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Polish and Ukrainian Future and Early-Career Educators' Perspectives on AI Competencies and Curriculum Priorities in Primary Computer Science Education

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Abstract

Artificial intelligence is becoming an important component of primary Computer Science education, creating new expectations for both pupil competencies and teacher preparation. This study examined how Polish and Ukrainian future and early-career educators perceive curriculum priorities, AI-related competencies for primary school pupils, professional-development needs, and directions for curriculum innovation in teacher education. A cross-sectional comparative mixed-methods design was applied to data from 64 respondents from Poland and Ukraine (32 per country). Quantitative data were analysed using descriptive statistics and Mann–Whitney U tests, with Holm adjustment for multiple comparisons and rank-biserial correlations as effect-size measures, while open-ended responses were examined through qualitative thematic analysis. Across both national samples, critical evaluation of AI-generated content and understanding AI-related risks were among the highest-rated AI competencies, whereas prompt engineering and AI-project creation were comparatively less emphasised. Although Ukrainian respondents rated prompt development more highly than Polish respondents in the unadjusted analysis ($U = 294.5$, $p = 0.007$), this difference did not remain statistically significant after Holm adjustment (adjusted $p = 0.056$). Ukrainian respondents also tended to report stronger professional-development needs; after adjustment for multiple comparisons, statistically significant differences remained only for robotics and STEAM education. Overall, the findings indicate broadly similar descriptive priorities across the two samples rather than evidence of cross-national equivalence. The results support a human-centred, competency-based approach to teacher education integrating AI foundations, critical evaluation, ethical and responsible use, practical applications, and context-sensitive professional learning.

Keywords: artificial intelligence in education; AI literacy; curriculum innovation; teacher education; pre-service teachers; computer science education; AI competencies; educational design; primary education; comparative study

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1. Introduction

The rapid development of artificial intelligence (AI), particularly generative AI (GenAI), is transforming educational practices, curriculum design, and teacher preparation.

AI-supported technologies increasingly assist with lesson planning, content generation, assessment, and personalised learning, while simultaneously raising concerns about misinformation, algorithmic bias, privacy, and responsible technology use (Holmes & Tuomi, 2022; Moorhouse et al., 2023; Rudolph et al., 2023). These developments require teacher education institutions to reconsider how future educators acquire the competencies necessary for teaching and learning in AI-rich environments.

This challenge is particularly important in primary education, where teachers contribute to children's initial understanding of digital technologies, computational thinking, and responsible participation in digital environments. The integration of AI into primary Computer Science education requires more than technical familiarity with digital tools. Future teachers must be prepared to introduce age-appropriate AI concepts, critically evaluate AI-generated information, address ethical issues, and design learning activities that support creativity, problem-solving, and digital safety (Miao & Cukurova, 2024; Sanusi et al., 2023).

Although AI literacy has become an increasingly important component of teacher professional competence, research indicates that pre-service teachers often lack systematic preparation for its pedagogical integration (Heine & König, 2025; Runge et al., 2025). Existing studies have primarily examined teachers' general AI acceptance, digital competence, or readiness to use AI-supported educational applications. Less attention has been devoted to how future primary educators perceive the specific curriculum priorities and AI-related competencies required for teaching Computer Science in the early years of schooling.

A further research gap concerns the limited comparative evidence from Central and Eastern Europe, particularly Poland and Ukraine. Previous research has examined ICT and digital competence development among prospective preschool and primary school teachers in Poland (Smyrnova-Trybulska, 2021), but comparative evidence concerning perceived AI-related curriculum priorities, pupils' competencies, and teacher professional-development needs remains limited. Examining these issues across two institutional contexts may provide useful insights into shared educational priorities and context-sensitive approaches to curriculum innovation. However, institutional sample comparisons should not be interpreted as representative national comparisons.

The main aim of this study is to examine and compare Polish and Ukrainian future and early-career educators' perceptions of curriculum priorities, AI-related competencies required for primary school pupils, and professional-development needs, and to identify implications for teacher education curricula supporting AI-enhanced primary Computer Science education.

The study addresses the following research questions and hypotheses:

RQ1. Which curriculum areas are perceived as most important for primary Computer Science education, and which item-level differences, if any, are observed between the Polish and Ukrainian samples?

H1. *At least one curriculum-priority item will differ between the Polish and Ukrainian samples.*

RQ2. Which AI-related competencies are perceived as most important for primary school pupils, and which item-level differences, if any, are observed between the Polish and Ukrainian samples?

H2. *At least one AI-related competency item will differ between the Polish and Ukrainian samples.*

RQ3. Which areas of professional preparation are perceived as most important for AI-enhanced primary Computer Science education, and which item-level differences, if any, are observed between the Polish and Ukrainian samples?

H3. *At least one professional-development item will differ between the Polish and Ukrainian samples.*

RQ4. What curriculum innovations and forms of professional preparation do participants recommend for preparing future primary educators for AI-enhanced Computer Science education?

The study combines item-level quantitative comparisons with exploratory qualitative evidence to inform curriculum development and teacher preparation. Its contribution lies in identifying perceived educational priorities and professional-learning needs within two institutional samples rather than establishing national differences or objectively measuring participants' AI competence.

2. Literature Review and Theoretical Background

2.1. AI Literacy and Digital Competence in Teacher Education

The growing integration of artificial intelligence into education has expanded the competency requirements for teachers and teacher candidates. Beyond using digital technologies for instructional purposes, educators are increasingly expected to understand AI-supported systems, evaluate their outputs, and address the pedagogical and ethical implications of their use. Consequently, AI literacy has emerged as an important dimension of contemporary teacher preparation (Long & Magerko, 2020; Mills et al., 2024).

AI literacy encompasses knowledge, skills, attitudes, and ethical awareness required to understand, critically evaluate, and responsibly interact with AI systems. UNESCO's AI Competency Framework for Teachers emphasises human-centred approaches, AI ethics, foundational knowledge and applications, AI pedagogy, and professional learning (Miao & Cukurova, 2024). These dimensions indicate that AI literacy should not be reduced to proficiency in using generative AI applications.

Although AI literacy overlaps with digital competence, the two constructs are not identical. The DigCompEdu framework defines educators' digital competence through professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence (Redecker, 2017). AI literacy introduces additional requirements concerning machine learning, algorithmic processes, data-related limitations, AI-generated content, and human oversight (Tenberga & Daniela, 2024). Thus, digital competence provides an important foundation, but AI-specific knowledge and critical judgement require explicit attention in teacher education.

Recent studies suggest that pre-service teachers generally recognise the potential of AI while reporting gaps in their conceptual understanding and pedagogical preparation (Zhang et al., 2023; Heine & König, 2025). Research on AI-related technological pedagogical content knowledge (AI-TPACK) further indicates that professional training may contribute to educators' confidence and intentions to integrate AI into teaching (Runge et al., 2025). These findings support the need to distinguish between perceived importance, self-reported competence, and demonstrated ability when examining teacher readiness.

