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Artificial Intelligence in Education: Why It Matters and the Tools Behind It

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Abstract The paper presents a comparative analysis of public spending on education relative to GDP while examining the PISA test results in mathematics and science of EU students. It seeks to identify a clearly defined and universally valid correlation (applicable to every member state) between the two indicators, yet no such relationship is found. Examples from countries such as Bulgaria and Cyprus illustrate the need for more precise targeting of public funds and a closer alignment with student performance. In this context, the potential of AI-based software to enhance the relevance of the educational system is explored. The study provides a detailed analysis of the following AI tools: Personalized and Adaptive Learning Platforms (ALS), Intelligent Tutoring Systems (ITS), Automated Grading and Assessment Systems with AI, Educational Games, Simulations and Virtual Reality (VR), Chatbots, and Machine Learning (ML)/Educational Data Mining (EDM) tools. Examples of such software and their applications are presented, and the mechanisms by which these AI tools affect student outcomes are identified and summarized. It is concluded that while the realization of positive effects from using AI in the educational sphere is not automatic, the implementation of such software holds significant potential for linking expenditures with tangible benefits.

Keywords AI in Education, Education Expenditures, Personalized and Adaptive Learning Platforms, Intelligent Tutoring Systems; Automated Grading and Assessment Systems with AI.

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Introduction

Over the past few years, a growing number of educators and IT specialists have been exploring the intersections between student performance in education and artificial intelligence (AI). Significant attention is given to the opportunities that AI tools offer for modernizing the educational process, diversifying pedagogical practices, personalizing learning, and enhancing student motivation and engagement (Moskal, Carter and Johnson, 2017; Taylor, Yeung and Bashet, 2021; Holmes and Tuomi, 2022; U.S. Department of Education, 2023). Implementing AI is projected to boost countries' competitiveness and capacity for innovation. Consequently, understanding the current educational attainment of EU students is vital, as is identifying AI tools that could improve it. This study, therefore, investigates AI software used in education as its primary focus (object), specifically analyzing the economic consequences of its deployment (subject). Based on this framework, the research proposes the following thesis: when implemented appropriately and aligned with existing risks, AI tools hold significant potential to enhance student performance and increase the efficiency of educational investments.

1. Education expenditures and student performance in the EU

School education expenditure, defined as an investment in the future, is of great importance for the development of human resources, for the qualification of the workforce and, on this basis, for labor productivity and for economic growth. The analysis of that expenditure and the assessment of its efficiency require that its dynamics should be examined as a ratio to GDP (see Table 1).

The analysis of the data in Table 1 shows that on average for the EU-27 in 2015, expenditure on primary and lower secondary education was 2.03% of GDP, and for upper secondary education – 0.99% of GDP. In 2018 and 2021, the average EU-27 expenditure on primary and lower secondary education to GDP ratio and expenditure on upper secondary education to GDP ratio were respectively: 2.00%, 1.01%, 2.10% and 0.98%. For Bulgaria, the expenditure on primary and lower secondary education to GDP ratio in 2015 was 1.56%, and the expenditure on upper secondary education to GDP ratio in the same year was 0.76%. The analyzed ratios for this country in 2018 and 2021 were respectively: 1.60%, 0.78%, 1.89% and 0.98%. For France, for example, in 2015, the expenditure on primary and lower secondary education was 2.36% of GDP, and for upper secondary education – 1.15% of GDP. In 2018 and 2021, for France, the expenditure on primary and lower secondary education to GDP ratio and the expenditure on upper secondary education to GDP ratio were respectively: 2.34%, 1.13%, 2.40% and 1.10%. *The lowest expenditure on school education was in Romania*. For example, the expenditure on secondary education to GDP ratio for Romania in 2015, 2018 and 2021 was 0.63%, 0.65% and 0.68% respectively.

