https://doi.org/10.53656/math2025-5-4-its

Educational Technologies
Образователни технологии

INTELLIGENT TECHNOLOGIES FOR SUPPORTING PERSONALIZED LEARNING

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Abstract. This study explores the use of artificial intelligence (AI) tools to support personalized learning in classroom environments, as well as their integration into project-based learning activities implemented within STEM interest clubs in the context of the Bulgarian school system. The research aims to examine the attitudes of teachers and students toward AI-supported personalized learning and to evaluate its potential impact on students' motivation and academic achievement. A quasi-experimental research design with pre-test and post-test measures was implemented between 2023 and 2025. Data were collected from 129 teachers, 86 students, and 42 parents through structured questionnaires, DigCompEdu-based self-assessment instruments, and classroom observations.

The findings reveal an improvement in student achievement, increasing from 70% to 83% following the implementation of AI-supported personalized learning activities. Furthermore, 95% of students reported positive attitudes toward learning with AI-based tools, while 67% of teachers perceived AI chatbots as useful instructional support instruments. Nevertheless, nearly half of the teachers expressed a need for additional professional development, and most parents reported concerns regarding the use of AI tools without the supervision of a teacher or mentor. The results suggest that AI technologies can significantly support personalized learning when combined with clearly structured, pedagogically grounded learning activities and appropriate teacher guidance. However, the study is limited by the absence of a control group and its focus on a single national educational context. Future research should therefore involve larger and more diverse samples in order to further validate these findings.

Keywords: Artificial Intelligence in Education (AIEd); personalized learning; STEM education; AI chatbots

1. Introduction

Artificial Intelligence in Education (AIEd) has rapidly evolved as a field concerned with the development and application of intelligent systems to support teaching and learning processes. In recent years, the emergence of generative AI has intensified scholarly and practical interest in their potential to facilitate adaptive and personalized learning. Empirical studies and meta-analyses report generally positive effects of AI-supported learning on student achievement; however, these effects appear to be highly contingent on instructional design, learner autonomy, and the specific educational context in which such technologies are implemented (e.g., Su & Yang, 2023; Tlili et al., 2025). At the same time, concerns remain regarding the ethical implications and practical integration of AI tools in everyday school settings.

Recent empirical and meta-analytic research provides a more nuanced understanding of the impact of artificial intelligence in education. Systematic reviews indicate that while AI-supported learning environments can improve student outcomes, the reported effects are typically moderate and highly dependent on pedagogical design, context, and the role of the teacher (Crompton & Burke, 2023). Similarly, longitudinal and multi-context empirical studies suggest that improvements in student achievement and engagement are not uniform, but vary according to implementation strategies and levels of learner support (Dasari et al., 2024; Laun & Wolff, 2025).

At the same time, a growing body of research highlights several limitations and potential risks associated with the use of AI in education. These include the possibility of students' over-reliance on AI-generated responses, reduced opportunities for deep cognitive processing, and concerns related to bias, transparency, and ethical use of data (Kasneci et al., 2023). In particular, the integration of generative AI tools such as chatbots raises questions about the alignment between automated support and pedagogical objectives, especially in school contexts where learners require structured guidance and critical scaffolding.

Personalization and differentiated instruction have long been recognized as effective pedagogical principles aimed at enhancing learner engagement and activity. Contemporary pedagogical frameworks distinguish between differentiated, individualized, and personalized learning (Gupta, 2019; Schofield, 2021), emphasizing that true personalization requires systematic adaptation based on dynamic learner data rather than static grouping alone.

Despite the growing body of research, the existing literature reveals several more specific empirical and methodological gaps. First, while meta-analyses report positive effects of AIEd on learning outcomes, most empirical studies rely on controlled experimental or higher-education settings, limiting ecological validity for school-based implementation. Second, there is a lack of longitudinal, practice-based evidence documenting how AI-supported personalization is enacted in authentic classroom environments, particularly in informal or semi-formal settings such as STEM interest clubs. Third, although attitudes toward AI are frequently discussed, few studies triangulate perceptions (students, teachers, parents) with observed changes in learning outcomes within the same intervention context. Finally, evidence from Eastern European school systems remains scarce, especially regarding the pedagogical integration of generative AI tools under real institutional constraints.