Research on university students' perceptions of artificial intelligence has also highlighted the importance of understanding the factors that shape their views on AI, providing a relevant perspective for designing educational approaches that support AI literacy (Przybyła-Kasperek et al., 2023).". Recent research further highlights the importance of developing AI literacy and related competencies in pre-service teacher education to prepare future educators for the pedagogically meaningful and responsible integration of AI into teaching and learning (Hsu, 2026).

2.2. AI-Supported Computer Science Education in Primary Schools

Primary Computer Science education increasingly extends beyond basic computer operation and programming to include computational thinking, data literacy, digital citizenship, and foundational understanding of AI. Introducing these concepts at an early educational stage requires developmentally appropriate pedagogical approaches that connect technological knowledge with children's everyday experiences.

AI-supported activities may offer opportunities to develop problem-solving, creativity, and critical thinking. However, their educational value depends on appropriate instructional design and teacher guidance. Young learners need support in recognising that AI-generated outputs may be inaccurate or biased and that digital technologies should be used responsibly (Kasneci et al., 2023; Su et al., 2023).

Preparing future primary teachers for this task presents particular challenges. Unlike specialist secondary Computer Science teachers, primary educators are often expected to teach multiple subjects and may have limited formal preparation in advanced computing concepts. Their professional development therefore requires an appropriate balance between foundational AI knowledge, practical classroom applications, and pedagogical strategies suitable for younger learners.

Research involving pre-service teachers indicates generally positive perceptions of AI-supported educational practices alongside concerns about misinformation, ethical risks, and excessive reliance on automated tools (Dayagbil et al., 2025). Previous studies on ICT integration in primary teacher preparation similarly highlight the importance of systematic competency development and practical educational experience (Morze et al., 2017; Smyrnova-Trybulska, 2021).

These findings suggest that AI-enhanced primary Computer Science education should combine established curricular priorities, including digital safety, computational thinking, and programming, with emerging competencies such as critical evaluation of AI-generated content and responsible AI use. Nevertheless, empirical evidence remains limited regarding how future and early-career educators prioritise these competencies and identify their own professional-development needs.

A scoping review by Su and Yang (2022), covering 17 studies, identified the potential of AI-supported educational activities, including robotics, to foster young children's understanding of AI concepts, computational thinking, and other learning-related competencies, while highlighting the need for further rigorous research.

2.3. Curriculum Innovation and Professional Preparation for AI-Enhanced Education

The integration of AI into teacher education requires curriculum innovation that extends beyond introducing isolated AI-related courses. Recent approaches emphasise the integration of AI literacy, ethical awareness, pedagogical design, and practical experience across teacher preparation programmes (Kelley & Wenzel, 2025; Mishra et al., 2025).

A competency-oriented approach should provide opportunities for future teachers to evaluate AI-generated materials, design age-appropriate learning activities, consider data privacy and ethical issues, and reflect on the educational value of AI-supported technologies. Such preparation may be strengthened through practical workshops, collaborative projects, and authentic classroom tasks.

The AI-TPACK perspective highlights the relationship between technological knowledge, pedagogical knowledge, and subject-specific teaching requirements (Runge et al., 2025). In primary Computer Science education, this relationship is particularly relevant because educators must adapt complex technological concepts to children's cognitive and developmental needs.

The UNESCO AI Competency Framework for Teachers additionally supports a systemic approach to professional preparation, connecting AI knowledge with responsible pedagogical practice and continuing professional development (Miao & Cukurova, 2024). Nevertheless, implementation may vary across institutions because of differences in curriculum structures, available technologies, staff expertise, and opportunities for practical training.

Comparative studies can contribute to curriculum development by identifying overlapping educational priorities and areas requiring context-sensitive support. In the Polish and Ukrainian institutional contexts examined in the present study, particular attention is given to perceptions of foundational digital competencies, critical and ethical AI literacy, robotics, STEAM education, and professional-development needs. These dimensions provide a basis for examining potential directions for curriculum innovation without assuming that the two samples represent their respective national teacher populations.

3. Materials and Methods

3.1. Research Design

This study employed a cross-sectional comparative convergent mixed-methods design to examine Polish and Ukrainian future and early-career educators' perceptions of AI-enhanced primary Computer Science education. Quantitative and qualitative data were collected through the same online questionnaire. The quantitative component addressed three prespecified domains: curriculum priorities, AI-related competencies for primary school pupils, and professional-development needs. Open-ended questions explored recommendations for curriculum innovation and teacher preparation. Both components were analysed separately and integrated during interpretation, with qualitative findings used to contextualise and elaborate on quantitative patterns rather than independently test the hypotheses.

The study was informed by multidimensional approaches to AI literacy (Ng et al., 2021) and human-centred, competency-based perspectives, including UNESCO's AI Competency Framework for Teachers (Miao & Cukurova, 2024). These frameworks guided the distinction between foundational digital competencies, AI-specific literacy, responsible AI use, and professional preparation for pedagogical integration.

3.2. Participants, Institutional Context, and Sampling

The final analytical sample comprised 64 respondents (Poland: $n = 32$; Ukraine: $n = 32$) associated with the University of Silesia in Katowice, Faculty of Arts and Educational Science, and Borys Grinchenko Kyiv Metropolitan University, Faculty of Pedagogical Education. Non-probability purposive sampling was used, primarily targeting students enrolled in pedagogy and teacher-education programmes, particularly those related to early childhood and primary education. Practising educators with relevant educational experience were also eligible. Inclusion in the analytical sample required informed consent and sufficiently complete responses to the variables analysed.

Participants were recruited through student groups and online course forums. As the number of individuals who received or viewed the invitation could not be established, a recruitment response rate was unavailable. Most respondents (54/64; 84.4%) were student teachers or pedagogical students; the remaining participants included practising teachers and other educators. Country-specific professional status and teaching experience are presented in Tables 1 and 2, respectively. In the Polish sample, 27 participants (84.4%) reported no professional teaching experience or teaching practice only, compared with 17 (53.1%) in the Ukrainian sample; 5 (15.6%) and 11 (34.4%), respectively, reported up to three years of experience, and 4 Ukrainian respondents (12.5%) reported 4–10 years of experience.

Table 1. Country-specific professional status of respondents.

Professional Status	Poland *n* (%)	Ukraine *n* (%)	Total *n* (%)
Student teacher/pedagogical student	30 (93.8)	24 (75.0)	54 (84.4)
Primary school teacher	0 (0.0)	6 (18.8)	6 (9.4)
Student and teacher	2 (6.3)	0 (0.0)	2 (3.1)
Computer Science teacher	0 (0.0)	1 (3.1)	1 (1.6)
Other educator/private tutor	0 (0.0)	1 (3.1)	1 (1.6)
Total	32 (100.0%)	32 (100.0%)	64

Table 2. Teaching experience of respondents.

