to address the issues comprehensively and to implement solutions simultaneously across all dimensions, ultimately contributing to the development of a common problem-solving strategy.

The purpose of this article is to assess the challenges and prospects of the use of artificial intelligence in forensics.

In order to achieve the stated goal, the following tasks are set:

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9 William G. Eckert (ed.), *Introduction to Forensic Sciences*, 2nd ed. (Boca Raton, FL: CRC Press, 1997), 10 // https://archive.org/details/Introduction_to_Forensic_Sciences_2nd_Edition_William_G._Eckert_CRC_Press_1997_3

10 Ido Hefetz, "Integrating AI Systems in Criminal Justice: The Forensic Expert as a Corridor Between Algorithms and Courtroom Evidence," *Forensic Sciences* 5(4) (2025): 1–14 // https://doi.org/10.3390/forensicsci5040053

11 Jiya Bhardwaj, Khushboo Goyal, C. Malsawmzuali and Aashna Narula, "Revolutionizing Forensic Science: The Role of Artificial Intelligence in Evidence Analysis," *International Journal of Interdisciplinary Approaches in Psychology* 3(1) (2025): 101 // https://doi.org/10.61113/ijiap.v3i1.643

12 Kęstutis Kardelis, *Mokslinių tyrimų metodologija ir metodai* (Research Methodology and Methods) (Vilnius: Mokslo ir enciklopedijų leidybos centras, 2016); John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. (Thousand Oaks, CA: SAGE Publications, 2018), 97–102, 129–133.

- To analyze the main challenges and prospects of the application of artificial intelligence in forensics.
- To assess the influence of artificial intelligence on the didactics of forensics, including the development of researcher/criminalist competencies.

To reveal the complexity of the research problem, several research methods were selected: analysis of legal acts (including court decisions) and scientific literature, as well as generalization, comparative, and modeling methods. In addition, taking into account the research objectives and the analysis of the identified sub-problems, a content analysis of law study programs in Lithuania and foreign countries (four countries in total) was conducted alongside semi-structured interviews with nine forensic science lecturers (experts). The analysis of legal acts was used to assess the main provisions governing the use of artificial intelligence. The analysis of scientific literature was employed to review existing research on the possibilities of using artificial intelligence, as well as to identify the main advantages, challenges, and problems related to its application in operational processes. The modeling method helped to define the content, scope, and boundaries of the use of artificial intelligence in forensic science.

AI-assisted technology was used in the preparation of this article for checking footnotes, grammar and spelling.

1. CHALLENGES OF ARTIFICIAL INTELLIGENCE IN FORENSICS

The use of artificial intelligence is focused on labor productivity and increasing qualitative and quantitative indicators, and is therefore primarily associated with the following elements:

- overall efficiency of activities,
- improvement of certain processes or their parts and tasks,
- reduction of the administrative burden,
- modernization of content presentation.

When specifying and modeling these provisions in forensics, it is important to identify the specific possibilities and scope of the use of artificial intelligence. In addition, given that the possibilities for using artificial intelligence in forensics are being analyzed increasingly, it is necessary to continue scientific discussions by more specifically assessing the challenges of its use, the risks posed, and the means of their control, as well as to begin assessing further prospects for its application in forensics.

In this section, we discuss the main challenges and prospects of using artificial intelligence in forensics.

1.1. The need for regulation of artificial intelligence in forensics

When assessing the use of artificial intelligence in forensics, it is important to emphasize that it is becoming an inevitable and integral part of forensics, and therefore of the investigation of criminal acts, specifically as a tool for improving operational processes. This connection must not be overlooked and must be properly established. In the opinion of the authors, it is important to define the place of artificial intelligence in forensics itself. The union of forensics and the use of artificial intelligence can and must be evaluated primarily through the discourse on the development directions of modern forensics. We agree with the position expressed that the use of artificial intelligence

should be one of the strategic directions for the development of forensics.[13] Therefore, in addition to the recently analyzed links between forensic policy and forensic strategy and the clarification of these components[14], the issues related to the use of artificial intelligence in forensics in the long term should also find their proper place.

Another aspect worth emphasizing relates to legal regulation. The arrival of artificial intelligence in forensics, its inevitability, and the specifics of its use are linked to the development of forensics. To realize this direction of development, it is necessary not only to clearly define and consolidate the possibilities for using artificial intelligence in the forensics strategy, but also to specifically determine how artificial intelligence is used in forensics and its components, i.e., to establish the essential provisions governing the use of artificial intelligence in forensics: what are the main rules for using artificial intelligence in the investigation of criminal acts, forensic expert examinations, etc. Such an obligation also arises from international legal acts, which provide that, on the basis of the first Artificial Intelligence Rules[15], countries are obliged to establish legal regulation of the use of artificial intelligence at the national level in a manner that clearly and transparently defines its application in specific areas of professional activity. Thus, for now, as scholars note, the legal regulation of the use of artificial intelligence remains of a general nature, and legal uncertainty can give rise to a number of problems.[16] Researchers, specifically assessing and studying the possibilities of using AI in the activities of forensic institutions, noted that so far there is only political-level regulation of the use of AI, and it is necessary to develop a framework for the use of AI in the activities of forensic institutions.[17] Therefore, in forensic science, not only must the place of artificial intelligence in the long-term perspective, i.e., in the strategic dimension of forensics, be assessed first, but guidelines for the use of artificial intelligence in forensics must also be prepared accordingly, along with detailed rules tailored to the profile of a specific part (area) of forensics, for example, in the field of pre-trial investigation or forensic expert examinations. EU countries, including Lithuania, do not yet have a legal act that regulates the use of artificial intelligence both in general and in its specific areas. Therefore, one of the prospective tasks for scholars and practitioners is to prepare legal regulation of the use of artificial intelligence in forensics, which would establish the essential principles of its use, determine its scope and limits, and assess the characteristics of its application.

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13 Jurgita Baltrūnienė, "Dirbtinis intelektas ir duomenų apsauga kriminalistikos plėtros kontekste" (Artificial Intelligence and Data Protection in the Context of the Development of Criminalistics), in *Kriminalistikos teorijos plėtra ir teismo ekspertologijos ateitis: kolektyvinė monografija. Liber Amicorum Profesoriui Vidmantui Egidijui Kurapkai* (Development of Criminalistics Theory and the Future of Forensic Examination: Collective Monograph. Liber Amicorum for Professor Vidmantas Egidijus Kurapka) (Vilnius: Lietuvos kriminalistų draugija; Mykolo Romerio universitetas, 2022), 201.