In response to these gaps, the present study investigates the implementation of AI-supported personalized learning in the Bulgarian school context, with a particular focus on classroom instruction and STEM interest clubs. Rather than aiming to establish causal relationships, the study adopts a practice-oriented and context-sensitive empirical approach, examining how AI-supported activities are integrated into existing pedagogical practices and what observable changes emerge in student performance and participant attitudes.

Methodologically, the study is based on a quasi-experimental design with pre- and post-intervention measures within the same learner groups, combined with survey data from students, teachers, and parents. The study is explicitly framed as exploratory, aiming to identify context-dependent effects, emerging practices, and perceived challenges associated with the use of AI in personalized learning. This framing ensures alignment between the research aims, methodological design, and the interpretation of findings, acknowledging both the potential and the current limitations of AI integration in school education. Within this context, the main research questions guiding the present study are:

- How do teachers and students perceive the role of AI tools in supporting personalized learning in the classroom and STEM interest clubs?
- What changes in students' academic performance are observed before and after the introduction of AI-supported personalization tasks within the same learner groups?
- What challenges and ethical concerns do teachers and parents report in relation to the use of AI tools in personalized learning?

2. Motivation and related works

The "Guidelines for the use of AI in the education system" (GAIE, 2024), recently developed by the Ministry of Education in Bulgaria, draw attention to the potential of AI to adapt and support school education both in management processes and in creating conditions for adaptive, personalized and inclusive learning. The implementation of such learning can be realized both in distance and blended learning through the use of intelligent cyber-physical educational platforms (Todorov, 2019) and through the use of AI tools for personalization of learning in schools.

The topic of the application of AI in the personalization of school education has the potential to change the way the entire learning process is organized and conducted. The term AIEd (Artificial Intelligence in Education) (Tlili, 2025), encompasses two aspects: the development of AI learning tools and the use of AI to organize, manage, and evaluate learning. AIEd includes both the creation of intelligent school education platforms and the use of chatbots and other intelligent tools to track and maintain learning processes and personalize learning. AIEd focuses on the interweaving of didactic theories and practices in the development and application of generative AI. This strategy ensures that the tools created meet technological standards and are consistent with the educational goals set (Chang, 2023).

The principle of personalization involves the development of mechanisms for personalized learning analysis, allowing learners to adapt their learning strategies. Su and Yang (Su, 2023), in their study of AI chatbots such as ChatGPT-4 in education, propose a theoretical framework that addresses identifying desired outcomes, determining the appropriate level of automation, ensuring ethical considerations, and evaluating effectiveness. The literature highlights the potential of generative AI and chatbots to provide personalized learning and effective feedback mechanisms, while addressing some challenges and ethical issues (Kaswan, 2024). Recent scholarly discussions have highlighted the problems associated with the integration of large language models (LLMs) into learning environments, expressing concerns about their compatibility with different educational methodologies and the risk of their uncritical adoption in learning processes (Eager, 2023). These issues highlight the need for a thoughtful and well-informed application of AI technologies in the real school environment.

This section synthesizes European and Bulgarian policy perspectives with pedagogical theories of personalization. The distinctions between differentiated, individualized, and personalized learning (Table 1) follow (Gupta, 2019; Schofield, 2021). Differentiated learning is a pedagogical approach in which the teacher adapts the learning content and learning process to group differences in the readiness, interests, and learning styles of students, without creating an individual plan for each learner. Individualized education focuses on the application of standardized curricula to meet the needs of a given student. It primarily involves a methodological approach to mastering knowledge and skills according to state educational standards and eventually increasing their level. Finally, personalized learning combines both the adapted content approach and methods of differentiated learning and the flexible pace of individualized learning, but is distinguished by the central role of the student in the choice of learning activities, resources, and even educational goals.

Personalized learning builds on differentiated and individualized learning by systematically adapting learning objectives, resources, activities, and assessments to students' personal characteristics, interests, and learning needs. Recent research shows that effective personalization requires continuous monitoring of learners' progress and dynamic adaptation of learning strategies based on collected and analyzed data. Artificial intelligence technologies provide new opportunities to support these processes through automated data analysis, adaptive task generation, personalized feedback, and recommendations for tailored learning pathways.

