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Digital Transformation in Secondary Mathematics Education in Albania: AI/ICT, STEM, and Teachers' Professional Readiness

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Abstract: This study aims to analyze the integration of Artificial Intelligence (AI) and Information and Communication Technology (ICT) within the framework of STEM education in pre-university education in Albania. Particular attention is given to mathematics teachers' perceptions of their professional readiness and to the influence of school infrastructure on the adoption of innovative technologies in the teaching process. The study is based on quantitative data collected through a questionnaire administered to secondary school mathematics teachers. This research instrument assesses teachers' digital competencies, the necessary conditions for integrating innovative technologies into teaching, and their pedagogical attitudes toward these technologies. The data were analyzed using reliability indicators, descriptive analysis, and statistical correlation analysis to identify the relationships between teachers' professional preparation and institutional technological support. Mathematics teachers report above-average knowledge and skills in integrating STEM, AI, and ICT into their teaching. However, they assess the current conditions in their schools somewhat more modestly. From this perspective, statistical analysis suggests that teachers' professional readiness is strongly correlated to the quality of technical support and the availability of institutional resources. The study highlights that the digital transformation of mathematics teaching in Albania requires a strategic intervention that combines teachers' professional development with infrastructural improvements to enable the effective integration of digital technologies and to support innovative educational policies and teaching practices.

Keywords: Mathematics education, Secondary education, STEM, Artificial Intelligence/ICT, Educational technology

Introduction

In recent decades, digital transformation has profoundly reshaped the ways in which individuals and institutions communicate, produce, disseminate, and utilize information, giving rise to new forms of social and economic interaction. It has reconfigured multiple dimensions of everyday life and professional activity, establishing itself as a fundamental driver of contemporary development across almost all sectors of society (García-Delgado et al., 2023). The education system, both globally and within the Albanian context, has not remained unaffected by these developments. According to Çika (2025), the integration of digital technologies, particularly Artificial Intelligence (AI) and Information and Communication Technologies (ICT), exerts a transformative influence on education, both pedagogically and institutionally. One of the most significant developments in the field of

education, driven by technological advancements, is the emergence of STEM education. This innovation integrates Science, Technology, Engineering, and Mathematics with the aim of fostering advanced skills in critical thinking, problem-solving in real-life contexts, and mathematical modeling, in alignment with contemporary STEM teaching practices (Kosova et al., 2025). According to Kristensen et al. (2024), mathematics functions simultaneously as both a goal and an essential tool within STEM activities. Furthermore, findings from the study by Selimi, Berisha, and Vula (2025) highlight the necessity of integrating STEM with project-based learning (PBL) in the educational process. This integration significantly contributes to improving students' mathematical achievement and skills in secondary education, while enriching them with interdisciplinary knowledge and supporting the development of essential life skills. Similarly, Kafazi, Tasho, and Zeqo (2025) argue that incorporating STEM approaches into mathematics instruction supports students in achieving a more profound and meaningful understanding of mathematical concepts, particularly when these are connected to real-world contexts.

However, according to Ortiz-Laso et al. (2023), in order to effectively leverage mathematics through STE(A)M projects, teacher professional development programs should provide personalized training and support during the project planning phase. In this context, it is considered essential for mathematics teachers to possess in-depth knowledge of effective pedagogical practices and to integrate them consistently in the implementation of STEM-based teaching. They must also develop the necessary knowledge and skills to continuously adapt and refine their instructional practices (Marfuah & Khikmawati, 2023). Recent studies indicate that, although teachers hold positive perceptions toward STEM integration, they still require a more comprehensive foundation in both theoretical and practical aspects (Khalil et al., 2024).

Furthermore, in the field of mathematics education, a qualitative study conducted by Sofroniou, Patel, and Premnath (2025), which analyzes forty-three studies published between December 2000 and October 2025, highlights that the use of digital tools has a significant and positive impact on the development of conceptual understanding, as well as on increasing students' motivation and engagement in the learning process. However, the authors emphasize that this potential can only be realized when it is supported by teachers' professional development, adequate infrastructure, and well-structured pedagogical integration.