Teaching Experience	Poland *n* (%)	Ukraine *n* (%)	Total *n* (%)
None/teaching practice only	27 (84.4)	17 (53.1)	44 (68.8)
Up to 3 years	5 (15.6)	11 (34.4)	16 (25.0)
4–10 years	0 (0.0)	4 (12.5)	4 (6.3)
Total	32 (100.0)	32 (100.0)	64 (100.0)

Given the small, non-probability samples and differences in professional experience, the findings describe the two institutional samples and are not representative of Polish or Ukrainian educators nationally.

3.3. Questionnaire Development and Structure

The questionnaire was developed within a broader comparative study of primary Computer Science education, drawing on relevant curricula, previous research, and frameworks concerning digital competence, AI literacy, and teacher preparation.

Instrument development involved two stages. First, a teacher-oriented questionnaire was pilot-tested with 76 practising teachers (January–March 2026) to assess item clarity, relevance, and comprehensibility. Second, the instrument was adapted for future and early-career educators (April–June 2026), retaining its substantive domains while revising item wording and respondent perspectives. Most student participants had completed teaching practicums and a Computer Science Teaching Methodology module involving curriculum analysis and lesson planning. The adapted version was not independently pilot-tested; therefore, the earlier pilot is regarded as part of instrument development rather than validation of the final version.

The present analyses focused on three quantitative domains: curriculum priorities, AI-related competencies for primary school pupils, and professional-development needs. Items covered foundational digital skills, computational thinking, programming, robotics, AI concepts, ethical and critical AI literacy, and relevant areas of teacher preparation. Responses were recorded on a five-point Likert-type scale (1 = least important; 5 = most important). Open-ended questions elicited recommendations concerning curriculum innovation, AI-supported activities, and professional learning.

3.4. Cross-National Linguistic and Conceptual Adaptation

Because the study involved participants from Poland and Ukraine, particular attention was paid to the linguistic clarity and conceptual comparability of the questionnaire across the two national and educational contexts. Polish participants completed the Polish-language version of the questionnaire, whereas Ukrainian participants completed the Ukrainian-

language version. The two versions were reviewed by bilingual researchers and members of the respective national research teams to ensure clarity of wording and correspondence of meaning across languages.

The adaptation process focused not only on linguistic correspondence but also on the conceptual equivalence of educational terminology that could be interpreted differently across national contexts. Particular attention was given to terms related to Computer Science education, algorithmic thinking, digital safety, artificial intelligence, prompt development, STEAM, and professional development. The national research teams reviewed the terminology in relation to the respective educational contexts, and identified discrepancies were discussed and resolved through consultation among the researchers.

A post hoc cross-version audit identified one substantive asymmetry in Question 7.3. The Polish version invited respondents with experience in AI-supported teaching to propose a short curriculum or, if interested in professional training, to indicate the preferred number of training hours. The Ukrainian version additionally prompted respondents to specify a preferred training format (e.g., face-to-face or distance; online or asynchronous). Because training format was explicitly elicited only in the Ukrainian version, format-related responses cannot be regarded as directly comparable cross-national evidence. Consequently, references to online, distance, blended, asynchronous, or other training formats are reported only as country- and question-specific exploratory qualitative observations and are not pooled to support cross-national conclusions about preferred training formats.

The adaptation procedure was intended to enhance the comparability of interpretation rather than to establish psychometric equivalence between the two language versions. Given the relatively small national samples, formal multi-group assessment of measurement invariance was not feasible and no claim of measurement invariance is made. Accordingly, between-country comparisons are interpreted cautiously as differences or similarities observed in the two study samples rather than as evidence of full linguistic, conceptual, or psychometric equivalence between the Polish and Ukrainian populations.

3.5. Data Collection Procedure

Data were collected between April and June 2026 for Poland and Ukraine. The questionnaire was administered online through the Google Forms platform (Questionnaire available on Supplementary Materials https://docs.google.com/forms/d/1bT3cWvS5ptI8A8KdRkF1dUKqMr3bucIQzmWe09JyOsE/preview (accessed on 20 June 2026)). Participants received information explaining the purpose of the research, the voluntary nature of participation, the intended scientific use of the data, and the procedures for protecting participant confidentiality.

Participation was voluntary, and all participants provided informed consent before completing the questionnaire. The questionnaire was completed individually online without researcher assistance. No personally identifying information was collected or used for the analyses reported in this study.

Recruitment was conducted in both countries through the channels described above, including student groups and online course forums. Because recruitment partly relied on open announcements distributed through these channels, the exact number of individuals who received or viewed the invitation could not be reliably determined; therefore, a precise recruitment response rate could not be calculated. The final analytical dataset comprised 64 complete questionnaires, including 32 responses from Poland and 32 from Ukraine. Only questionnaires meeting the inclusion and completeness criteria specified above were retained for analysis. The same substantive questionnaire domains were administered to participants in both countries.

3.6. Quantitative Data Analysis

Quantitative analyses were conducted using Python 3.12 (SciPy, Pandas, and NumPy) and PQStat 1.8.6.128. For each rating item, n, mean (M), standard deviation (SD), median, and interquartile range (IQR) were calculated separately for the Polish and Ukrainian samples and, where useful descriptively, for the combined sample. Because the items used five-point ordinal scales and the two national groups were independent and relatively small, item-level between-country comparisons were performed using two-sided Mann–Whitney U tests. The Holm procedure for multiple-comparison adjustment was applied separately within the three prespecified families of comparisons: curriculum priorities, AI-related competencies, and professional-development needs. Both unadjusted and Holm-adjusted p values are reported, but inferential conclusions are based on Holm-adjusted p values at $\alpha = 0.05$. Rank-biserial correlations (rrb) with 95% confidence intervals were used as effect-size measures. Non-significant tests are interpreted as an absence of statistically detectable differences in these samples and not as evidence of cross-national equivalence. Where a response contained two simultaneously selected scale values, the prespecified reconstruction used their arithmetic mean. The 95% confidence intervals accompanying rank-biserial effect sizes will be presented in Section 4. These intervals describe uncertainty in the effect-size estimates and are not multiplicity-adjusted. Statistical conclusions regarding item-level comparisons are based on Holm-adjusted p values rather than on whether the unadjusted effect-size intervals exclude zero.

3.7. Qualitative Data Analysis

The qualitative component comprised open-ended responses to Questions 7.1–7.3 concerning educational practices, changes needed in primary Computer Science education, AI-related curriculum recommendations, and professional preparation. Of the 64 participants, 53 provided a substantive response to at least one analysed open-ended question (Poland: 24/32, 75.0%; Ukraine: 29/32, 90.6%). Response rates differed by question and country: in Poland, Q7.1 was answered by 15 participants, Q7.2 by 22, and Q7.3 by 9; in Ukraine, Q7.1 and Q7.2 were each answered by 29 participants and Q7.3 by 15. These unequal response rates were considered when interpreting theme frequencies.