Table 1. Comparative table between differentiated, individualized and personalized learning

Characteristics	**Differentiated Learning**	**Individualized Learning**	**Personalized Learning**
Basic feature	Organizing the learning process according to the common needs of groups of students	The training is tailored to the individual characteristics of a particular student.	Learning is built around the student's personal interests, goals, and choices.
Focus	Groups of students with different levels/needs	The individual student and their pace, learning style	The student's personal interests, goals, and choices
Role of the teacher	Organizes and manages the process according to the general needs of the groups	Adapts the tasks and approach to each individual student within the framework of the general program.	Facilitator, mentor and learning partner
Role of the student	Works on tasks selected for his/her group	Works on individually tailored tasks	Actively participates in planning and choosing their own learning
Control and assessment	Mostly the teacher	The teacher, considering the student	Students have the greatest autonomy, self-assessment
Example	Different groups solve problems of varying difficulty	Student receives adapted reading texts according to their abilities	robotics project covers learning objectives in mathematics, IT and physics

3. Methods

3.1. Research Design, Participants and Context

The present study adopts a quasi-experimental research design with pre-test and post-test measures applied to the same group of participants. The aim is to examine observable changes in students' academic achievement and attitudes following the implementation of AI-supported personalized learning activities. The study does not attempt to establish causal relationships but rather to identify trends and associations within a real educational context.

A mixed-methods approach was employed, combining quantitative data (achievement tests and structured questionnaires) with qualitative insights from classroom observations and open-ended survey responses. This approach enables a more comprehensive understanding of both learning outcomes and participant perceptions.

The study was conducted between 2023 and 2025 within the context of classroom instruction and STEM interest clubs in a Bulgarian secondary school (SU "Hristo Smirnenski", Brezovo). The participants included:

- 86 students (grades 7 – 9), actively engaged in STEM learning activities;
- 129 teachers from different schools participating in survey-based data collection;
- 42 parents providing feedback on attitudes toward AI use in education.

The selected school represents a typical regional educational environment in Bulgaria, which allows for contextually relevant insights, although it limits generalizability.

3.2. Intervention Procedure

The intervention was implemented over one academic cycle and included the following stages:

- Step 1. Initial assessment (pre-test) of students' knowledge and skills;
- Step 2. Grouping of students based on learning characteristics using the "personas" approach supported by AI tools;
- Step 3. Implementation of AI-supported learning activities, including: chatbot-assisted learning (e.g., generating explanations, ideas,

feedback); personalized assignments adapted to student profiles; project-based learning in robotics and STEM clubs;

- Step 4. Continuous formative feedback and adaptation of tasks;
- Step 5. Final assessment (post-test) after completion of the intervention.

Teachers actively moderated and validated all AI-generated content to ensure pedagogical appropriateness.

3.3. Measurement Instruments

Academic achievement was measured using standardized task-based assessments developed for the robotics and STEM curriculum. The assessment instrument included:

- 20–25 tasks per test;
- a combination of multiple-choice and problem-solving items;
- tasks aligned with key STEM competencies such as logical reasoning, problem-solving, and conceptual understanding.

Each correct answer was scored as one point, forming a total percentage score (0–100%). The pre-test was administered at the beginning of the learning cycle, and the post-test was administered after completion of the AI-supported activities.

Although students participated in different roles (e.g., programming, hardware assembly, data analysis), the assessment focused on common cognitive competencies, ensuring comparability across participants.

Structured questionnaires were used to assess the attitudes of students, teachers, and parents toward AI-supported learning. The instruments included Likert-scale items measuring:

- perceived usefulness of AI tools;
- motivation and engagement;
- concerns related to ethics and independent use.

The internal consistency of the teacher questionnaire was evaluated using Cronbach's alpha ($\alpha = 0.78$), indicating acceptable reliability.

Qualitative data were collected through classroom observations conducted during the implementation phase. These observations focused on:

- student engagement;

- collaboration and participation;
- interaction with AI tools.