From this perspective, attention returns to the role of the teacher, who, according to Paul Drijvers (2015), remains a decisive factor in the effective integration of technology in mathematics teaching. The author emphasizes that digital technology does not replace the pedagogical process; rather, it requires the active mediation of the teacher to structure learning activities, guide discussions around the outcomes generated by digital tools, and meaningfully connect them with mathematical concepts. In this sense, the focus should not be placed solely on the availability of technological tools in schools, but also on the level of teachers' readiness and professional competence to integrate them effectively into the teaching and learning process.

Digital transformation in mathematics education represents a critical milestone in the modernization of STEM fields, enabling innovative approaches to improving learning outcomes, while key challenges remain closely linked to teachers' readiness (Akpalu et al., 2025). According to Christine Redecker (2017), the widespread use of digital devices and the responsibility to support students in becoming digitally competent require teachers to continuously develop their own digital competences. Furthermore, Prodani et al. (2022) identify access, competence, and motivation as the main factors influencing teachers' integration of digital technologies into the teaching process. Moreover, García-Delgado et al. (2023) emphasize that teachers' digital competences, their experience in using educational technologies, and the technological infrastructure of educational institutions constitute essential factors for the successful integration of STEM, AI, and ICT in teaching.

In light of the above, it becomes evident that, in order to effectively integrate AI, ICT, and STEM into teaching, it is essential to examine teachers perceived readiness, taking into account their digital competencies as well as the extent to which school conditions support such integration. Granström and Oppi (2025) emphasize the need for targeted professional development programs, ethical guidelines, and policy-level support in order to enhance teachers' readiness and facilitate the responsible integration of AI into educational practices.

According to Li et al. (2025), both educational policies and teaching practices should place greater emphasis on the pedagogical appropriateness of technology, ensuring that AI becomes an effective tool for the transformation and improvement of STEM education. Similarly, the study by Garcia (2026) indicates that the integration of AI, when guided by a well-defined pedagogical approach and a clear ethical vision, has the potential to fundamentally reshape the way mathematics is taught in an interconnected and human-centered world.

In the context of pre-university education in Albania, the digital transformation of the teaching process remains an ongoing and evolving development. This process began gradually in the early 2000s, accelerated significantly during the pandemic period, and in recent years has continued to consolidate progressively. The use of online learning during the COVID-19 pandemic clearly revealed existing challenges and highlighted the need to strengthen teachers' professional preparedness in Albania, particularly with regard to the pedagogical use of technology (Hoti, Dragusha, & Ndou, 2022).

The pandemic significantly affected teaching practices and required the adaptation of instructional methods, including the implementation of hybrid and digital approaches to mathematics teaching (Kafazi et al., 2023; Kafazi et al., 2021). In further studies on the use of digital tools and online platforms by teachers, Kafazi et al. (2023) report that the main challenges are associated with teachers' and students' limited familiarity with digital platforms, the lack of appropriate technological equipment, and poor internet connectivity. Nevertheless, despite these difficulties, the authors emphasize that the methods employed during online teaching had a positive impact in addressing the challenges posed by the pandemic and in ensuring the continuity of the educational process.

The situation created by the pandemic may have acted as a catalyst for more concrete actions undertaken by the Ministry of Education in recent years toward the integration of digital tools into the education system. These initiatives include equipping schools with technological devices such as computers and tablets, developing online platforms to support the teaching process, organizing teacher training on the pedagogical use of technology, and improving internet infrastructure within educational institutions. Specifically, the Agency for Quality Assurance in Pre-University Education (ASCAP) is implementing several training modules for mathematics teachers, which include:

1) *The use of effective teaching and learning methods during mathematics lessons;*
2) Improving the quality of the teaching–learning process, with a focus on applying mathematical knowledge in real-life contexts;
3) The development of teachers' practical skills for implementing interactive methods in the mathematics classroom;
4) Curriculum updates aligned with subject profiles, as well as the integration of technology and Artificial Intelligence (AI) into school practice.