In comparative terms, attention should also be paid to the fact that in 2015, the expenditure on school education (primary, lower secondary and upper secondary) on average for the EU-27 was 3.02% of GDP. For the same year, the expenditure on school education in Bulgaria was 2.32% of GDP, i.e. the relative share of school education expenditure (the share is calculated to GDP) in Bulgaria represented 76.8% of the relative share of expenditure on school education on average for the EU Member States. In 2018 the average expenditure on school education for the EU-27 and Bulgaria was 3.01% of GDP and 2.38% of GDP, respectively, i.e. the relative share of school education expenditure in Bulgaria was 79.1% of the relative share of the same expenditure on average for the EU Member States.

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In 2021, the average expenditure on school education (primary, lower secondary and upper secondary) for the EU-27 was 3.08% of GDP. For the same year, school education expenditure in Bulgaria was 2.87% of GDP, i.e. the relative share of school education expenditure in Bulgaria was 93.2% of the relative share of school education expenditure on average for the EU Member States (6.8% lower than the relative share of the same expenditure on average for the EU-27). *The conclusion is that the gap between Bulgaria and the EU average is narrowing*.

Table 1. Public expenditure on primary, lower secondary and upper secondary education in EU

	2015 (% of GDP)		2018 (% of GDP)		2021 (% of GDP)	
	Primary and lower secondary	Upper secondary	Primary and lower secondary	Upper secondary	Primary and lower secondary	Upper secondary
EU – 27	2,03	0,99	2	1,01	2,1	0,98
Belgium	2,43	1,85	2,4	1,71	2,41	1,63
Bulgaria	1,56	0,76	1,6	0,78	1,89	0,98
Czechia	1,65	0,85	1,85	0,9	2,17	0,9
Denmark	-	-	2,63	1,08	2,62	0,99
Germany	1,81	0,83	1,83	0,82	2,04	0,81
Estonia	1,88	0,73	2,14	0,75	2,38	0,57
Ireland	2,02	0,63	1,65	0,58	1,46	0,47
Greece	1,95	0,71	1,98	0,67	-	-
Spain	1,9	0,83	1,85	0,82	2,14	0,98
France	2,36	1,15	2,34	1,13	2,4	1,1
Croatia	-	-	-	0,85	1,73	0,87
Italy	1,73	1,05	1,63	1,37	1,76	1,18
Cyprus	3,28	1,4	2,96	1,27	2,93	1,13
Latvia	2,36	0,92	1,88	0,8	1,82	0,82
Lithuania	1,77	0,48	1,72	0,41	1,83	0,45
Luxembourg	1,99	0,83	1,77	0,81	1,91	0,84
Hungary	1,44	1,08	1,29	1,05	1,4	0,76
Malta	1,66	1,3	1,81	1,19	2,01	1,11
Netherlands	2,39	1,03	2,25	1,05	2,32	1,06
Austria	2,12	1	1,99	0,91	2,05	0,91
Poland	2,19	0,78	2,14	0,68	2,01	0,78

Portugal	2,51	0,99	2,47	0,98	2,5	1,02
Romania	1,06	0,63	1,06	0,65	1,11	0,68
Slovenia	2,15	0,95	2,19	0,92	2,39	0,98
Slovakia	1,76	0,9	1,84	0,79	2,2	0,96
Finland	2,56	1,53	2,41	1,24	2,52	1,34
Sweden	2,6	1,22	2,84	1,28	2,78	1,26

Source: Eurostat

Globalization and dynamically developing technologies lead to significant changes in the labor market and in the requirements for the qualification and acquired knowledge of students. The practical implementation of these requirements directly correlates with the education expenditure and their efficiency and effectiveness. An important result that is related to the efficiency of expenditure is the share of low-achieving students (below the second level of the PISA scale) in mathematics and science.