The qualitative data were analyzed using thematic analysis to identify recurring patterns and insights.

3.4. Data Analysis

Quantitative data were analyzed using descriptive statistics and inferential methods. To evaluate changes in student achievement before and after the intervention, a paired-samples t-test was applied.

Effect sizes were considered to assess the magnitude of observed differences. In addition, survey data were analyzed using frequency distributions and mean values.

Several methodological limitations should be acknowledged. The absence of a control group restricts the ability to draw causal conclusions. The study is based on a single-school sample, which limits generalizability. Furthermore, some data (e.g., teacher competencies) rely on self-assessment, which may introduce subjective bias. Despite these limitations, the longitudinal nature of the study and the use of multiple data sources contribute to the robustness of the findings.

To assess the internal consistency of the scale, Cronbach's α-coefficient was calculated. The obtained value indicates good reliability of the measurement instrument ($\alpha = 0.78$), confirming that the items used in the questionnaire measure a similar latent construct related to teachers' attitudes toward the use of artificial intelligence in education.

The χ^2 test revealed a statistically significant difference in the distribution of grades ($\chi^2(4) = 34.42$, $p < 0.001$), indicating that the observed improvement is unlikely to be due to chance.

Furthermore, 95% of students reported a positive perception of the impact of AI tools on their understanding of the learning material and their learning motivation ($M = 4.13$; $SD = 1.14$). These findings suggest that the integration of AI-based learning tools may contribute not only to improved academic outcomes but also to increased student engagement and motivation.

4. AI-Supported Personalization in Classroom and STEM Contexts

The introduction of the "Digital Backpack" in Bulgaria provides the technical infrastructure for the implementation of personalized learning by creating a basis for the use of individual student profiles. In combination with widely used digital tools such as electronic diaries and virtual classrooms, artificial intelligence can facilitate the identification of learning gaps and improve feedback and student progress. On the other hand, the automation of administrative tasks, using AI tools, can reduce the workload of teachers and provide them with more time for organizing the learning process.

AI tools and chatbots, such as ChatGPT-4 and Copilot, can support personalized learning by generating adapted learning materials, providing formative feedback, and assisting teachers in planning and organizing learning activities, as well as analyzing results. In this study, personalization was implemented through a persona-based approach, in which students with similar learning characteristics are grouped into profiles representing common needs, interests, and levels of competence (Nielsen et al., 2013).

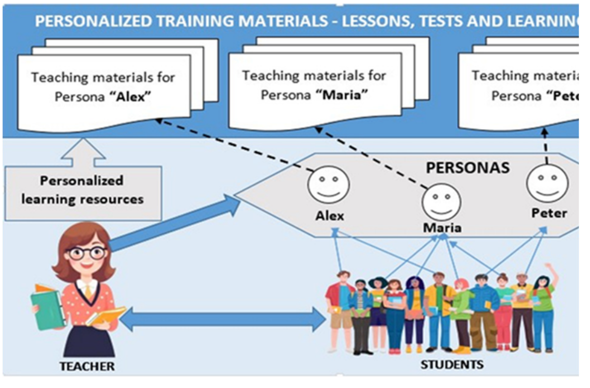

Figure 1. Personalization of learning through the use of Personas

AI-generated personas and learning tasks can be previewed and adapted by teachers before implementation, thus ensuring alignment with defined learning objectives (Fig.1).

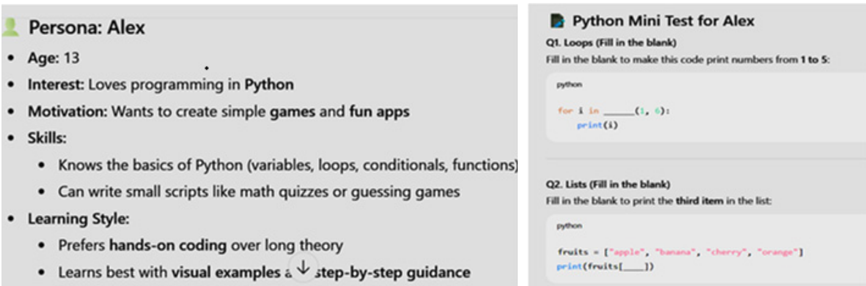

Figure 2. Use of Personas in the organization of learning (ChatGPT-4)

For example, in the preliminary preparation of a lesson for the Robotics Club, the teacher receives a proposal from the chatbot for several Personas, for each of which suitable learning tasks are offered, tailored to the teacher's goals, personal characteristics and interests (Fig. 2).