In addition, ASCAP has published a guideline prepared by Rapti (2025) on project-based teaching, which provides practical guidance and support for teachers in the implementation of innovative instructional methods.
Although the aforementioned studies have examined the use of digital technologies and STEM approaches in education, within the Albanian context there remains a lack of empirical research that simultaneously analyzes the professional readiness of mathematics teachers and the infrastructural conditions of schools in relation to the integration of AI, ICT, and STEM into the teaching process.

In this context, the present study was conducted within the framework of the project "Enhancing the Education of Mathematics Teachers through the Focus on STEAM, ICT/AI, and Explorative Perspectives," which is part of the Research Expertise from the Academic Diaspora (READ) program, funded by the Albanian-American Development Foundation (AADF). Focused on improving the education of future mathematics teachers through the integration of contemporary approaches such as STEAM, ICT/AI, mathematical modeling, and exploratory learning, the project provides an important foundation for the development of this study.

For this reason, the present study aims to contribute to the existing body of literature by examining the relationship between mathematics teachers' professional readiness to integrate digital technologies and the infrastructural conditions of schools in secondary education in Albania. Furthermore, the study seeks to explore how these factors interact within the process of the digital transformation of teaching. The results indicate that the effective integration of digital technologies requires a strategic approach that combines teachers' professional development with sustained infrastructural improvements, enabling not only the effective use of technology but also the development of innovative educational policies and teaching practices.

Research Methodology

This study is based on a quantitative research approach and aims to examine the relationship between mathematics teachers' professional readiness to integrate digital technologies into the teaching process and the infrastructural conditions of secondary education institutions in Albania. The primary focus of the study is the role of AI, ICT, and STEM in the digital transformation of the mathematics teaching process.

Data were collected during the implementation of the project through a structured electronic questionnaire designed and distributed via the Google Forms platform, enabling efficient and well-organized data collection. The research instrument was designed to gather data on two main aspects:

1) *Teachers' digital readiness and competencies* – assesses teachers' knowledge and skills in using digital technologies in mathematics instruction.
2) *Schools' infrastructural conditions* – includes the evaluation of the availability of technological equipment and the level of institutional support for the use of technology in the teaching process.

The study instrument is a questionnaire consisting of closed-ended questions, structured according to a Likert scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree), with the aim of systematically assessing teachers' attitudes and perceptions in relation to issues associated with the research topic. A total of 152 mathematics teachers from secondary education in Albania participated in this study. The participants had been involved in professional development activities and pedagogical training programs organized by the Agency for Quality Assurance in Pre-University Education (ASCAP), with a focus on improving teaching quality and promoting the use of contemporary methods in school mathematics. Participation in the study was voluntary and anonymous. Participants were informed about the purpose of the study, and the data collected were used solely for research purposes. Among the surveyed teachers, 77.6% were female, while 22.4% were male. In terms of age distribution, the largest group belonged to the 31–40 age category (34.9%), followed by those over 50 years old (28.9%). Meanwhile, 25.7% of participants fell within the 41–50 age group, and 10.5% were under the age of 30. This distribution suggests that the majority of participants possess a relatively high level of professional experience.

Regarding teaching experience, 36.8% of the teachers reported having more than 20 years of experience, while 32.9% had between 11 and 20 years of experience. A smaller proportion of participants reported 5 to 10 years of experience (17.18%), whereas 13.2% indicated less than 5 years of experience in the profession. These findings further reinforce that the study sample predominantly consists of teachers with substantial professional experience in the field of education. With regard to the type of educational institution in which they are employed, the vast majority of participants (95.4%) work in public schools, while only 4.6% are employed in private educational institutions. Meanwhile, the analysis of school location indicates that 57.2% are situated in urban areas, 39.5% in rural areas, and a small proportion operate in both contexts. This distribution suggests a relatively balanced geographical representation of the study sample.