Responses were analysed using thematic content analysis. Coding was primarily data-driven, but it was not treated as purely inductive because the wording of Q7.2 and Q7.3 explicitly prompted several domains (e.g., curriculum, instructional time, teacher competence, educational robotics/programming, training duration, and—only in the Ukrainian Q7.3—training format). The analysis therefore combined data-driven coding of participants' substantive recommendations with sensitivity to the structure of the prompts. Researchers first read the full response set, identified meaning units, and assigned initial codes. Related codes were grouped into categories and higher-order themes. Coding decisions were compared among the researchers and disagreements were resolved through discussion and consensus. No statistical intercoder-agreement coefficient was calculated.

Theme frequencies are reported only as descriptive indicators and should not be interpreted as prevalence estimates because open-ended response rates differed by country and question and some themes were partly elicited by the prompts. Representative quotations were selected to illustrate major themes. Polish and Ukrainian quotations were translated into English and reviewed for preservation of meaning. Because only the Ukrainian Q7.3 explicitly asked about training format, format-related themes are reported separately and are not pooled as evidence of a shared cross-national preference.

3.8. Integration of Quantitative and Qualitative Components

Quantitative and qualitative findings were integrated at the interpretation stage through a thematic comparison of the three quantitative domains with relevant open-ended recommendations. Ratings concerning curriculum priorities, AI-related competencies, and professional-development needs were examined alongside open-ended recommendations to identify complementary or contrasting perspectives. Qualitative evidence was used to contextualise quantitative patterns rather than independently verify statistical hypotheses. The integration was interpretive rather than a formal joint-display or participant-level linkage analysis; accordingly, the qualitative strand illustrates possible explanations but does not establish why the quantitative patterns occurred. Because Q7.3 differed between the Polish and Ukrainian versions, training-format recommendations were interpreted only as country- and question-specific exploratory observations.

3.9. Ethical Considerations

The study was conducted in accordance with the ethical principles applicable to research involving human participants. Ethical approval was obtained from the Ethics Committee of the University of Silesia in Katowice (Approval No. KEUS/O/40/01.25). All participants were informed about the purpose of the study and the intended scientific use of the collected data. Participation was voluntary and anonymous, and participants could withdraw at any stage before submitting the questionnaire. The dataset used for analysis did not contain information intended to directly identify individual participants.

The data are not publicly available because of ethical and privacy considerations associated with research involving human participants and the conditions under which informed consent was obtained. Data supporting the findings may be made available by the corresponding author upon reasonable request, subject to applicable ethical and data-protection restrictions.

3.10. Use of Generative Artificial Intelligence

During preparation of the manuscript, the authors used ChatGPT 4.0 (OpenAI) for literature-review support and proofreading, as declared in the original submission. The use of the tool involved literature identification, organisation of literature themes, synthesis of the literature, and language editing.

Generative AI was not used in the development of the study design, not used in questionnaire development, not used in statistical analysis, and not used in interpretation of the empirical findings. It was not used to generate participant responses or research data. All bibliographic references identified or processed with AI assistance were independently checked by the authors against the original publications. The authors reviewed and edited all AI-assisted material, verified the reported analyses and interpretations, and take full responsibility for the accuracy, integrity, and final content of the manuscript.

4. Results

4.1. Sample Characteristics

The study included 64 respondents (32 from each country), predominantly student teachers or pedagogical students (84.4%). The Ukrainian sample included a higher proportion of practising educators than the Polish sample (Table 1).

Country-specific teaching experience is presented in Table 2. These differences in sample composition should be considered when interpreting between-country comparisons.

Table 2 shows that 27 of 32 Polish respondents (84.4%) and 17 of 32 Ukrainian respondents (53.1%) reported no professional teaching experience or teaching practice only. Up

to three years of experience was reported by 5 Polish (15.6%) and 11 Ukrainian (34.4%) respondents, while 4 Ukrainian respondents (12.5%) reported 4–10 years. Thus, teaching experience was more common in the Ukrainian institutional sample, a compositional difference that may affect between-sample comparisons.

4.2. Curriculum Priorities

This section examines the substantive aspects of Computer Science education in primary schools. Respondents were asked to evaluate the importance of selected curriculum topics, indicate the educational tools used during instruction, and assess the frequency of applying different teaching methods. The objective was to identify the competencies, technologies, and pedagogical approaches that currently shape Computer Science education in Poland and Ukraine. Respondents evaluated the importance of nine curriculum topics using a five-point scale ranging from 1 (least important) to 5 (most important). Higher values indicate greater perceived importance of a given topic.

Digital safety was the highest-rated curriculum priority in both samples (Poland: M = 4.62; Ukraine: M = 4.78), followed by internet and online interaction and basic computer skills. AI-related content was also rated highly, whereas robotics and basic programming received comparatively lower ratings (Table 3).

Table 3. Perceived importance of key topics in Computer Science education.

Topic/Competency	Sample	*n*	M	SD	Median	IQR
Digital safety	Poland	32	4.62	0.71	5	0.25
Digital safety	Ukraine	32	4.78	0.66	5	0
Digital safety	Total	64	4.70	0.68	5	0
Internet and online interaction	Poland	32	4.44	0.91	5	1
Internet and online interaction	Ukraine	32	4.53	0.88	5	1
Internet and online interaction	Total	64	4.48	0.89	5	1
Basic computer skills	Poland	32	4.38	0.98	5	1
Basic computer skills	Ukraine	32	4.50	0.80	5	1
Basic computer skills	Total	64	4.44	0.89	5	1
Media literacy	Poland	32	4.00	0.95	4	2
Media literacy	Ukraine	32	4.25	1.02	5	1
Media literacy	Total	64	4.12	0.98	4	1.25
Artificial intelligence and its role	Poland	32	4.16	0.92	4	2
Artificial intelligence and its role	Ukraine	32	4.09	0.82	4	1
Artificial intelligence and its role	Total	64	4.12	0.86	4	1.25
Algorithmic thinking	Poland	32	3.81	1.06	4	2
Algorithmic thinking	Ukraine	32	4.22	0.98	4.5	1
Algorithmic thinking	Total	64	4.02	1.03	4	2
Robotics	Poland	32	3.62	1.04	4	1
Robotics	Ukraine	32	3.59	0.95	4	1
Robotics	Total	64	3.61	0.99	4	1
Basics of programming	Poland	32	3.38	1.19	3	2
Basics of programming	Ukraine	32	3.69	1.15	4	1.25
Basics of programming	Total	64	3.53	1.17	4	1
Other topics	Poland	14	2.64	1.55	2.5	3
Other topics	Ukraine	32	3.03	1.58	3	4
Other topics	Total	46	2.91	1.56	3	3

Descriptive statistics in Table 3 indicate broadly similar curriculum priorities in both countries. Digital safety received the highest ratings in both the Polish and Ukrainian samples, followed by internet and online interaction and basic computer skills. The high medians and relatively narrow IQRs for these topics indicate strong agreement regarding their importance. Artificial intelligence was also rated highly in both countries, while robotics and basics of programming received comparatively lower ratings.

No curriculum-priority item showed a statistically significant between-sample difference after Holm adjustment (Table 4). The largest observed rank-biserial effect concerned algorithmic thinking (U = 398.5, $p = 0.109$, adjusted $p = 0.870$, rrb = 0.222), but this difference was not statistically significant.