Within the STEM interest clubs, personalized learning was implemented through project-based activities that allowed students to take on different roles according to their interests, competencies, personal characteristics, and goals (Pavlova & Momcheva, 2024). The use of AI tools facilitated the creation and implementation of appropriate learning tasks, access to personalized resources, and continuous feedback throughout the learning process. This approach encouraged student engagement, activity, collaboration, and individual responsibility.

In this context, next-generation Open Science practices serve as a key source of inspiration for innovation in STEAM environments by promoting transparency and knowledge sharing (Momcheva & Pavlov, 2025).

For the example robotics club: if one student is more interested in AI, they can develop an algorithm for searching in a state space or for pattern recognition; if another student prefers to work with hardware, they can be responsible for assembling the robot; and if a third student is good at presenting the results, they will prepare a presentation, promote, and defend the project before a competition jury or before classmates, parents, and teachers. Thus, personalization makes learning more motivating and useful because each student sees meaning and contribution in the common project.

5. Results

This section examines the quantitative and qualitative data collected during the period 2023 – 2025, encompassing students' academic achievement as well as teachers' attitudes and self-assessment of their digital competencies. The findings are interpreted within the framework of contemporary research perspectives, while also addressing the practical challenges associated with the implementation of AI-supported personalized learning.

5.1. Academic Performance

The analysis of the application of this approach in the work of several STEM interest clubs provides grounds for concluding that setting personal tasks for students, based on the application of artificial intelligence tools, significantly increased students' success rate, interest, and motivation. In addition, a higher level of integration, inclusion, and work efficiency were observed in teamwork in the implementation of various robot "missions", where teams were formed according to the chatbot's suggestions.

Student academic performance was assessed using pre- and post-intervention test scores (n=86). The mean score increased from M=4.09 (SD=X) before the intervention to M=4.98 (SD=X) after the intervention.

A paired-samples t-test was conducted to compare pre- and post-intervention scores. The results indicated that the difference between the two measurements was statistically significant, $t(85)=X$, $p<.05$. The effect size, calculated using Cohen's d, was $d=X$, indicating a [small/moderate/large] effect (Table 2).

Table 2. Student Achievement (Pre–Post Comparison)

Measure	***n***	**Mean (*M*)**	**SD**		***t***	**P**	**Cohen's *d***
Pre-test	86	4.09	X				
Post-test	86	4.98	X		X	$<.05$	X

The success rate of students increased from 70% to 83%, which indicates a positive effect. However, this finding should be interpreted with caution due to the lack of a control group of students and the small sample size. The comparison is for the same group of students before and after the application of the pedagogical approach. The experiment was repeated in three consecutive years, but the results show sustainability.

5.2. Survey results

Survey data were collected from students (n = 86), teachers (n = 129), and parents (n = 42) using structured questionnaires. The questionnaires included Likert-scale items assessing attitudes toward AI use, perceived usefulness, and concerns related to ethical and pedagogical aspects:

- Among students, 95% (n = 82 of 86) reported a positive attitude toward the use of AI tools in learning.
- Among teachers, 67% (n = 86 of 129) indicated that AI tools are useful for supporting personalized learning.
- Among parents, 75% (n = 32 of 42) expressed concerns about students' independent use of AI tools outside the classroom.

Table 3. Summary results of implementing AI-powered personalization

Group	n	Indicator	%	n
Students	86	Positive attitude	95%	82
Teachers	129	Perceive AI as useful	67%	86
Parents	42	Express concerns	75%	32

The results support previous findings (Tetzlaff, 2021) that personalized learning is most effective when AI tools complement rather than replace teacher guidance and when learner characteristics are measured repeatedly as instruction is continually adapted. The study highlights that AI technologies can support and complement, rather than replace, the teacher's human pedagogical judgment. The high acceptance rate among students (95%) contrasts with the serious concerns of parents (75%) about unsupervised use of AI, once again highlighting the new role of the teacher as a mentor and facilitator (see Table 1). However, the gains in achievement should be interpreted with caution due to the lack of a control group, which limits the ability to be certain that AI is the sole factor behind success.