Furthermore, with regard to the educational level at which they conduct their teaching activities, 70.4% of teachers teach in lower secondary education, while 39.5% teach in upper secondary education. A proportion of participants reported being engaged in both levels of education. This indicates that the sample includes teachers operating across different levels of pre-university education, thereby providing a broader perspective on teaching practices and experiences. The participants in the study represent a wide range of educational regions in Albania, including Pogradec, Korçë–Pustec, Përrenjas, Devoll, Maliq, Përmet–Këlcyrë, Kolonjë, Gjirokastër, Tirana, Elbasan, and Durrës. This geographical distribution enhances the representativeness of the sample and enables a more comprehensive overview of diverse educational contexts at the national level.

The collected data were analyzed using the statistical package SPSS version 29, with the aim of conducting descriptive analyses and testing the statistical relationships between the main variables of the study. The key variables included teachers' skills and competencies for integrating digital technologies, as well as the infrastructural conditions of schools for their use in teaching.

The reliability of the instrument was assessed using Cronbach's alpha coefficient, while the normality of the data distribution was examined through the Shapiro–Wilk test. The results indicated that the variables did not follow a normal distribution. Consequently, nonparametric statistical tests were employed for data analysis, including Spearman's rho correlation coefficient, the Kruskal–Wallis test, and the Mann–Whitney test.

Results of the Study

This section presents the results of the statistical analysis of the data collected through the questionnaire administered to 152 mathematics teachers in secondary education in Albania. The analysis was organized according to the two main sections of the instrument: teachers' skills and professional readiness to integrate STEM, AI, and ICT into teaching, as well as the current institutional and infrastructural conditions that support

this integration. For each section, the analysis included the assessment of instrument reliability for each group of items, descriptive analysis, testing of data normality, correlation analysis, and nonparametric comparative tests. The reliability of the instrument was assessed using Cronbach's alpha coefficient. The results indicated a very high level of internal consistency for both dimensions of the questionnaire: teachers' skills and competencies (α = .930) and current institutional and infrastructural conditions (α = .924). These values demonstrate that the instrument has excellent reliability and is suitable for further statistical analysis.

For the interpretation of descriptive statistical data, a scoring scale based on the literature (Erol Sözen & Ufuk Güven, 2019) was applied. Specifically, the intervals were defined as follows: 1.00–1.80 for *Strongly Disagree*, 1.81–2.60 for *Disagree*, 2.61–3.40 for *Neutral*, 3.41–4.20 for *Agree*, and 4.21–5.00 for *Strongly Agree*.
The descriptive analysis of the data indicates that teachers report an above-average level of skills for integrating digital technologies into teaching (Mean = 3.64, Standard Deviation = 0.83, Median = 3.71), reflecting a generally positive perception (*Agreement*) of their professional readiness. With regard to the standard deviation, the value being below 1 suggests that responses are closely clustered around the mean, indicating a relatively high level of consensus among respondents. Figure 1 presents the distribution of responses for the skills section, where a pronounced concentration is observed in the categories *"agree"* and *"strongly agree,"* reflecting a high level of self-assessed competence among teachers.

