

Mathematical Foundations of AI and Machine Learning: A Pilot Study Among Graduates of Specialized Secondary School Students

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The rapid expansion of tools based on large language models and neural networks in everyday educational practice has introduced new challenges for curriculum designers. Secondary school students in specialized mathematics and computer science tracks represent a particularly relevant group for analysis, as they are expected to possess a high level of abstract reasoning and mathematical competence. However, in contemporary educational discourse, a frequent misconception arises: the ability to use AI interfaces (e.g., prompting ChatGPT) is often equated with genuine digital literacy in artificial intelligence. Genuine AI literacy extends beyond tool consumption and presupposes an understanding of the underlying mathematical principles.

This pilot study was conducted in June 2024 with the aim of assessing the relationship between students' exposure to AI tools and their conceptual and mathematical understanding of artificial intelligence and machine learning. The sample consisted of 22 final-year students from specialized Informatics (SI) and Mathematics (SM) tracks at the First Grammar School in Kragujevac, Serbia. The research instrument comprised two parts: a questionnaire on students' usage habits and attitudes toward curricular change, and a knowledge test consisting of both closed-ended and open-ended questions addressing mathematical foundations of AI systems (derivatives, regression, linear programming, and decision-making algorithms).

The results indicate very limited formal exposure to AI-related content within the current secondary school curriculum. Machine learning concepts were encountered in school by only three students, all from the SI track within the subject *Computer Applications*; no SM-track student reported any such exposure. Despite this, a moderate level of intrinsic motivation was observed, as seven students expressed interest in independently exploring AI and machine learning topics.

Regarding practical experience, AI tools are widely used among students. To the question "Have you ever used any artificial intelligence tool?", 81.82% (N = 18) responded affirmatively, while 18.18% (N = 4) reported no prior use. However, self-assessed knowledge does not fully align with this high level of usage. The majority of students (59.09%, N = 13) rated their knowledge as basic, meaning they recognize the concept but do not understand underlying mechanisms. A further 31.82% (N = 7) rated their knowledge as good, while the lowest and highest rating categories were minimal (4.55%, N = 1 each). This discrepancy between usage and conceptual understanding is also reflected in students' attitudes toward curriculum reform: 63.64% (N = 14) support introducing a dedicated AI course, while 22.73% (N = 5) favor interdisciplinary integration. Overall, 86.37% of respondents support systematic inclusion of AI education in schools.

The knowledge test reveals the most important didactic insight of this study. Students demonstrated partial understanding of basic terminology, with correct responses for data mining (68.60%) and big data (81.80%), indicating familiarity with contemporary data science vocabulary at a surface level.

However, significant gaps emerge in responses to more complex open-ended questions requiring understanding of underlying mathematical structures. Only two students provided meaningful explanations of the role of first-order derivatives in optimization processes such as gradient descent, which form the basis of neural network training. No student provided correct answers regarding linear programming applications, clustering methods, or regression-based modeling frameworks. Only three students demonstrated basic awareness of regression analysis, while five provided partially meaningful but superficial explanations of decision tree algorithms. Additionally, only three respondents correctly identified artificial neural networks and deep learning as mathematical frameworks approximating learning mechanisms inspired by the human brain.

The findings confirm a gap among students in specialized tracks: while they are frequent users of AI tools and familiar with related terminology, their understanding of the mathematical foundations of these systems remains underdeveloped. Importantly, this gap does not appear to stem from cognitive limitations or lack of student ability. Rather, it reflects insufficient institutional exposure to AI as a mathematical discipline. Since students show a high willingness to learn (86.37%), the results represent a clear empirical indication for curriculum development in Serbia, suggesting the need for systematic integration of AI and machine learning topics into mathematics and informatics education through explicit mathematical modeling.

Future research should extend this study to a larger sample and focus on designing instructional frameworks that support a deeper understanding of the mathematical principles underlying AI and machine learning systems.

Keywords: artificial intelligence, machine learning, mathematical foundations, secondary education, curriculum development

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