The analysis of the data in Table 2 shows that in Bulgaria in 2015 the relative share of low-achieving students in mathematics was 42.1%, in science this share was 37.9% respectively. In 2018, for the same country the share of low-achieving students (below the second level of the PISA scale) in mathematics was 44.4% and in science 46.5%. In 2022, the trend towards increasing the percentage of low-achieving students was maintained and it was 53.6% in mathematics and 48.0% in science. It must be explicitly stated that the deterioration of the indicators is accompanied by an increase in expenditures relative to GDP in Bulgaria. Throughout the entire studied period 2015-2022, the relative share of low-achieving students (below the second level of the PISA scale) in mathematics and science on average for the EU-27 *was lower than that for Bulgaria*. For example, in 2018 the analyzed values for the EU-27 were respectively 22.9% relative share of low-achieving students in mathematics and 22.3% relative share of low-achieving students in science, and in 2022 the same values for the EU-27 were respectively 29.5% low-achieving students in mathematics and 24.2% low-achieving students in science, i.e. the indicated values were almost two times lower than those for Bulgaria. *The students in Estonia were the highest achievers in mathematics and science* among all EU-27 Member States. For example, in 2018 the relative share of low-achieving students in science for Estonia was 8.8%. The achievements of students in mathematics, and science were also high in Denmark, the Netherlands, Germany and Ireland. *The lowest, but close to those of Bulgaria* (below the second level of the PISA scale) were the achievements of Cypriot students. For example, the relative share of low-achieving students in mathematics in 2022 in Cyprus was 53,2. Romania and Greece also belong to this Member States group. The weak performance of Cypriot students sharply contrasts with the high education expenditures relative to the country's GDP.

Table 2. Low achieving 15-year-olds in mathematics or science in EU

	2015 (%)		2018 (%)		2021 (%)	
	Math	Science	Math	Science	Math	Science
EU – 27	22,2	21,1	22,9	22,3	29,5	24,2
Belgium	20,1	19,8	19,7	20	25	22,4
Bulgaria	42,1	37,9	44,4	46,5	53,6	48
Czechia	21,7	20,7	20,4	18,8	25,5	19,9
Denmark	13,6	15,9	14,6	18,7	20,4	19,5
Germany	17,2	17	21,1	19,6	29,5	22,9
Estonia	11,2	8,8	10,2	8,8	15	10,1
Ireland	15	15,3	15,7	17	19	15,6
Greece	35,8	32,7	35,8	31,7	47,2	37,3
Spain	22,2	18,3	24,7	21,3	27,3	21,3
France	23,5	22,1	21,3	20,5	28,8	23,8
Croatia	32	24,6	31,2	25,4	32,9	22,4
Italy	23,3	23,2	23,8	25,9	29,6	23,9
Cyprus	42,6	42,1	36,9	39	53,2	51,8
Latvia	21,4	17,2	17,3	18,5	22,2	16,5
Lithuania	25,4	24,7	25,6	22,2	27,8	21,8
Luxembourg	25,8	25,9	27,2	26,8	-	-
Hungary	28	26	25,6	24,1	29,5	22,9
Malta	29,1	32,5	30,2	33,5	32,6	30,3
Netherlands	16,7	18,5	15,8	20	27,4	27,3
Austria	21,8	20,8	21,1	21,9	24,9	22,7
Poland	17,2	16,3	14,7	13,8	23	18,6
Portugal	23,8	17,4	23,3	19,6	29,7	21,8
Romania	39,9	38,5	46,6	43,9	48,6	44
Slovenia	16,1	15	16,4	14,6	24,6	17,8
Slovakia	27,7	30,7	25,1	29,3	33,2	30,6
Finland	13,6	11,5	15	12,9	24,9	18
Sweden	20,8	21,6	18,8	19	27,2	23,7

Source: (OECD, 2023)

In comparative terms, attention should also be paid to the fact that in 2018, the share of low-achieving students (below the second level of the PISA scale) in mathematics in Bulgaria was 193.9% higher than EU average. In the same year, the relative share of low-achieving students in science in Bulgaria was 208.5% higher than this share on average for the EU-27. In 2022, students in Bulgaria again were low-achievers in mathematics and science compared to their peers from the EU Member States. In 2022, the share of low-achieving students in mathematics was 181.7%, in science – 198.3% higher than those of low-achieving students in the EU Member States.

The analysis of the data clearly highlights that *the efficiency of school education expenditure in Bulgaria is low*, i.e. school education expenditure does not directly correlate with the results achieved. The situation in other EU countries, such as Cyprus, is not much different. Artificial intelligence is of great importance for increasing the efficiency of school education expenditure and the quality of teaching in the institutions of the school education system.