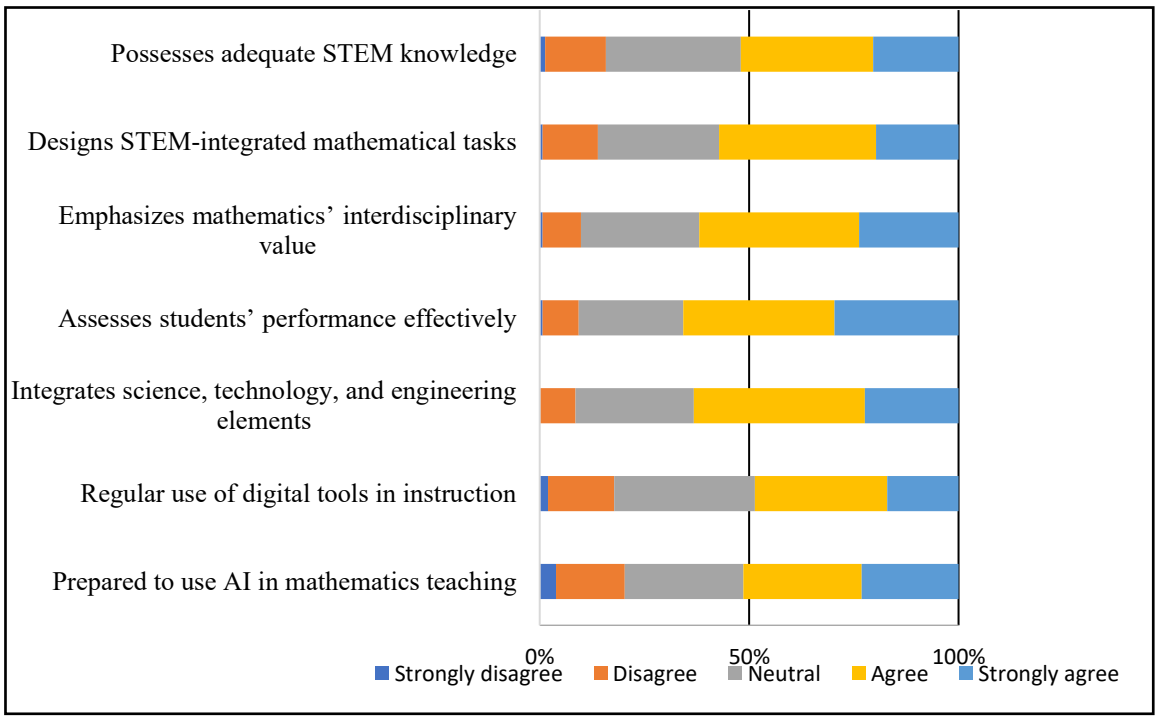

Fig. 1. Teachers' readiness to integrate ICT and AI in STEM

On the other hand, the evaluation of schools' infrastructural conditions appears more moderate (Mean = 3.28, Standard Deviation = 0.87, Median = 3.30), indicating general agreement that institutional and technological support is not at the same level as teachers' competencies. Regarding the standard deviation, as the value is also below 1, this suggests that responses are clustered around the mean, indicating a relatively strong consensus among respondents. Figure 2 shows that the distribution of responses regarding current conditions exhibits a tendency toward moderate evaluations, with a concentration of responses in the categories *"agree"* and *"partially agree."*

However, compared to Figure 1, a more moderate distribution is observed, with responses being less concentrated at the higher end of the scale. This suggests that, although there is a relatively positive perception of infrastructural conditions and institutional support, these are not at the same level as teachers' abilities. In this context, Figure 2 reinforces the findings regarding the existence of a gap between teachers' professional competencies and the actual conditions required for the effective integration of digital technologies in teaching.The Shapiro–Wilk test was statistically significant ($p < .05$), indicating a deviation from normal distribution for both the skills variable ($p = .001$) and the current conditions variable ($p = .027$). Thus, nonparametric tests were employed. Thus, Spearman's rho coefficient revealed a strong, positive, and

statistically significant relationship between teachers' skills and current conditions ($\rho = .684$, $p < .001$). This indicates that improvements in infrastructural and institutional conditions are closely associated with increased professional readiness of teachers for the integration of digital technologies.