5.3. Teachers' Self-Assessment of DigCompEdu

Teachers' self-assessment of digital competencies (n = 129) was conducted using a DigCompEdu-based instrument. The distribution of responses across competency levels is presented in Figure 3.

The largest proportions of respondents were observed at levels B1 (20%) and A2 (23%), while only a small percentage reported high-level competencies (C1 – C2).

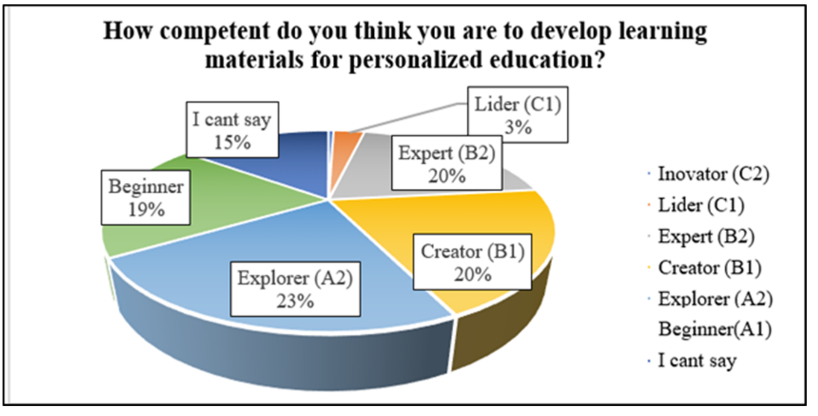

Figure 3. Self-assessment of DigCompEdu competencies related to personalization

6. Discussion

This study examines approaches to implementing personalized learning through AI capabilities in a real-world school context and assesses their relationship with student learning outcomes. Findings show generally positive attitudes toward AI-supported learning among students. At the same time, teachers and parents express more cautious opinions, particularly regarding the need for pedagogical supervision and responsible use of AI tools. These results are consistent with previous studies highlighting that AI is most effective when it complements rather than replaces teacher guidance.

A possible explanation for the observed patterns may also depend on how AI tools are used to support structured personalization practices. In particular, the use of AI-generated learning tasks and persona-based grouping may have facilitated better alignment between student needs and learning activities. However, given the study design, these mechanisms remain preliminary and require further investigation in more controlled research settings.

The limitations of the study have important implications for the interpretation of the findings. The absence of a control group limits the ability to draw causal conclusions, and the relatively small and context-specific sample restricts generalizability. These limitations suggest that the findings should be interpreted as context-dependent and exploratory, providing insights into possible trends rather than definitive evidence of effectiveness.

The analysis of these data confirms the need for additional support and training in the field of personalized education and its connection with the effective use of AI in methodological, administrative, and assessment processes.

7. Conclusion

This investigation, conducted from 2023 to 2025, confirms that AI technologies can effectively support personalized learning when integrated into clear pedagogical frameworks and accompanied by specific guidance from the teacher. The use of AI chatbots and the concept of "personas" allow for systematic adaptation of the learning process, thereby enabling a measurable increase in academic achievement and student engagement in STEM learning.

This study examines the implementation of AI-powered personalized learning in a Bulgarian school context, focusing on student performance and stakeholder attitudes. Findings show positive trends in both achievement and attitudes; however, these results should be interpreted with caution due to the research design and methodological limitations. The results should be interpreted with caution due to the lack of a control group and the limited sample size. Future research should include larger and more diverse groups of participants, use more rigorous research designs, and further explore the long-term effects of AI-powered personalization in school education.

Acknowledgments

This study is supported by the project FP25-FMI-010 "Innovative interdisciplinary research in informatics, mathematics and educational pedagogy" at the Plovdiv University "Paisii Hilendarski".

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