14 Vidmantas Egidijus Kurapka, Žaneta Navickienė and Ilona Tamelė, "Pagrindinių kriminalistinės politikos sąvokų klausimu – harmonizavimo vektorius" (On the Key Concepts of Criminalistic Policy: The Vector of Harmonization), in *Kriminalistika ir teismo ekspertologija: mokslas, studijos, praktika = Criminalistics and Forensic Examination: Science, Studies, Practice: Collection of Peer-Reviewed Scientific Articles* (Vilnius: Lietuvos teismo ekspertizės centras; Lietuvos kriminalistų draugija; Mykolo Romerio universitetas, 2022), 13–19.

15 Council of the European Union, *supra* note 4.

16 Nataliia Filipenko, Serhii Lukashevych, Oleksandra Andrieieva and Aleksandar Ivanović, "Application of Artificial Intelligence and Information and Communication Technologies: Socio-Ethical Problems (Review Article)," *Theory and Practice of Forensic Science and Criminalistics* 34(1) (2024): 12 // https://doi.org/10.32353/khrife.1.2024.02

17 Janet Stacey, Rachel Fleming, Dion Sheppard, Jan Sheppard, Gillian Dobbie and Deepak Karunakaran, "A Responsible Artificial Intelligence Framework for Forensic Science," *Forensic Science International* 375 (2025): 8 // https://doi.org/10.1016/j.forsciint.2025.112548

1.2. The use of artificial intelligence in forensics: the dilemma of scale and reliability

The use of artificial intelligence in forensics, which is increasingly being analyzed by scholars, generally shows that artificial intelligence is becoming an instrument capable of fundamentally transforming crime investigation methods, forensic expertology, and evidence analysis processes.[18] This means that artificial intelligence is seen as a tool for more efficient work. However, at the same time, questions arise regarding the scope of the use of artificial intelligence in forensics. Such concerns are primarily related to the methods and techniques that have been used in forensics to date. Traditional forensics is based on methods such as crime scene examination, trace identification, comparative analysis of evidence, and expert assessment. These methods remain relevant, but AI technologies are changing the nature of their application.[19] Is it therefore possible to use artificial intelligence in forensics without the involvement of the human factor? AI-based systems enable the automation of large-scale data analysis, including video review, facial recognition, voice analysis, and digital footprint classification. In this way, forensic investigation becomes not only faster but also more oriented toward statistical and algorithmic modeling. However, it is argued that AI is effective only to a limited extent in such cases.[20] This is based on the originality of the entire set of circumstances surrounding criminal acts, as well as the uniqueness of the methods and modalities of their commission. It is understood that the development of algorithms (or procedural sequences) for the investigation of specific types of crimes is necessary and particularly useful, as it can enhance the efficiency of organizing investigations, especially when a pre-trial investigation officer lacks experience or is in the process of developing expertise in a particular type of crime. Mastering typical situations can strengthen an officer's ability to identify circumstances specific to a certain crime type, group relevant data, and, more broadly, apply standard investigative models.

However, it should also be emphasized that crimes may be similar in their manner and mechanism, allowing for some algorithmization through identification of the main steps in planning, organizing, and conducting an investigation, thus forming a sequence of essential (not detailed) steps. However, there will still be no identical circumstances of the commission of the crime, identical methods or mechanisms. Each criminal act is unique, requiring an individual approach to the situation and a careful assessment of the entire set of circumstances.

Consequently, it is reasonable to question whether full intervention by artificial intelligence in criminal investigations is feasible or appropriate, given that each investigation involves unique data and circumstances that must ultimately be assessed through human reasoning and judgment.

For example, in the investigation of hate crimes in cyberspace, programs are already used to detect potential signs of hate speech, employing technical solutions to identify possible criminal content. Nevertheless, a human-based assessment remains

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[18] Snieguolė Matulienė, Dirbtinis intelektas kriminalistikoje: galimybės ir grėsmės (Artificial Intelligence in Criminalistics: Opportunities and Threats), in *Kriminalistika ir teismo ekspertologija: mokslas, studijos, praktika = Criminalistics and Forensic Expertology: Science, Studies, Practice*: *A Collection of Peer-Reviewed Scientific Articles* 21 (2025): 569.

[19] Abiodun A. Solanke and Maria Angela Biasiotti, "Digital Forensics AI: Evaluating, Standardizing and Optimizing Digital Evidence Mining Techniques," *KI – Künstliche Intelligenz* 36(2) (2022): 143 // https://doi.org/10.1007/s13218-022-00763-9

[20] Rashmi Mandayam, "The Impact of Artificial Intelligence on Digital Forensic," *Journal of Artificial Intelligence & Cloud Computing* 3(6) (2024): 3 // https://doi.org/10.47363/JAICC/2024(3)414

essential to determine whether the specific statements, based on their meaning, intensity, frequency, and contextual circumstances, constitute a criminal offense or, conversely, fall within lawful expression. The assessment of hate speech is particularly complex, as it involves social, cultural, and psychological dimensions, influenced by political, historical, and cultural factors. Researchers, drawing on the practice of the European Court of Human Rights and the Supreme Court of Lithuania in hate crime cases, emphasize that each instance must be evaluated individually. This often requires the involvement of experts with specialized knowledge, such as linguists or historians, and consideration of various contextual factors, including political or social tensions, timing, the nature of the public forum, and the number of potential participants. Such evaluations highlight the necessity of human analytical judgment alongside technological tools in the investigation of crimes.[21]