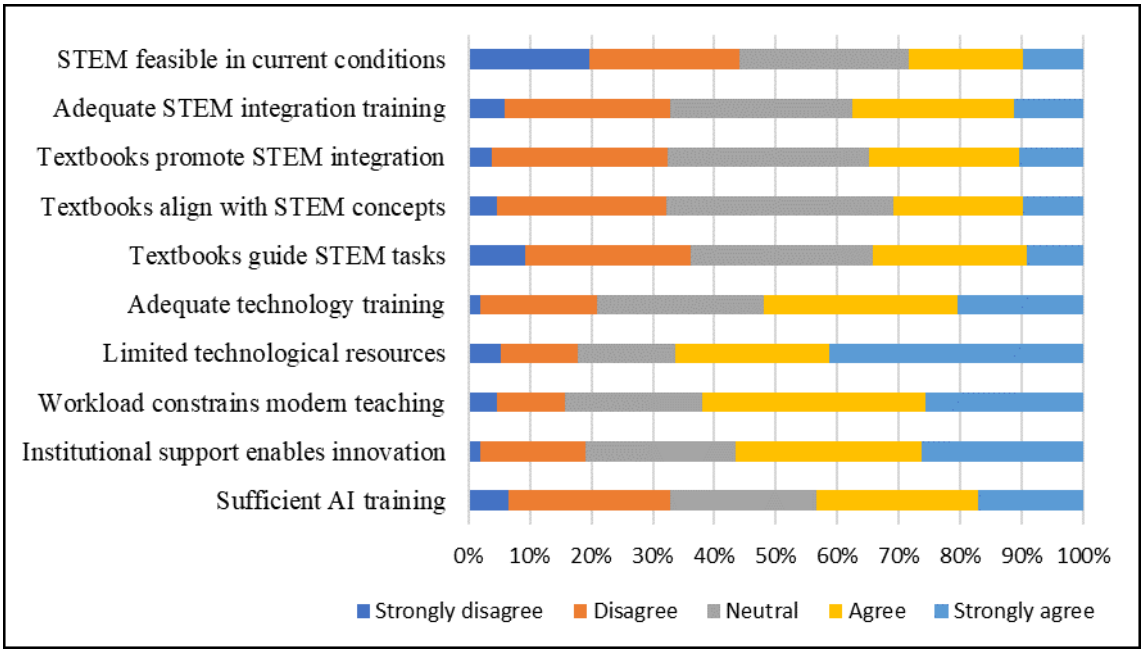

Fig. 2. Teachers' perceptions of STEM integration, training adequacy, and institutional and technological support

To examine differences across various demographic groups, the nonparametric Mann–Whitney U and Kruskal–Wallis H tests were employed, due to deviations from normal distribution. Analysis of Table 1 indicates that teachers' abilities do not differ significantly across any of the demographic variables examined. There were no statistically significant differences between male and female teachers, among different age groups, across years of teaching experience, between public and private school sectors, among levels of secondary education taught, or between urban and rural school locations.

*This implies that p*erceived abilities are fairly consistent among teachers, suggesting that factors other than demographics (e.g., training, personal interest, or institutional support) may play a larger role in STEM teaching competence.

Table 1. Differences in abilities across demographic variables

Variable	*Groups*	*N*	*Mean Rank*	*Test statistic*	*Sig.*
Gender	Female	118	74.07	U=1719.500	.204
	Male	34	84.93		
Age group	<30	16	95.34	H=6.211	.102
	31-40	53	73.91		
	41-50	39	83.27		
	>50	44	66.77		
	<5	20	95.80	H=4.506	.212
Years of teaching	5-10	26	74.56		
experience	11-20	50	72.37		
	>20	56	74.20		
School sector	Public	145	75.35	U=340.500	.141
	Private	7	100.36		
Secondary	Lower	107	75.40	H=.275	.872
education level	Higher	36	79.83		
	Both	9	76.28		
School location	Urban area	87	73.16	H=1.355	.508
	Rural area	60	80.32		
	Both	5	88.90		

Analysis of Table 2 shows that teachers' perceptions of current conditions are significantly influenced by age and years of teaching experience, but not by gender, school sector, secondary education level, or school location. Specifically, younger teachers under 30 perceive the conditions more positively than teachers over 50 (p=.015) in Figure 3, left chart, and teachers with less than 5 years of experience perceive conditions more favorably than those with 11–20 years of experience (p=.030), in Figure 3, right chart according to post-hoc pairwise comparisons. No significant differences were found between male and female teachers, between public and private schools, among levels of secondary education taught, or between urban and rural school locations. This could indicate that newer teachers are more adaptable or optimistic about integrating innovative approaches like STEM and technology in teaching, whereas more experienced teachers may encounter constraints or feel less supported in current conditions.