Table 4. Cross-country comparison of key Computer Science education topics.

Topic	U	*p*	Holm-Adjusted *p*	rrb	95% CI for rrb
Basic computer skills	487.5	0.706	1.000	0.048	[−0.187, 0.278]
Algorithmic thinking	398.5	0.109	0.870	0.222	[−0.054, 0.465]
Digital safety	450.0	0.225	1.000	0.121	[−0.064, 0.309]
Media literacy	422.0	0.199	1.000	0.176	[−0.094, 0.422]
Robotics	530.0	0.806	1.000	−0.035	[−0.304, 0.226]
Basics of programming	429.0	0.252	1.000	0.162	[−0.104, 0.427]
Internet and online interaction	488.0	0.704	1.000	0.047	[−0.196, 0.279]
Artificial intelligence and its role	542.0	0.673	1.000	−0.059	[−0.324, 0.212]

To determine whether Polish and Ukrainian respondents differed in their evaluations of key Computer Science curriculum topics, Mann–Whitney U tests were conducted for each topic (Table 4). To control for multiple comparisons, Holm adjustment was applied across the family of comparisons related to key Computer Science education topics. Effect sizes were additionally reported as rank-biserial correlations (rrb) with 95% confidence intervals. No statistically significant differences were found between Polish and Ukrainian respondents for any of the analysed topics after Holm adjustment. The largest, although still non-significant, effect was observed for algorithmic thinking (U = 398.5, $p = 0.109$, adjusted $p = 0.870$, rrb = 0.222, 95% CI [−0.054, 0.465]). Small effect sizes were observed for media literacy (rrb = 0.176), basics of programming (rrb = 0.162), and digital safety (rrb = 0.121). Overall, the findings indicate overlapping descriptive priorities in the two institutional samples regarding the key topics that should be included in primary school Computer Science education.

4.3. AI Competency Priorities for Primary School Pupils

Respondents evaluated the importance of competencies that primary school students should acquire regarding artificial intelligence.

Table 5 indicates that critical evaluation of AI-generated responses and understanding AI-related risks were among the highest-rated competencies in both samples. Descriptive differences were greatest for prompt development, which received higher ratings from Ukrainian respondents.

Table 5. Importance of AI-related competencies.

Topic/Competency	Sample	*n*	M	SD	Median	IQR
Applying critical thinking when evaluating AI responses	Poland	31	4.29	1.16	5	1.50
Applying critical thinking when evaluating AI responses	Ukraine	32	4.75	0.57	5	0

Table 5. *Cont.*

Topic/Competency	Sample	*n*	M	SD	Median	IQR
Applying critical thinking when evaluating AI responses	Total	63	4.52	0.93	5	0.50
Understanding the risks of AI	Poland	30	4.47	0.86	5	1
Understanding the risks of AI	Ukraine	32	4.53	0.67	5	1
Understanding the risks of AI	Total	62	4.50	0.76	5	1
Basic understanding of what AI is	Poland	31	4.16	1.07	5	1.50
Basic understanding of what AI is	Ukraine	32	4.62	0.61	5	1
Basic understanding of what AI is	Total	63	4.40	0.89	5	1
Understanding new opportunities provided by AI	Poland	31	4.32	0.87	5	1
Understanding new opportunities provided by AI	Ukraine	32	4.41	0.67	4.5	1
Understanding new opportunities provided by AI	Total	63	4.37	0.77	5	1
Difference between human thinking and algorithms	Poland	31	4.13	1.12	5	2
Difference between human thinking and algorithms	Ukraine	32	4.59	0.62	5	1
Difference between human thinking and algorithms	Total	63	4.37	0.92	5	1
Ethical principles	Poland	31	4.35	0.92	5	1
Ethical principles	Ukraine	32	4.31	0.82	4.5	1
Ethical principles	Total	63	4.33	0.86	5	1
Creating simple projects using AI	Poland	31	3.81	1.30	4	2
Creating simple projects using AI	Ukraine	32	4.34	0.75	4.5	1
Creating simple projects using AI	Total	63	4.08	1.08	4	2
Developing effective prompts	Poland	30	3.40	1.19	3	1.75
Developing effective prompts	Ukraine	32	4.19	0.93	4	1
—-	Total	62	3.81	1.13	4	2
Other competencies	Poland	13	2.31	1.32	2	2
Other competencies	Ukraine	32	3.22	1.70	3.5	4
Other competencies	Total	45	2.96	1.64	3	4

Table 6 summarizes the results of the Mann–Whitney U tests comparing the perceived importance of AI-related competencies between respondents from Poland and Ukraine.

Table 6. Comparison of AI-related competencies between Poland and Ukraine (Mann–Whitney U tests).

Competency	U	*p*	Holm-Adjusted *p*	rrb	95% CI
Applying critical thinking when evaluating AI responses	412.0	0.133	0.792	0.169	[−0.044, 0.380]
Understanding the risks of AI	483.5	0.960	1.000	−0.007	[−0.253, 0.236]
Basic understanding of what AI is	384.0	0.080	0.560	0.226	[−0.013, 0.462]
Understanding new opportunities provided by AI	491.5	0.952	1.000	0.009	[−0.249, 0.265]
Difference between human thinking and algorithms	399.5	0.132	0.792	0.195	[−0.054, 0.440]
Ethical principles	527.0	0.641	1.000	−0.062	[−0.315, 0.200]
Creating simple projects using AI	398.0	0.151	0.820	0.198	[−0.076, 0.456]
Developing effective prompts	294.5	0.007	0.056	0.389	[0.126, 0.634]

To identify potential differences between countries, Mann–Whitney U tests were performed for each competency. To control for multiple comparisons, Holm adjustment was applied across the family of AI-related competency comparisons. Effect sizes were addi-

tionally reported as rank-biserial correlations (rrb) with 95% confidence intervals. The unadjusted analysis suggested a difference in the perceived importance of developing effective prompts (U = 294.5, $p = 0.007$, rrb = 0.389, 95% CI [0.126, 0.634]), indicating higher ratings among Ukrainian respondents. However, this result did not remain statistically significant after Holm adjustment (adjusted $p = 0.056$). No statistically significant differences were identified for the remaining competencies. Overall, the findings indicate similar descriptive trends in the two institutional samples regarding the AI-related competencies that should be included in primary education.

4.4. Professional-Development Needs

Respondents evaluated the importance of selected professional-development topics using a five-point scale ranging from 1 (least important) to 5 (most important).

Professional-development needs were rated relatively highly in both samples, particularly digital safety, AI education, and STEAM. Ukrainian respondents reported higher descriptive ratings for robotics and STEAM education (Table 7).

Table 7. Professional development needs in Computer Science education.