This transformation raises the question of whether forensics is losing its classical empiricism, which is grounded in the assessment of individual cases. Algorithmic analysis depends on the quality of data sets, and, consequently, forensic methods are increasingly reliant on technological solutions.[22] This, in turn, creates the conditions for assessing whether template-based forensics introduces risks associated with bias. For example, scholars note that the use of artificial intelligence in forensics is often accompanied by a lack of transparency in decision-making and the presence of algorithmic bias.[23] The latter is emphasized in more than one scientific source.[24] AI systems are trained using historical data, which may reflect social or institutional practices, as well as systemic errors.[25] This may lead to inaccurate or discriminatory conclusions in forensics. For example, when testing the reliability of artificial intelligence systems and modeling the results obtained, it has been observed that different AI systems generate divergent outcomes and may present results in ways that differ from those recommended in forensic guidelines.[26] Therefore, in this context, the question of trust in artificial intelligence systems arises. Trust in artificial intelligence refers to the willingness of a person to rely on an AI system and the organization that developed it, based on the expectation that the operation and outputs of a specific AI system will be valid without requiring additional human intervention—that is, without the need to control or monitor how it was created—and that its use will yield accurate results. Scholars have identified three main factors that influence trust in AI systems: social and ethical considerations,

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21 Aurelijus Gutauskas and Žaneta Navickienė, "Neapykantos nusikaltimai ir neapykantos kalba: kur prasideda ir kur baigiasi saviraiškos laisvės ribos?" (Hate Crimes and Hate Speech: Where the Boundaries of Freedom of Expression Begin and End), *Public Security and Public Order* 29 (2022): 74–92 // https://doi.org/10.13165/PSPO-22-29-08

22 Ate Kloosterman, Anna Mapes, Zeno Geradts, Erwin van Eijk, Carola Koper, Jorrit van den Berg, Saskia Verheij, Marcel van der Steen and Arian van Asten, "The Interface between Forensic Science and Technology: How Technology Could Cause a Paradigm Shift in the Role of Forensic Institutes in the Criminal Justice System," *Philosophical Transactions of the Royal Society B: Biological Sciences* 370(1674) (2015):2 // https://doi.org/10.1098/rstb.2014.0264

23 Snieguolė Matulienė, *supra* note 18, 563.

24 Dattatraya Hari Pethkar, "Artificial Intelligence in Forensic Science: Bridging Systematic Challenges with Next-Generation Applications," *International Journal of Scientific Research in Science and Technology* 12(8) (March–April 2025): 538 // https://doi.org/10.32628/IJSRST

25 Pravallika Kondapalli, Parminder Singh, Arun Malik and C. S. A. Teddy Lesmana, "A Literature Review: Bias Detection and Mitigation in Criminal Justice," *Engineering Proceedings* 107(1) (2025): 2 // https://doi.org/10.3390/engproc2025107072

26 In December 2025, experts from the Criminal Investigation Unit of the Vilnius County Chief Police Commissariat conducted an experiment using an AI system. They submitted a query to the system concerning the sequence for recording traces. Upon evaluation of the results, it was observed that the sequence proposed by the AI differed from the sequence established in the applicable legal acts (recommendations). Sergej Boldyrev, conversation with the author Žaneta Navickienė, Vilnius, March 12, 2025.

technical and design features, and user characteristics.[27] In unique situations that require the inclusion of human reasoning in the crime investigation process—such as reconstructing the mechanism of a crime by assessing the uniqueness of its circumstances—artificial intelligence systems are unable to "design actions" or reconstruct the crime mechanism solely based on technical or design features, as such reconstruction would exceed the established limits of their capabilities. Trust in these systems is also reinforced by the principle of fairness, which entails that individuals within a group, as well as across different groups, are treated consistently, and that the predictions or outputs of the model are uniform for all. In this context, it is important to emphasize that the application of technological solutions must not result in discrimination.

1.3. Artificial intelligence: is safety guaranteed, and can all outcomes always be fully explained?

Another critical issue in the use of artificial intelligence in forensics is explainability, that is, whether the application of an AI system in the criminal investigation process is sufficiently justified and whether the system's operation is clearly defined. Scholars have observed that this important aspect is often associated with a lack of explainability[28], particularly regarding the explainability of decisions[29]. It is essential to develop a comprehensive understanding of how AI can be applied in specific areas of activity related to forensics, as well as how to implement particular AI provisions at the operational level. Many advanced AI models function as so-called "black boxes," whose decision-making logic is not readily interpretable.[30]

The lack of explainability has raised substantial concerns in judicial practice, particularly regarding the admissibility and contestability of AI-generated evidence. In United States courts, the question arises whether, in the absence of the underlying algorithm and source code, defendants are deprived of the ability to challenge the credibility of the evidence. The admissibility of such evidence is generally assessed under either the older Frye standard of "general acceptance"[31] or the modern Daubert[32] standard, which emphasizes scientific validity and reliability. In practice, under Daubert, courts have often treated validation studies as sufficient to establish reliability without requiring disclosure of source code, potentially limiting defendants' ability to meaningfully scrutinize the evidence.

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27 Tita Alissa Bach, Amna Khan, Harry Hallock, Gabriela Beltrão and Sonia Sousa, "A Systematic Literature Review of User Trust in AI-Enabled Systems: An HCI Perspective," *International Journal of Human–Computer Interaction* 40(5) (2024): 1251 // https://doi.org/10.1080/10447318.2022.2138826

28 Nagadivya Balasubramaniam, Marjo Kauppinen, Antti Rannisto, Kari Hiekkanen and Sari Kujala, "Transparency and Explainability of AI Systems: From Ethical Guidelines to Requirements," *Information and Software Technology* 159 (2023): 1 // https://doi.org/10.1016/j.infsof.2023.107197

29 Komal Patel, "Artificial Intelligence in Forensic Medicine," *International Journal for Research in Applied Science & Engineering Technology* 13(VIII) (August 2025): 586 // https://doi.org/10.22214/ijraset.2025.73606

30 Rolf J. Ypma, D. Ramos and Didier Meuwly, "AI-Based Forensic Evaluation in Court: The Desirability of Explanation and the Necessity of Validation," *Artificial Intelligence and Forensic Sciences* 2 (2023), quoted in Maruf Billah, "Explainable AI for Digital Forensics: Ensuring Transparency in Legal Evidence Analysis," *Journal of Forensic Science and Research* 9(2) (2025): 109.