Table 2. Differences in current conditions across demographic variables

Variable	Group	N	Mean Rank	Test statistic	Sig.
Gender	Female	118	76.75	U=1977.000	.898
	Male	34	75.65		
Age group	<30	16	104.50	H=10.172	.017*
	31-40	53	72.90		
	41-50	39	82.17		
	>50	44	65.64		
Years of teaching experience	<5	20	100.60	H=8.277	.041*
	5-10	26	80.13		
	11-20	50	67.95		
	>20	56	73.84		
School sector	Public	145	75.66	U=386.000	.285
	Private	7	93.86		
Secondary education level	Lower	107	74.07	H=1.135	.567
	Higher	36	82.86		
	Both	9	79.94		
School location	Urban area	87	75.61	H=.579	.749
	Rural area	60	76.58		
	Both	5	91.00		

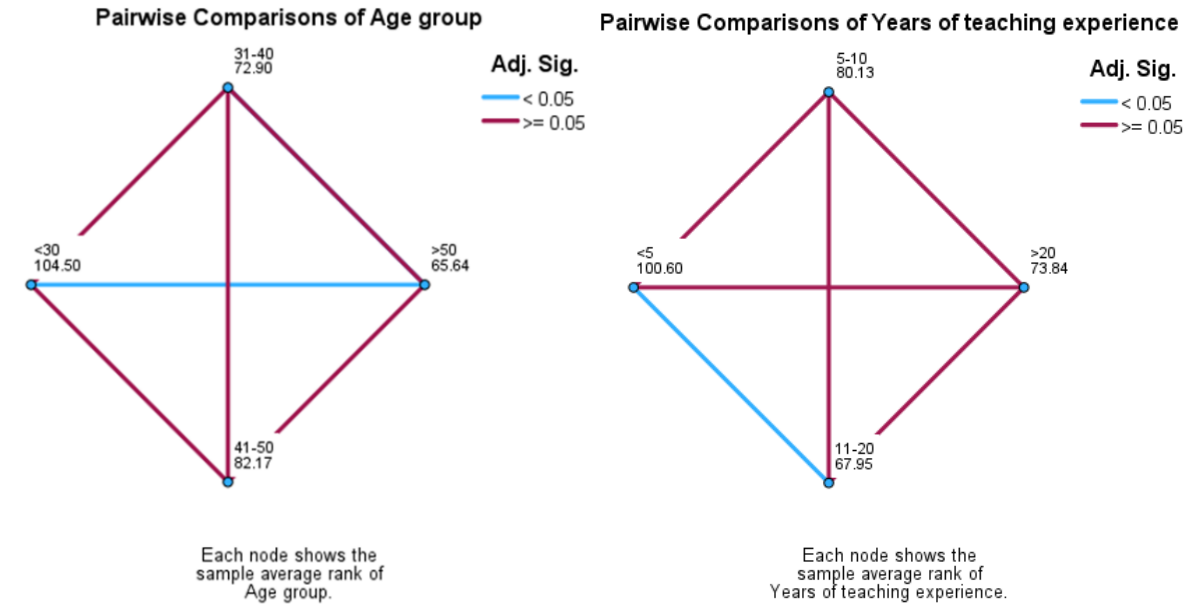

Figure 3. Pairwise comparisons of age groups and teaching experience based on mean ranks based on current conditions

Overall, the results indicate that mathematics teachers demonstrate a relatively high level of skills for integrating digital technologies and STEM approaches into teaching, while current institutional and infrastructural conditions are evaluated at a more moderate level. This contrast highlights the existence of a gap between professional competencies and the actual conditions for implementation. At the same time, the strong

relationship between these two dimensions suggests that improvements in school conditions may directly enhance the effectiveness of technology integration in the teaching process.

Discussion

The findings of this study indicate that mathematics teachers in secondary education in Albania report a relatively good level of skills for integrating digital technologies into the teaching process (Mean = 3.64), reflecting an above-average level of professional readiness. However, infrastructural conditions and institutional support are evaluated at a more moderate level (Mean = 3.28), highlighting a gap between individual capacities and the actual opportunities for implementing pedagogical innovation in practice. This result supports the argument that digital transformation in education requires a combination of teachers' competencies with adequate institutional and technological conditions (García-Delgado et al., 2023). One of the most significant findings of the study is the strong, positive, and statistically significant relationship between teachers' skills and current conditions ($\rho = 0.684$, $p < .001$). This result indicates that these two factors do not operate independently but are closely interconnected and mutually influential in the process of integrating digital technologies into mathematics teaching. This interpretation is consistent with the theoretical framework of DigCompEdu (Redecker, 2017), which emphasizes that the development of teachers' digital competences must be accompanied by systematic and infrastructural support in order to be effective.