Topic/Competency	Sample	*n*	M	SD	Median	IQR
Digital safety	Poland	32	3.91	1.25	4	2
Digital safety	Ukraine	32	4.38	0.87	5	1
Digital safety	Total	64	4.14	1.10	5	1.25
Artificial Intelligence (AI) education	Poland	32	3.62	1.24	3.5	2
Artificial Intelligence (AI) education	Ukraine	32	4.25	0.84	4	1
Artificial Intelligence (AI) education	Total	64	3.94	1.10	4	2
STEAM	Poland	32	3.53	1.32	3.5	2
STEAM	Ukraine	32	4.31	1.00	5	1
STEAM	Total	64	3.92	1.23	4	2
Programming in primary school	Poland	32	3.59	1.13	4	1.25
Programming in primary school	Ukraine	32	4.12	0.98	4	1
Programming in primary school	Total	64	3.86	1.08	4	2
Robotics	Poland	32	3.38	1.34	3	3
Robotics	Ukraine	32	4.31	1.00	5	1
Robotics	Total	64	3.84	1.26	4	2
Other topics	Poland	13	2.23	1.54	1	3
Other topics	Ukraine	32	3.38	1.68	4	3.25
Other topics	Total	45	3.04	1.71	3	4

After applying Holm adjustment for multiple comparisons, statistically significant between-sample differences remained only for robotics (U = 302.5, adjusted $p = 0.016$, rrb = 0.409, 95% CI [0.144, 0.646]) and STEAM education (U = 329.0, adjusted $p = 0.038$, rrb = 0.357, 95% CI [0.107, 0.596]), both rated more highly by Ukrainian respondents. Differences in programming, AI education, and digital safety were not statistically significant after adjustment (Table 8).

After Holm adjustment (Table 8), only robotics (adjusted $p = 0.016$) and STEAM education (adjusted $p = 0.038$) showed statistically significant between-sample differences. Both received higher ratings in the Ukrainian institutional sample.

After Holm-adjusted *p*-values (Table 8), however, only the differences in Robotics (adjusted $p = 0.016$, rrb = 0.409, 95% CI [0.144, 0.646]) and STEAM education (adjusted $p = 0.038$, rrb = 0.357, 95% CI [0.107, 0.596]) remained statistically significant. The between-country differences in Programming in primary school (adjusted $p = 0.123$, rrb = 0.296,

95% CI [0.035, 0.532]), Artificial Intelligence education (adjusted $p = 0.123$, rrb = 0.296, 95% CI [0.035, 0.532]), and Digital Safety (U = 410.0, $p = 0.138$, adjusted $p = 0.138$, rrb = 0.199, 95% CI [−0.069, 0.444]) were not statistically significant after adjustment. Thus, the results indicate broadly similar professional-development priorities across the Polish and Ukrainian samples, with statistically significant cross-country differences after multiplicity correction limited to Robotics and STEAM education, both of which were rated more highly by Ukrainian respondents.

Table 8. Comparison of professional-development needs between Poland and Ukraine (Mann–Whitney U tests).

Topic	U	*p*	Holm-Adjusted *p*	rrb	95% CI for rrb
Digital safety	410.0	0.138	0.138	0.199	[−0.049, 0.451]
Artificial Intelligence (AI) education	367.0	0.041	0.123	0.283	[0.024, 0.531]
STEAM	329.0	0.010	0.038	0.357	[0.107, 0.596]
Programming in primary school	370.5	0.048	0.123	0.276	[0.006, 0.521]
Robotics	302.5	0.003	0.016	0.409	[0.144, 0.646]

The final open-ended question invited respondents to share recommendations regarding AI education and professional training; preferred training format was explicitly prompted only in the Ukrainian version of Q7.3.

Figure 1 presents the frequency of occurrence of the principal themes identified during the qualitative analysis of respondents' recommendations regarding AI education and teacher professional development. The figure is based on qualitative responses provided by 53 participants (24 from Poland and 29 from Ukraine) who answered at least one of the open-ended questions (Q7.1–Q7.3). Themes were identified across all analysed qualitative responses and subsequently aggregated for descriptive presentation. The frequencies presented in Figure 1 represent the number of responses in which a given theme was identified during the qualitative coding procedure. Since respondents frequently addressed more than one aspect of AI education within a single answer, responses could be assigned to multiple thematic categories. Consequently, each plotted value counts responses coded with that theme (at most once per theme per response), not distinct participants across themes; a response may contribute to multiple categories. The counts are descriptive and are not adjusted for the unequal question-specific response rates. Open-ended responses were analysed using primarily data-driven thematic content analysis, while acknowledging the categories explicitly prompted by Q7.2 and the Ukrainian version of Q7.3. The identified themes were subsequently quantified by counting the number of responses assigned to each category. For example, a response such as "Children should understand what AI is, learn to critically evaluate AI-generated responses, and use AI ethically" was assigned simultaneously to the categories Introduction to AI concepts and literacy, Critical evaluation of AI outputs, and Ethical and responsible AI use. Figure 1 demonstrates that respondents most frequently emphasized the need to introduce basic AI concepts and AI literacy into primary education. Closely related themes included ethical and responsible use of AI, critical evaluation of AI-generated outputs, and prompt engineering, all of which were repeatedly highlighted as essential competencies for future learners. The figure also shows that respondents attached considerable importance to practical AI applications, including AI-supported projects and content generation activities. Several respondents stressed that AI education should extend beyond theoretical knowledge and provide opportunities for hands-on experience with contemporary AI tools. Recommendations concerning teacher professional development also appeared in the responses. Mentions of online or blended training formats are questionnaire-version-specific observations, because training format

was explicitly requested only in the Ukrainian version of Q7.3. This finding suggests that successful integration of AI into Computer Science education requires not only curriculum changes but also systematic support for teachers. The source population for the qualitative analysis comprised the 64 questionnaire respondents (32 per institutional sample). Of these, 53 participants supplied at least one substantive response to Q7.1–Q7.3 (Poland: 24; Ukraine: 29). The question-specific response populations were Q7.1: Poland $n = 15$, Ukraine $n = 29$; Q7.2: Poland $n = 22$, Ukraine $n = 29$; and Q7.3: Poland $n = 9$, Ukraine $n = 15$. The plotted thematic counts refer to coded open-ended responses rather than a denominator of all 64 respondents; a participant could provide responses to more than one question. Accordingly, values should not be interpreted as percentages of participants or directly compared as national prevalence estimates.