31 The "Frye standard" is a legal rule stating that expert opinion is admissible if the scientific technique on which the opinion is based is "generally accepted" as reliable in the relevant scientific community. *Frye v. United States*, 293 F. 1013 (D.C. Cir. 1923)

32 The "Daubert Standard" provides a systematic framework for a judge to assess the reliability and relevance of expert witness testimony before it is presented to a jury. Under the standard, the court considers the following factors to determine whether the expert's methodology is valid: Whether the technique or theory in question can be, and has been tested; Whether it has been subjected to publication and peer review; Its known or potential error rate; The existence and maintenance of standards controlling its operation; Whether it has attracted widespread acceptance within a relevant scientific community. *Daubert v. Merrell Dow Pharmaceuticals Inc.*, 509 U.S. 579 (1993).

In *State v. Loomis*[33], the core issue was the use of the COMPAS risk assessment algorithm in criminal sentencing. The problem was that the defendant could not examine or challenge how the algorithm produced its risk score because it was proprietary (a "black box"), raising concerns about transparency, fairness, and due process—especially the ability to contest evidence used against him. The Wisconsin Supreme Court held that the use of COMPAS did not violate due process and was permissible at sentencing, but only with important limitations. The Court emphasized that the algorithm must not be the determinative factor, and judges must be warned about its limitations, including potential biases and lack of transparency.[34]

Similar concerns regarding scientific reliability and evidentiary admissibility can also be observed in Canadian jurisprudence. In *Lundy v The Queen*[35] and *R. v. J.-L.J.*[36] courts evaluating admissibility have applied factors closely mirror the Daubert standard: testability, peer review, known error rate, and general acceptance.

Comparable concerns regarding transparency and proportionality have also emerged in the European legal context, particularly in relation to biometric surveillance technologies. In *R (Bridges) v Chief Constable of South Wales Police* court examined the lawfulness of automated facial recognition (AFR) used by law enforcement. The Court of Appeal held that the deployment of AFR violated Article 8 of the European Convention on Human Rights due to the indiscriminate and non-consensual processing of biometric data in public spaces. The Court found that the current legal framework for the use of AFR afforded police officers too broad a discretion; the South Wales Police Force's (SWP's) Data Protection Impact Assessment was deficient; and the SWP had not taken reasonable steps to comply with the Public Sector Equality Duty in regards to the characteristics of race and sex.[37]

AI decision-making logic is particularly problematic in forensics, where every conclusion must be justified from both legal and methodological perspectives.[38] Explainability refers to the extent to which the decision-making process of an AI system is understandable to humans, and that users are able to understand the rationale behind their results. As the researchers state,

> simpler AI models are typically easier to provide an explanation of their process and inner workings whereas models with significantly more complexity may provide higher performance but be more challenging to explain.[39]

Explainability is also reinforced by the possibility of repeating the obtained results and testing devices and instruments. This issue is particularly relevant in forensic procedural actions where evidentiary circumstances cannot later be reproduced or re-evaluated under identical conditions. For example, the act of identifying a person is unique in that, according to the provisions of criminal procedure, it cannot be repeated. Therefore, proper preparation for this action and the assessment of all circumstances require human reasoning to ensure that the action is carried out correctly and procedural or tactical errors are avoided.

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33 *State v. Loomis*, 881 N.W.2d 749, 767 (Wis. 2016).
34 Ibid.
35 *Lundy v The Queen,* [2013] UKPC 28 (Privy Council).
36 *R. v. J.-L.J.*, 2000 SCC 51, [2000] 2 S.C.R. 600 (Supreme Court of Canada).
37 *R (Bridges) v Chief Constable of South Wales Police* ([2020] EWCA Civ 1058).
38 Sandra Wachter, Brent Mittelstadt and Chris Russell, "Counterfactual Explanations Without Opening the Black Box: Automated Decisions and the GDPR," *Harvard Journal of Law & Technology* 31(2) (2018): 842–43 // https://jolt.law.harvard.edu/assets/articlePDFs/v31/Counterfactual-Explanations-without-Opening-the-Black-Box-Sandra-Wachter-et-al.pdf
39 Janet Stacey, *supra* note 17, 4.

There are also some debatable issues when assessing the safety of AI systems. A safe system should take into account not only performance and reliability, but also the risk of system failure and the potential impact on individuals, organizations, society, and the environment. Researchers have also noted that the unpredictable failure of an AI tool constitutes a risk that can lead to AI-related accidents, potentially causing serious harm to the people working with it.[40] Therefore, the security of artificial intelligence systems remains an open question that requires further attention.

The issues of explainability and security are also closely linked to liability. In the process of investigating criminal acts, the entity conducting investigative actions or forensic expert examinations is responsible for documenting accurate information and ensuring the reliability of the conclusions obtained. This implies that full responsibility rests with the person performing a specific task and presenting the results of the investigation. However, questions regarding liability emerge when artificial intelligence systems are used: in situations where data generated by AI is provided, the issue of liability remains undefined. Consequently, the use of AI raises the question of responsibility: who is accountable for an incorrect forensic conclusion—the investigator, the expert, or the technology developer?[41] This issue becomes particularly relevant in pre-trial investigation, especially when collecting and recording data pertinent to the investigation. Researchers have also noted that this issue arises in the assessment of AI in court proceedings.[42]

In addition to the challenges of using artificial intelligence in forensics already discussed, other dilemmas emerge, namely data protection and ethical issues.

> It is emphasized that existing ethical regulation of use of information and communication technologies and artificial intelligence is mostly limited to framework, declarative documents indicating only general approaches and the purpose of the interaction of humanity with artificial intelligence systems, a kind of warning about possible negative consequences of the use of technologies.[43]

It is noted that the collection of large amounts of data by AI may violate provisions concerning the protection of individuals' privacy, as it is often unclear whether individuals have been informed about the collection and use of data pertaining to them in AI activities: "As AI systems often require access to large amounts of data for training and analysis, there are concerns about the potential misuse of personal information and the infringement of privacy rights."[44] Researchers emphasize that the use of AI to enhance efficiency raises questions regarding its compatibility with the principle of a fair process:

> We identify several key ethical challenges, including algorithmic bias, lack of transparency in decision-making processes, and the potential erosion of human judgment in critical legal determinations.[45]

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40 Ibid.