2. AI tools for enhancing the efficiency of the educational process

AI is often presented as a technology poised to revolutionize the processes of teaching and learning (U.S. Department of Education, 2023; Chen et al., 2020), promising improved student outcomes. There is a diverse range of applications aimed at increasing engagement, discovering patterns in student data and performance, and automating assessment. The tools, including Personalized and Adaptive Learning Platforms (ALS), Automated Grading and Assessment Systems, and Educational Data Mining (EDM) Tools, are suitable for personalizing learning content and supporting students who face difficulties. All of these, directly or indirectly, have the potential to improve the efficiency of the educational process.

For the purposes of this study, it is necessary to:
1) Summarize the distinct groups of AI applications relevant to the performance of primary and secondary education students and discuss their key characteristics;
2) Analyze the mechanisms (ways) through which AI tools influence student outcomes.

There exists a diverse range of AI applications with the potential to positively impact student performance. These can be categorized into several major groups.

Personalized and Adaptive Learning Platforms (ALS) can be very useful in education (Taylor, Yeung, and Bashet, 2021). They use algorithms and student performance data and, on this basis, a diagnostic assessment of student knowledge level is performed. Based on the diagnostic results, an individual learning plan is created for each student. Lessons, activities, and questions are tailored to the established initial level of knowledge and understanding. The learning process focuses on the areas where the student needs assistance. Personalization is also expressed in the ability for each student to follow their own pace. The analyzed tools find application in areas such as mathematics (*DreamBox Learning*; *ALEKS*, *i-Ready*), chemistry, statistics (*ALEKS*), foreign language learning (*Duolingo*), and reading (*i-Ready*).

Intelligent Tutoring Systems (ITS) refine and significantly enhance ALS. Here, personalization is taken to a new level (Nwana, 1990; Bradáč and Kostolányová, 2017). An argument for this is the fact that they not only adapt lessons and questions but, with the assistance of AI, attempt to simulate interaction with a personal human tutor. A typical example is *Khanmigo* (an experimental feature of Khan Academy), which adopts the behavior of a supportive mentor, answers questions, and provides guidance. *MATHia*, in turn, uses cognitive models to understand the student's thinking, monitors their actions, and provides help at the most appropriate moment. *AutoTutor* encourages students to justify their reasoning. Other tools are emerging that use LLM (Large Language Models) for educational purposes. It is assumed that in the near future, they will become fully-fledged ITS.

Checking and assessing student knowledge is often a laborious process that demands teachers' attention and time. Delayed feedback, in turn, negatively affects student preparation. *Automated Grading and Assessment Systems* automate these processes without the need for direct human intervention (Gnanaprakasam and Lourdusamy. 2024 Yakkala, 2024). This type of tool is perfectly applicable for grading test questions (Multiple Choice, True/False, Matching). LMS platforms like *Moodle, Canvas, Blackboard,* and *Google Classroom* have built-in modules for creating and automatically grading tests with closed-ended questions. *Scantron* scans and grades special answer sheets. Grading open-ended questions, essays, and coursework is not as straightforward. Often, Automated Grading and Assessment Systems cannot capture the depth of reasoning and argumentation (although they cope well with assessing structure and spelling). Despite this, the analyzed tools are used for grading tests like TOEFL (*ETS e-rater*), essays (*IntelliMetric*), programming code (*Gradescope; Codio, Autolab*), and in subjects like mathematics, physics, and chemistry (*WebAssign, MyMathLab, Mastering Physics/Chemistry, Gradescope*).