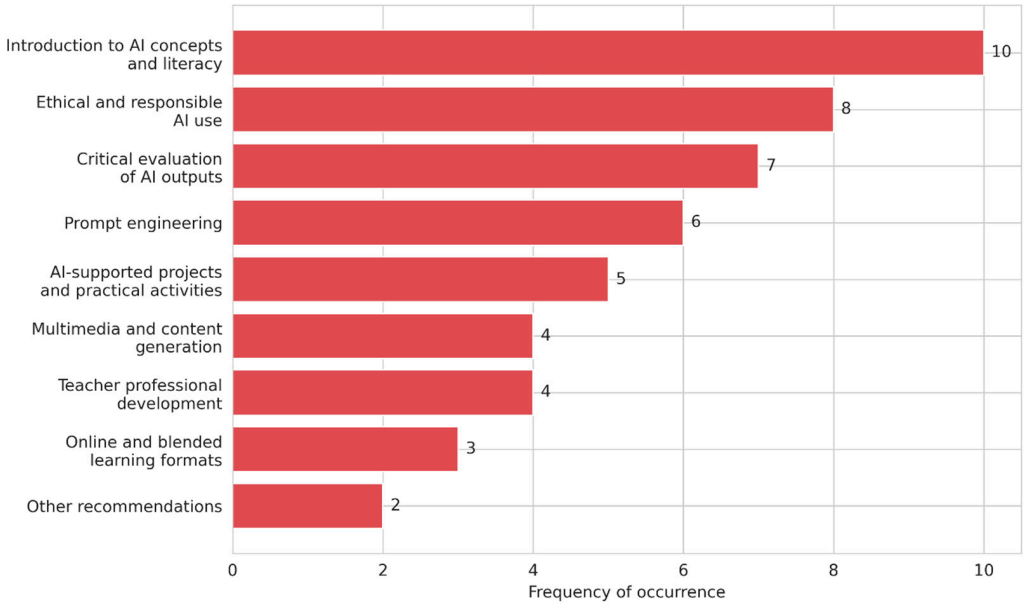


Figure 1. Main themes identified in AI curriculum recommendations. Values represent counts of responses coded with each theme (at most once per theme per response); multiple themes per response were permitted. The source material comprises open-ended answers to Q7.1–Q7.3 (Poland: Q7.1 $n = 15$, Q7.2 $n = 22$, Q7.3 $n = 9$; Ukraine: Q7.1 $n = 29$, Q7.2 $n = 29$, Q7.3 $n = 15$). Across questions, 24 Polish and 29 Ukrainian respondents provided at least one substantive answer; the question-specific counts must not be added to obtain unique participant totals. Theme counts are descriptive, not percentages of participants.

4.5. Qualitative Findings and Curriculum Recommendations

Open-ended responses provided additional perspectives on curriculum innovation and teacher preparation. Selected quotations (Table 9) illustrate recommendations concerning foundational AI literacy, responsible AI use, critical evaluation of AI-generated content, practical programming activities, and AI-supported projects. Participants also suggested improving teacher preparation, technological resources, and opportunities for hands-on learning.

Because only the Ukrainian version of Q7.3 explicitly requested preferred training formats, responses concerning online, blended, or asynchronous learning were treated as question-specific exploratory observations rather than comparable cross-national findings.

Question 7.3 was not fully equivalent across the Polish and Ukrainian questionnaire versions. Both versions invited respondents to propose AI-related curriculum content or indicate a desired training duration, but only the Ukrainian version explicitly requested a preferred training format. Consequently, responses concerning online, distance, face-to-face,

or asynchronous formats cannot be pooled or interpreted as a cross-national preference. In the Ukrainian sample, some Q7.3 respondents proposed flexible or asynchronous formats; for example, one participant recommended asynchronous game-based quests and interactive presentations. Polish Q7.3 responses are used primarily to illustrate proposed curriculum content and training duration unless a format preference was volunteered spontaneously. The qualitative synthesis therefore treats curriculum-content recommendations as the principal cross-sample finding and reports training-format observations as version-specific exploratory evidence.

Table 9. Selected illustrative quotations from Polish and Ukrainian respondents concerning curriculum changes and AI education (Q7.2–Q7.3).

Country/Respondent	Question	Main Theme	Illustrative Quotation (English Translation)
Poland, CPL1	Q7.2	Curriculum time and digital competence	"It is worth increasing the number of hours allocated to this subject, because digital competences are becoming necessary in everyday life and future professional work."
Poland, CPL1	Q7.3	AI literacy and responsible use	"Introduction to artificial intelligence"; "Safe and responsible use of AI"; "Machine learning fundamentals."
Ukraine, CUA22	Q7.2	Practical learning and teacher competence	"Computer science education [...] requires an increase in the number of hands-on activities, updating the curriculum [...] and improving teachers' digital competencies."
Ukraine, CUA12	Q7.2	Programming and AI integration	"The curriculum needs to be updated, with more emphasis placed on hands-on activities, programming, and the use of AI."
Ukraine, CUA25	Q7.2	Creative learning and visual programming	"Modern computer science [...] should teach children to create technology through play, rather than simply consume content."
Ukraine, CUA22	Q7.3	AI curriculum content	"The fundamentals of artificial intelligence, the safe and ethical use of AI, creating effective prompts [...] verifying the accuracy of information."
Ukraine, CUA25	Q7.3	Age-appropriate AI learning	"The program should focus on visual programming, safe information search, and creating drawings or stories with the help of AI."

Note. Quotations were translated into English and shortened for clarity. Ellipses indicate omitted text. Respondent identifiers correspond to the study dataset. The examples are illustrative and do not indicate the frequency of the themes.

The qualitative analysis revealed strong support for active, project-oriented, and interdisciplinary approaches to Computer Science education. Respondents consistently advocated increasing instructional time, strengthening teacher preparation, improving technical infrastructure, and expanding opportunities for programming, robotics, and AI education. Furthermore, the responses indicate that future AI curricula should emphasise critical thinking, ethical awareness, prompt engineering, and practical applications, while professional development programmes should be practice-oriented. Suggestions concerning online or blended formats were elicited explicitly only in the Ukrainian version of Q7.3 and cannot be interpreted as a shared preference across the two samples.

5. Discussion

The present study examined curriculum priorities, AI-related competencies for primary school pupils, professional-development needs, and curriculum innovation recommendations among Polish and Ukrainian future and early-career educators. The findings reveal broadly overlapping descriptive priorities concerning digital safety, foundational digital competencies, and responsible AI literacy, alongside statistically significant between-sample differences in selected professional-development areas. These patterns suggest that

AI-enhanced primary Computer Science education may benefit from shared competency principles combined with context-sensitive approaches to teacher preparation. However, the findings relate to the two institutional samples and should not be interpreted as evidence of national-level convergence or equivalence.

5.1. Curriculum Priorities and Critical AI Literacy (RQ1–RQ2)

The findings addressing RQ1 indicate that respondents in both samples placed considerable importance on digital safety, online interaction, foundational computer skills, and AI-related education. No curriculum-priority item showed a statistically significant between-sample difference after Holm adjustment; therefore, H1 was not supported. This finding suggests overlapping descriptive priorities rather than demonstrated cross-national equivalence. Consistent with the rejection of H1, none of the curriculum-priority items remained statistically significant after Holm adjustment.

The results indicate that the introduction of AI-related content need not displace established digital and computational competencies. Instead, AI education can be integrated into a broader curriculum encompassing digital literacy, computational thinking, problem-solving, and responsible technology use. This interpretation is consistent with research advocating the integration of AI literacy into existing K–12 educational frameworks rather than treating AI as an isolated technical subject (Sanusi et al., 2023; Su et al., 2023; Chiu et al., 2024). It also aligns with UNESCO's student AI competency framework, which emphasises human-centred thinking, ethics, AI techniques and applications, and responsible design (Miao et al., 2024).