41 Kumar Shaswat Anand and Shailja Thakur, "Challenges and Limitations of AI in Forensic Science: A Critical Review," *International Journal of Research Publication and Reviews* 6(1) (January 2025): 5627 // https://ijrpr.com/uploads/V6ISSUE1/IJRPR38264.pdf

42 Endre Nyitrai, "Artificial Intelligence in Criminalistics: New Dimensions of AI Copywriting," *Belügyi Szemle* 73(1) Special Issue (2025): 207 // https://doi.org/10.38146/BSZ-AJIA.2025.v73.SI1.pp199-210

43 Nataliia Filipenko, Serhii Lukashevych, Oleksandra Andrieieva and Aleksandar Ivanović, *supra* note 16, 12.

44 Rashmi Mandayam, *supra* note 20, 3.

45 Rahul Kailas Bharati, "Ethical Implications of AI in Criminal Justice: Balancing Efficiency and Due Process," *Research Review International Journal of Multidisciplinary* 9(7) (2024): 93 // https://doi.org/10.31305/rrijm.2024.v09.n07.014

Research indicates that EU member states lack transparency in explaining the extent of artificial intelligence use in criminal cases, including which systems are employed, how they process data, and what data is utilized.[46] Lack of transparency implies that it is impossible to verify compliance with the provisions of the General Data Protection Regulation[47], and that neither individuals nor supervisory authorities can assess the legal basis for processing personal data. Legal requirements for data protection help ensure that the benefits of artificial intelligence are realized responsibly. The ability of AI to access large volumes of data also raises another concern: when datasets contain excessive personal information, the risk of overuse and disclosure of data that is not necessary for the research increases. Scholars further emphasize that data processing must always adhere to the principles of lawfulness and honesty:

> As personal data must only be processed for specific and lawful purposes, they should not be used in a way that is not compatible with these purposes and they should not be further processed in a way that the subject of the data considers to be unexpected, unsuitable or questionable (principle of honesty).[48]

When data processing involves personal data, questions arise regarding how other personal rights associated with such processing will be ensured:

> When artificial intelligence is used, the rights of data subjects have particular importance. So, the control anyone must have over their personal information results in the following rights: the right of data subjects not to be subject to automated decisions influencing them significantly without having their opinion taken into consideration, the right to be informed of the reasoning based on which the process of data is conducted by the algorithms, the right to object to such process and the right of judicial protection.[49]

Questions regarding the legality of data processing are inevitably intertwined with ethical considerations. Legal regulation that provides users with the right to control their data simultaneously constitutes an ethical imperative:

> Data privacy-preservation ... and data deletability ... directly support an individual's right to control their personal information and digital footprint, aligning with the 'right to be forgotten'.[50]

In cases where AI employs unclear algorithms that affect individual freedoms, situations arise that clearly highlight both legal and ethical challenges: "Multiple studies have uncovered instances of inherent racial, gender, and other biases in AI systems, which result in discriminatory outcomes and worsen the existing disparities within the

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46 Giulia Cascone, "The Use of Artificial Intelligence in EU Criminal Justice Systems: First Insights and Emerging Trends in an Evolving Landscape," *Open Research Europe* 5 (2025): (article 361) // https://doi.org/10.12688/openreseurope.21780.1

47 *Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC* (General Data Protection Regulation), OJ L 119, 4 May 2016, 1–88 // https://eur-lex.europa.eu/eli/reg/2016/679/oj

48 Fotios Spyropoulos and Evangelia Androulaki, "Aspects of Artificial Intelligence on E-Justice and Personal Data Limitations," *Journal of Legal, Ethical and Regulatory Issues* 26(3) (2023): 1–8 // https://www.abacademies.org/articles/aspects-of-artificial-intelligence-on-ejustice-and-personal-data-limitations-15867.html

49 Ibid.

50 Lucas Bourtoule et al., "Machine Unlearning," in *Proceedings of the 2021 IEEE Symposium on Security and Privacy* (IEEE, 2021), 141–159, quoted in Yiming Li et al., "Rethinking Data Protection in the (Generative) Artificial Intelligence Era," *arXiv* (July 3, 2025), 10 // https://doi.org/10.48550/arXiv.2507.03034

criminal justice system."[51] This, in turn, raises the question of the extent to which trust can be placed in AI.

When assessing the possibilities of using artificial intelligence in the investigation of criminal acts, particularly in conducting specific pre-trial investigation actions, the protection of pre-trial investigation data must also be considered. The procedure for publishing pre-trial investigation data is generally regulated by the national legal acts of each country. For instance, in Lithuania, this is defined by an order of the Prosecutor General of the Republic of Lithuania. The Prosecutor General's recommendations on the publication of pre-trial investigation data establish that such data include information contained in the pre-trial investigation file, obtained in accordance with procedures established by laws and the Code of Criminal Procedure, as well as the personal data of participants in the process, which are stored separately from other pre-trial investigation materials, and other information recognized by the pre-trial investigation officer or prosecutor as pre-trial investigation data.[52] Data contained in the materials of terminated and suspended pre-trial investigations also constitute pre-trial investigation data. The aforementioned legal act further regulates the procedure for publishing such data and the conditions under which permission to publish may be granted. In this context, when assessing the possibilities of using artificial intelligence, a key problem arises: the protection of such data is not ensured. For example, if significant photographs are taken at the crime scene and AI is tasked with describing the environment captured in these photographs, such a task could facilitate the work of the investigator on the scene, as the investigator could incorporate the AI-generated description into the crime scene inspection report. However, uploading such photographs and formulating the task does not inherently guarantee the protection of pre-trial investigation data, as it remains unclear where, how, and when the photographs provided to the AI will be used. Thus, while AI could, based on the submitted query, assist the investigator by documenting the environment and other significant factual circumstances in the crime scene inspection report, the issue of data protection for pre-trial investigation materials would remain unresolved. Hypothetically, data security could be ensured if AI systems were closed—that is, designed to be used exclusively within the scope of work with pre-trial investigation materials.

Another pertinent example illustrating the use of artificial intelligence in pre-trial investigation allows for a comprehensive assessment of both the possibilities and risks of such use. During an interview, the investigator could employ AI to transcribe audio recordings. In this scenario, the investigator could focus more on the psychological aspects of the interview, concentrate on the questions being asked, and observe the interviewee's reactions, while the AI system would record the conversation and generate a transcription of the audio. However, the use of AI in interviews raises the issue of data protection, as the confidentiality of pre-trial investigation data would not be guaranteed, data security would remain uncertain, and it is unclear how, where, and when such data would be used by the AI system in the future. This example demonstrates that AI could be employed in pre-trial investigation actions, but the issue of pre-trial investigation data security must be addressed.