The learning process in primary and secondary education should not be monotonous or boring. It can be engaging and fun. *Gamification*, the use of *educational simulations*, *virtual reality*, and *chatbots* help here (Baidoo-Anu and Ansah, 2023; Shabir et al. 2025). *Minecraft: Education Edition*, for example, is an education-focused application that includes modules in mathematics, science, and programming. *DragonBox* is a math-focused application suitable for use in primary education. *Semantris* (Google AI Experiments) uses word games to expand vocabulary and improve students' associative thinking. Some games from the *Osmo Genius Starter Kit* use AI to improve performance in spelling, drawing, and mathematics. AI features are also being introduced in *ClassVR*. This is an integrated VR system created specifically for education. It provides VR headsets, software, and curriculum-aligned educational content. Such tools are considered to improve engagement and aid in memorizing new knowledge. Chatbots (especially *Socratic tutors*), without giving direct answers, guide students and contribute to the development of independent and critical thinking.

For their successful operation, a number of software applications applied in the field of education use *Machine Learning (ML) and Educational Data Mining (EDM) tools* (Baker and Siemens, 2014). *MOOC (Massive Open Online Courses)* platforms like *Coursera, edX,* *and Udacity* offer a wide range of online courses, often created in collaboration with top universities and industry leaders. *Udacity* works with companies like Google and IBM; *Coursera* offers courses by partnering with universities like Stanford and Yale. *edX* courses are developed in collaboration with MIT, Harvard, Berkeley, Microsoft, and IBM. The broad spectrum of training offered makes it suitable both for narrow specialists seeking to upgrade their qualifications and for curious secondary school students. Primarily in higher education institutions, experiments are being conducted with the use of Learning Analytics Dashboards - LADs (SensEnablr). The idea is for learners and educators to be aware of learning behavior patterns.

An analysis of the key features of AI applications that positively influence student performance makes it possible to summarize *the mechanisms behind this impact*. In fact, the *ability of AI to personalize the learning process* is of paramount importance (Moskal, Carter and Johnson, 2017; Taylor, Yeung and Bashet, 2021; U.S. Department of Education 2023). AI tailors instruction to the individual progress of students, adjusts lesson difficulty, changes the pace of introducing new knowledge, and adapts illustrative materials based on student preferences. (Baker, Siemens, 2014). This mechanism is central to Adaptive Learning Systems (ALS) and Intelligent Tutoring Systems (ITS). Personalization leads to more efficient and effective learning by directly addressing individual student needs and closing knowledge gaps. AI systems (ITS and Automated Grading and Assessment Systems with AI) can provide learners with *immediate feedback* on their answers, indicating correctness or highlighting errors. This feedback can be targeted, explaining why an answer is incorrect or suggesting specific areas for improvement. Several AI applications are designed with the explicit goal of *making learning more engaging and motivating*. This is often achieved through interactive elements found in educational games, simulations, VR environments, AI robots, and chatbots Thus, increased engagement leads to greater student interest in the subject matter and more active participation in learning activities. Educational Data Mining (EDM) and Machine Learning (ML) are useful in *identifying students who are having difficulty* mastering the course material. Overall class performance improves as a result. AI can *automate various routine and time-consuming tasks* and free up valuable teacher time. This reclaimed time can then be redirected towards more complex pedagogical activities.

The realization of AI's potential positive effects in primary and secondary education is *not automatic*. In this context, two groups of considerations must be addressed. First, there are inherent risks (challenges) associated with the use of such software, including ethical concerns, data privacy protection, impacts on emotional intelligence, and effects on the development of skills and competencies. Second, it is crucial to ensure that AI tools are implemented appropriately within the educational process, as AI cannot replace human interaction. These highlighted considerations must not be underestimated. They should be regarded as a starting point for subsequent research in the field.

Conclusion

Within the EU, expenditures on primary and secondary education (as a percentage of GDP) vary widely. Their efficiency - represented by the proportion of low-achieving students on the PISA scale in mathematics and science - also differs across member states. Bulgaria's practice (among others) demonstrates the absence of a direct correlation between funds allocated to education and student performance. In primary and secondary education, the use of AI-based software solutions - including Adaptive Learning Systems (ALS), Intelligent Tutoring Systems (ITS), Automated Grading and Assessment Systems, Educational Data Mining (EDM), and others - enables personalized learning, immediate feedback, gamification of the learning process, and supports administrative tasks. When implemented appropriately and aligned with existing risks, AI tools hold significant potential to enhance student performance and increase the cost efficiency of educational investments.

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