In this context, the findings of the study reinforce the argument of Paul Drijvers (2015), according to which the success of technology integration in mathematics teaching depends not only on the availability of digital tools, but also on how they are used in a pedagogically structured manner. Thus, although teachers in this study report a good level of skills, the relative lack of appropriate conditions may limit the full potential of these competencies in teaching practice. The absence of statistically significant differences in teachers' skills across demographic variables indicates a consistent and homogeneous distribution of competencies within the study sample. This finding suggests a broad acquisition of basic digital skills among teachers, reflecting progress in professional development toward the integration of technology in education, in line with the work of Christine Redecker (2017), who emphasizes the importance of developing digital competences at all levels of education.
In contrast, the differences observed in the perception of current conditions across age groups and teaching experience suggest that individual factors influence how institutional reality is interpreted. Younger teachers and those with less experience tend to have a more positive evaluation of infrastructural conditions, whereas more experienced teachers exhibit a more critical perspective. This may be associated with a higher level of adaptability to technology and innovative approaches among younger teachers, while more experienced teachers may possess a more critical awareness of systemic limitations.

In the Albanian context, these results are consistent with findings from previous studies, which have identified challenges related to technological infrastructure, access to equipment, and the level of teachers' digital preparedness (Kafazi et al., 2023; Hoti et al., 2022). However, these studies also highlight the positive potential of technology in enhancing the teaching and learning process, particularly in exceptional situations such as the COVID-19 pandemic.

In conclusion, the findings of this study confirm that the digital transformation of mathematics teaching is a complex process that requires an integrated approach, combining teachers' professional development with improvements in infrastructural conditions and institutional support. As also emphasized by Granström and Oppi (2025), the effective integration of advanced technologies, such as artificial intelligence, requires not only individual competencies but also well-structured policies and systematic support.

Conclusions and Recommendations

This study examined the professional readiness of mathematics teachers to integrate digital technologies, including AI and ICT, within the framework of STEM education in pre-university education in Albania. Through a questionnaire administered to secondary school mathematics teachers, the study analyzed teachers' professional competencies, the infrastructural conditions of schools, and the relationship between these two dimensions in the process of integrating digital technologies into teaching. Based on the findings of the study, the following main conclusions are drawn:

- Mathematics teachers report a relatively good level of competencies and skills in the use of digital technologies in the teaching process, reflecting an above-average level of professional readiness.

- Infrastructural conditions and technological support in schools are evaluated at a more moderate level, highlighting a gap between teachers' professional readiness and the actual opportunities provided by school infrastructure for the effective integration of digital technologies.
- The correlation analysis revealed a strong, positive, and statistically significant relationship between teachers' competencies and the infrastructural conditions of schools ($\rho = 0.684$, $p < 0.001$), suggesting that these two dimensions are closely interconnected and mutually influence the process of technology integration in teaching.
- The effective integration of digital technologies in mathematics teaching requires an integrated approach, in which the development of teachers' professional competencies is accompanied by improvements in institutional and infrastructural conditions.

Based on these findings, the following actions are recommended:

- Strengthening teachers' professional development through structured and continuous training programs focused on the pedagogical use of digital technologies, including applications of AI and advanced ICT and STEM tools.
- Improving technological infrastructure in schools through sustained investments in digital equipment, educational platforms, and high-quality internet access, as essential conditions for the implementation of innovative teaching methods.
- Designing and implementing educational policies that support the systematic and sustainable integration of digital technologies into the teaching process.
- Promoting further research that examines the impact of digital technology use on students' achievement and motivation in mathematics.

In conclusion, the findings of this study emphasize that the digital transformation of mathematics teaching does not depend on a single factor, but rather on the interaction between teachers' professional competencies and the infrastructural conditions of schools. For this reason, the results can serve as an important foundation for the development of educational policies in Albania.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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