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[51] Neeti Pandey and Chetna Sharma, "Ethical and Legal Implications of Artificial Intelligence (AI) in Criminal Justice System," *Universal Research Reports* 12(3) (2025): 713 // https://doi.org/10.36676/urr.v12.i3.1613

[52] General Prosecutor's of the Republic of Lithuania Order No. I-278, *Dėl ikiteisminio tyrimo duomenų skelbimo rekomendacijų patvirtinimo* (On the Approval of Recommendations for Publishing Pre-Trial Investigation Data), (TAR, August 18, 2017, No. 13412, last updated January 1, 2019, art. 5.3).

In summary, it can be stated that although the possibilities of using artificial intelligence are extensive and increasingly applicable in specific areas of law enforcement activities, its use still raises a number of issues related to legal regulation, practical implementation, proper data protection, and ethical considerations. The challenges analyzed also influence the development of researcher competence. Therefore, in the next section, the main principles of forming investigator's competence, particularly in relation to the use of artificial intelligence systems, will be discussed.

2. THE IMPACT OF ARTIFICIAL INTELLIGENCE ON FORENSIC DIDACTICS AND THE COMPETENCES OF THE INVESTIGATOR/CRIMINALIST

Digitalization processes in crime investigation create important premises for scientific discussion of the forensics didactics: how the use of artificial intelligence affects the teaching of forensics, how the competencies of both future and current pre-trial investigation officers are changing, and how the development of such competencies can be ensured. Therefore, this section assesses the challenges and opportunities associated with the use of artificial intelligence in the forensic didactics[53], including the transformation of the competencies of a pre-trial investigation officer (investigator, criminalist).

The word "didactics" originates from the Greek language and means instructive.[54] It is a theory of teaching that examines the teaching process and instructional methods. The dictionary defines didactics as: 1) a branch of pedagogy that studies teaching and education, including the goals, content, organization, methods, and principles of instruction; 2) instruction or moralization.[55] Modern didactics increasingly examines the interaction and, at times, tension between humans and robots in the teaching process. Scholars appropriately raise and discuss the question of the extent to which the teaching process can be automated or "robotized."[56] At the same time, scientific research shows that, in modern investigations of specific types of crimes, investigators will continue to apply the classical structure of forensic methodology and rely on it throughout the investigation process. It will remain significant in the investigation of any type of crime, even though various technologies are used and modern crime investigation methods are integrated into the investigative process.[57]

Forensics didactics is focused on the application of targeted teaching methods in the study of forensics—from a general understanding of the discipline to the application of specific investigative methods, techniques, and tools in the investigation of particular types of criminal acts and the implementation of preventive measures. It has

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[53] The authors of this article define forensic science didactics as a branch of forensic science that examines the principles and methods for effectively teaching forensic science disciplines. It encompasses instructional approaches aimed at conveying knowledge of criminal investigation methods and tools, with the objective of facilitating the clarification of criminal acts, the presentation of evidence in court, and the prevention of crime. Similar conceptualizations of forensic science didactics have also been proposed by other scholars. For further discussion, see: Valery Shepitko, Mykhaylo Shepitko and Mariietta Kapustina, "Criminalistics in Ukraine – Between Theory, Practice and Training," *Zagadnienia Społeczne* 1(18) (2023): 44–54 // https://bibliotekanauki.pl/articles/59467035.pdf

[54] Dictionary of Lithuanian language terms. Definition of the term *didaktika* (the branch of pedagogy that studies teaching and learning methods and principles), (accessed January 30, 2026) // https://www.lietuviuzodynas.lt/terminai/Didaktika

[55] Ibid.

[56] Albertas Milinis and Kristina Pranevičienė, "Can Robot Lectures Be Useful in Teaching Law Students?" in *Human Right to Education in the Age of Innovations and Smart Technologies*, ed. Edita Gruodytė and Ausrinė Pašvenskienė (Berlin: Peter Lang, 2024), 271–291.

[57] Žaneta Navickienė and Mindaugas Bilius, "Are Traditional Didactic Tools Appropriate for Methodics of Modern Crime Investigation?" in *Human Right to Education in the Age of Innovations and Smart Technologies*, ed. Edita Gruodytė and Ausrinė Pašvenskienė (Berlin: Peter Lang, 2024), 309–330.

repeatedly been emphasized that forensics is a discipline oriented toward the practical needs of law enforcement institutions.

However, it is also important to stress that forensics didactics, despite its pedagogical nature, has a distinctive feature: a strong emphasis on the development of practical skills. This demonstrates its particular significance, practical benefit, and close connection with law enforcement activities. Attention has consistently been devoted to forensics didactics, not only by emphasizing the importance of applying practical methods in education, but also by arguing that insufficient attention to forensics science as a discipline—and consequently to its didactics—may result in ineffective law enforcement performance (for example, due to inadequate forensic expertise or insufficient knowledge of forensics).[58] A lack of forensic knowledge and skills may constitute a serious reason for insufficient professional competence in the investigation of criminal acts, including the improper recording of traces and other circumstances significant to the investigation at the crime scene, errors in performing investigative actions, and deficiencies in collecting and analyzing other relevant information that may assist in understanding the method and mechanism of committing a criminal act.

Therefore, the statement of scientists that "attention to forensic didactics, which should reflect changes taking place in real practice, and at the same time be a connecting link between forensics as a science, study discipline and practical activity, must only increase"[59], demonstrates the close relationship between the methods applied in forensic didactics and practical activity. In other words, the applied teaching methods must seek to replicate, to the greatest possible extent, real actions and experiences characteristic of practical activity.

This is also confirmed by the study conducted by the authors of this article. To determine the practical possibilities and scope of the use of AI in the forensic science study process, interviews were conducted between April 15 and May 7, 2026. Nine scholars and practicing lecturers teaching forensic science at higher education institutions in four European countries (the Czech Republic, Lithuania, Slovakia, and Ukraine) participated in the interviews.

When preparing the interviews, the focus was placed on two main questions: first, whether the forensic science study process develops students' abilities to work with AI; and second, in which forensic science topics and to what extent AI-related competencies are developed. Due to the limitations and scope of the study, the interview results serve only as supplementary data alongside the findings obtained through other scientific research methods applied in this research. Therefore, the results should be interpreted only as indicative trends related to forensic science and AI, aimed at substantiating the relevance and identifying the problems associated with the use of AI. The data obtained from the interviews complement the other data collected during the study and are not used as a basis for independent conclusions.

During the interviews, it was established that artificial intelligence is increasingly being used in the teaching of forensic science. Four lecturers noted that they do not purposefully use AI in forensic science studies and do not prepare specific tasks related

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[58] Vidmantas Egidijus Kurapka, Snieguolė Matulienė, and Eglė Bilevičiūtė, "Kriminalistikos didaktika Lietuvoje: lūkesčiai ir galimybės" (Criminalistics Didactics in Lithuania: Expectations and Opportunities), in *Kriminalistika ir teismo ekspertizė: mokslas, studijos, praktika* (Forensics and forensic examination: science, studies, practice), Vol. 2 (Vilnius–Charkovas: Lietuvos teismo ekspertizės centras, 2013), 87–107.

[59] Vidmantas Egidijus Kurapka, Hendryk Malevski and Snieguolė Matulienė, "Kriminalistika Lietuvoje 1990–2020: nuo naujų paradigmų paieškos iki realizuotų mokslinių koncepcijų ir ateities įžvalgų" (Criminalistics in Lithuania 1990–2020: From the Search for New Paradigms to Implemented Scientific Concepts and Future Insights), *Visuomenės saugumas ir viešoji tvarka* 24 (2020): 279.

to the use of AI; however, they allow students to rely on AI systems when searching for targeted information or performing specific tasks. The majority of the lecturers who participated in the interviews, namely five, stated that they purposefully integrate artificial intelligence into forensic science studies in the following areas:

1) formulating specific tasks for students related to individual areas of forensic science, including forensic techniques, forensic tactics, and specific research methodologies, in order to implement actions associated with criminal acts;
2) encouraging students to use AI to search for relevant information;
3) using AI to summarize, visualize, and schematize relevant information;
4) assigning tasks that require students to compare the similarity and reliability of results generated by different AI systems.

Thus, the possibilities of using AI are related to the specifics of criminal investigation, including information gathering, identifying types of data relevant to an investigation, task preparation, question formulation, and targeted searches of scientific literature and legal acts, among other activities. All lecturers applying AI systems in the forensic science teaching process noted that the integration of AI serves only as an aid for students and/or lecturers in better understanding and performing individual tasks, but AI should not perform tasks on behalf of the student. Therefore, when using AI, students are encouraged to think critically, verify the obtained data, and ensure that the information and generated outputs are valid. In addition, the lecturers noted that AI is a useful assistant in the preparation of scientific articles, particularly in generating ideas and searching for targeted literature; however, it is always necessary to disclose the use of AI systems and indicate the purpose for which they were used.

Summarizing the results of this study, it can be observed that competencies related to working with AI are already being developed within forensic science studies. However, the development of such competencies is still characterized by a high degree of discretion, as lecturers remain free to decide whether to develop these competencies, what specific tasks to assign, and to what extent AI should be integrated into the study process. In this context, clear links can be identified between the development of competencies for working with AI systems in academic studies and the competencies required for the practical application of AI systems in professional activities. Nevertheless, from this perspective, there remains a lack of a clear vision and definition regarding the specific competencies that should be developed for working with AI in forensic science studies.

In light of these considerations, several significant questions arise. First, what competencies are required of a modern pre-trial investigation officer (investigator) to ensure that he or she possesses sufficient knowledge and skills to properly initiate and conduct crime investigations? Second, as digital tools are increasingly used in the investigation process, how can it be ensured that the pre-trial investigation officer acquires and continuously strengthens the necessary competencies, taking into account the changing circumstances of the global environment, evolving methods of committing crimes, advancing technological processes, and other factors related to professional activity? Third, how can future competency needs in crime investigation be anticipated so that forensics didactics becomes a leading force rather than a reactive follower?

In our view, the use of artificial intelligence in forensics, and specifically in the investigation of criminal acts, directly affects forensics didactics and the competencies of investigators, particularly through visible changes in the structure of professional competencies. Accordingly, these issues should be examined in parallel and may form

the basis of a strategic progress document (e.g., guidelines or a similar instrument) on digitalization in the pre-trial investigation process.

Thus, the discussion on how forensics education is transforming, what changes have occurred in the structure of investigators' competencies, and which competencies are required of a pre-trial investigation officer should begin with a review of the content of vocational training and/or higher education programs. Researchers have noted that the implementation of AI is transforming not only forensic methods but also the very structure of investigators' competencies[60]: traditional competencies, such as trace analysis or tactical thinking, must increasingly be combined with technological literacy. Therefore, in this context, it is important to note that, alongside the development of other competencies (e.g., social, communicative), technological competencies should be considered a mandatory component of all competencies being cultivated. Consequently, it is essential to update the content of forensics education by incorporating modules on AI[61], data analysis, and technological ethics.[62] Both the instructor and the learner should recognize that technological competencies are essential, as they determine the routine use of mandatory digital tools. It is argued that, in the digital era, forensics is shifting from a classical model to a technological one, and new concepts are emerging within the discipline, such as "technological forensics," which must be clearly defined to ensure their proper understanding and purposeful application.[63]

It is also important to emphasize that technological competencies should be developed comprehensively and broadly, simulating not only the current technological processes applied in the activities of law enforcement agencies, but also anticipating future transformations and possibilities. Consequently, whether through theoretical teaching methods (e.g., explanation, narration, comparison) or practical teaching methods (e.g., preparation and resolution of tasks or scenarios, simulation of practical activities), the development of technological competencies is essential.

A modern forensic scientist must understand the principles of AI, be able to critically evaluate the results provided by algorithms[64], and recognize possible systematic errors.[65] Thus, the investigator becomes not a passive user of technology, but an active controller of decisions. In the opinion of the authors, the development of technological competencies may also involve certain risks, which must be appropriately managed. The process of investigating crimes is multifaceted, relying not only on the application of established procedures but also on the ability to generate and test all possible hypotheses, critically assess the circumstances of an event, pose challenging questions, identify connections between individual details, think creatively, and move beyond

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60 Ido Hefetz, *supra* note 10, 8.

61 Angelika Dudek, Anna Dąbek, Iwona Zborowska and Jakub Lichosik, "Integrating Artificial Intelligence in Forensic Science," *E-Methodology* 10(10) (2023): 15 // https://doi.org/10.15503/emet2023.15.28

62 Nicholas Rabb and Desen Ozkan, "Beyond Case Studies: Teaching Data Science Critique and Ethics Through Sociotechnical Surveillance Studies," *arXiv* (May 3, 2023), 1 // https://arxiv.org/pdf/2305.02420

63 Yuliia Hres, "Концептуальні вектори розвитку положень криміналістичної тактики: від ідей В. Ю. Шепітька до формування технологічного підходу" (Conceptual Vectors of the Development of Forensic Tactical Provisions: From V. Yu. Shepitko's Ideas to the Formation of a Technological Approach), in *Нове століття криміналістики та судових наук. Liber Amicorum на честь академіка Валерія Шепітька* (The New Century of Criminalistic and Forensic Sciences. Liber Amicorum in Honor of Academician Valeriy Shepitko) (Kharkiv: Pravo, 2026), 483–484.

64 Paola Di Maio, "Towards Open Standards for Systemic Complexity in Digital Forensics," in *Artificial Intelligence and Digital Forensics: Advancements, Applications, Challenges, and Solutions*, ed. Naveen Kumar Chaudhary, Archana Patel, Abinash Mishra and Chothmal Kumawat (Boca Raton, FL: CRC Press/Taylor & Francis, 2025), 37–38.

65 Europol, *AI and Policing: The Benefits and Challenges of Artificial Intelligence for Law Enforcement*, Observatory Report (Luxembourg: Publications Office of the European Union, 2024), 32 // https://www.europol.europa.eu/cms/sites/default/files/documents/AI-and-policing.pdf

templated approaches. Therefore, in the development of technological competencies, it is important not to adopt a narrow ("corridor") perspective, but to ensure that technologies are applied without restricting or suppressing creativity, critical thinking, and initiative. According to researchers, it is essential to emphasize that AI does not eliminate the role of humans in forensics, but rather transforms it.[66] This indicates that artificial intelligence will remain an assistant and will not fully replace the investigator's work: tasks such as the search for truth, reconstruction of the mechanism of committing a crime, logical justification, assessment of the sequence of events, determination of motive or causal connections, and evaluation of the suspect's personality when selecting preventive measures, among other aspects, must and will continue to be verified by a human. Consequently, decision-making and full responsibility will remain with the investigator, as artificial intelligence lacks the capacity to exercise the creativity and critical thinking required for such judgments. Other authors express a similar view, suggesting that a hybrid forensics model is the most promising approach, in which AI functions as an analytical aid while final decisions are made by a human.[67]

As methods of committing crimes evolve, new technological solutions are introduced, and innovative investigative techniques are applied, it is crucial to align the content of training so that it fully addresses the needs of practice. In transforming the structure of the investigator's competencies and integrating technological competencies into a unified framework, the ability to assess the circumstances of an event, recognize the uniqueness of each situation, exercise creativity, and foster critical thinking and initiative should remain central components of professional competence. Therefore, we fully concur with the position of other researchers that human judgment remains essential, particularly when evaluating context, motives, and causal relationships that AI cannot fully comprehend.[68]

Summarizing the analyzed issues in forensics didactics, certain visions of the future emerge. It is anticipated that, in the future, the transformation of competencies for both practicing pre-trial investigation officers and students—i.e., future pre-trial investigation officers—will occur in parallel with the advancement of various digital tools, artificial intelligence systems, and the introduction of new technological solutions. According to researchers, with respect to the prospects of AI integration in forensics, even broader incorporation of AI into investigative practice is expected[69], particularly in digital crime investigations, big data analysis, and virtual reconstruction of crime scenes. Consequently, these developments will also influence the didactics of forensics. It is predicted that, due to ongoing digitalization, innovations in pre-trial investigation, and other technological changes, forensics didactics will face numerous challenges in the future: it will need to become more dynamic and flexible, respond to changes in practice more rapidly and effectively, and continuously review and adapt the structure of investigators' competencies.

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66 Kamshad Mohsin, "Artificial Intelligence in Forensic Science," *International Journal of Forensic Research* 4) (1) (2023): 173 // https://www.opastpublishers.com/open-access-articles/artificial-intelligence-in-forensic-science.pdf

67 Ioannis Ketsekioulafis, Giorgos Filandrianos, Konstantinos Katsos, Konstantinos Thomas, Chara Spiliopoulou, Giorgos Stamou and Emmanouil I. Sakelliadis, "Artificial Intelligence in Forensic Sciences: A Systematic Review of Past and Current Applications and Future Perspectives," *Cureus* 16(9) (2024): e70363 // https://doi.org/10.7759/cureus.70363

68 Silvia Lucia Sanna, Leonardo Regano, Davide Maiorca and Giorgio Giacinto, "Exploring the Robustness of AI-Driven Tools in Digital Forensics: A Preliminary Study," *arXiv* (December 2, 2024), 32 // https://doi.org/10.48550/arXiv.2412.01363

69 Rashmi Mandayam, *supra* note 20, 3.

CONCLUSIONS

The results of the analysis indicate that the main challenges of using artificial intelligence in forensics are associated with its consolidation within the long-term perspective of the discipline, the absence of national-level legal regulation in EU countries, the justification and explainability of reliability, the assurance of data security and ethical compliance, and the insufficiency of necessary competencies. Artificial intelligence in modern forensics is expected to become an important tool for collecting and analyzing data relevant to investigations, performing and recording investigative actions, and organizing and planning criminal investigation activities. However, it will not fully replace the activities of responsible entities, nor can it completely substitute for humans in the criminal investigation process, as only human logic, reasoning, and creativity can address atypical or unique situations. Therefore, a hybrid model combining artificial intelligence and human activity is anticipated in future forensics.

The use of artificial intelligence in criminal investigation processes directly impacts the evolution of forensics didactics: the content of forensics training, both for students preparing to become investigators and for the professional development of practicing pre-trial investigation officers, must be updated to incorporate technological competencies, and the structure of the pre-trial investigation officer's (investigator's) competencies must be periodically revised to respond effectively to changes in practice.

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