Regarding RQ2, critical evaluation of AI-generated content and understanding AI-related risks received higher ratings than prompt development and simple AI-project creation. Although Ukrainian respondents rated prompt development more highly in the unadjusted comparison, the difference did not remain statistically significant after Holm adjustment (adjusted $p = 0.056$). Consequently, H2 was not supported.

This ordering suggests that respondents assigned particular importance to critical and responsible AI literacy for younger learners. Such an emphasis is consistent with multidimensional conceptualisations of AI literacy that integrate conceptual understanding, ethical awareness, critical evaluation, and practical application (Lintner, 2024; Chiu et al., 2024). Research on AI education for younger learners similarly highlights the importance of developmentally appropriate activities that combine technological understanding with critical judgement and responsible use (Su et al., 2023; Sanusi et al., 2023).

The comparatively lower rating of prompt development should not be interpreted as evidence that this competency is unimportant. Rather, the findings suggest that respondents prioritised the ability to evaluate the accuracy, safety, and appropriateness of AI-generated information over more specialised interaction skills. This distinction is particularly relevant in primary education, where generative AI may expose learners to misinformation, bias, and excessive reliance on automated responses (Kasneci et al., 2023). Accordingly, AI literacy education should develop pupils' capacity to question and evaluate AI outputs alongside their ability to interact with AI systems.

5.2. Professional-Development Needs and Context-Sensitive Teacher Preparation (RQ3)

The findings addressing RQ3 indicate substantial perceived professional-development needs across the examined domains. After adjustment for multiple comparisons, statistically significant between-sample differences remained only for robotics and STEAM education, with Ukrainian respondents reporting higher perceived needs in these areas.

H3 was supported, as statistically significant between-group differences remained for robotics and STEAM education after Holm-adjusted p-values.

These findings reinforce the importance of systematic professional preparation for AI-enhanced education. Previous research indicates that teachers' readiness to integrate AI depends not only on technological familiarity but also on pedagogical confidence, perceived usefulness, ethical awareness, and opportunities for professional learning (Sanusi et al., 2024; Ayanwale et al., 2024). Studies involving pre-service teachers further emphasise the value of practical training, collaborative learning, AI-related pedagogical knowledge, and reflective engagement with emerging technologies (Pei et al., 2025; Prilop et al., 2025; Khalid et al., 2026).

The stronger perceived needs in robotics and STEAM education among Ukrainian respondents may be associated with differences in prior coursework, teaching experience, institutional resources, or access to specialised training. However, the present study did not directly test these explanations. Moreover, perceived training needs should not be equated with objectively measured competence, as higher reported needs may also reflect greater awareness of professional requirements or stronger motivation for further learning.

From a curriculum-development perspective, the findings support combining common foundational competencies, such as digital safety and responsible AI use, with flexible professional-development opportunities responsive to the needs of particular learner groups and institutional contexts. Robotics and STEAM education represent areas warranting further investigation rather than evidence of generalised national differences in teacher competence.

5.3. Implications for Curriculum Innovation in Teacher Education (RQ4)

The qualitative findings addressing RQ4 provide practical directions for integrating AI into primary Computer Science education and initial teacher preparation. Participants' recommendations included foundational AI concepts, critical evaluation of AI-generated information, ethical and responsible use, visual programming, age-appropriate AI-supported projects, and practice-oriented teacher training. These recommendations complement the quantitative findings by illustrating possible ways to translate perceived competency priorities into educational activities.

The findings suggest that AI literacy should be integrated into authentic pedagogical tasks rather than taught exclusively through isolated technical instruction. Such tasks may include evaluating AI-generated content, designing age-appropriate learning activities, exploring simple AI applications, and reflecting on privacy, bias, and ethical responsibilities. This approach is consistent with research advocating intentional integration of AI literacy into teacher preparation and collaborative pedagogical design (Kelley & Wenzel, 2025; Blonder et al., 2025; Sun & Huang, 2025).

A further implication concerns the relationship between shared competency principles and locally adapted implementation. The descriptive overlap in curriculum and AI-literacy priorities suggests that common educational objectives may provide a useful foundation for teacher-education curriculum development. However, differences in professional-development needs and institutional conditions indicate that training content, resources, and implementation strategies should remain adaptable.

Recommendations concerning online, blended, or asynchronous professional-development formats require particular caution. Because the Ukrainian version of Q7.3 explicitly requested training-format preferences whereas the Polish version did not, these responses cannot establish comparable preferences across the two samples. They are therefore interpreted as country- and question-specific exploratory observations.

5.4. Theoretical and Practical Contributions

The study contributes to discussions of AI-enhanced teacher education by distinguishing between perceived curriculum priorities, AI-related competencies expected of pupils,

and educators' professional-development needs. Its findings suggest that these dimensions are related but should not be treated as interchangeable.

At the conceptual level, the results support a human-centred understanding of AI literacy in which critical judgement, ethical responsibility, digital safety, and technological understanding are considered complementary educational objectives. The findings also highlight the importance of distinguishing perceived competency priorities from demonstrated competence and professional-development needs.

At the practical level, the study suggests three directions for curriculum development: integrating AI literacy with foundational digital and computational competencies; embedding critical evaluation and responsible AI use in age-appropriate learning activities; and providing differentiated professional-development opportunities that combine pedagogical reflection with practical experience.

These implications should be understood as research-informed recommendations rather than empirically validated curriculum interventions. Their effectiveness requires examination through future implementation and evaluation studies.

5.5. Limitations and Future Research

Several limitations should be considered when interpreting the findings. First, the study involved relatively small, non-probability samples from two institutional contexts ($n = 32$ per country), limiting statistical power and preventing generalisation to national populations. Second, although the sample consisted predominantly of future educators, it also included practising teachers and other early-career educators, introducing variation in professional experience and educational background.

Third, the study measured perceived priorities and professional-development needs rather than objectively demonstrated AI competence. Fourth, although linguistic and conceptual adaptation procedures were undertaken, formal measurement invariance was not established. Consequently, the absence of statistically significant differences should not be interpreted as evidence of cross-national equivalence.

The qualitative component was subject to additional limitations. Open-ended response rates differed across questions and national samples, and some themes were explicitly suggested by the questionnaire prompts. Furthermore, Q7.3 was not fully equivalent across language versions because only the Ukrainian version explicitly elicited training-format preferences. These factors restrict the interpretation of theme frequencies and comparisons concerning professional-learning formats.

Future research should employ larger, multi-institutional samples, harmonised and independently piloted instruments, and performance-based assessments of AI-related competencies. Longitudinal and intervention studies could examine how structured AI-related coursework influences critical evaluation, ethical reasoning, pedagogical design, and classroom implementation. Complementary interviews or focus groups using equivalent protocols would also help clarify the contextual factors shaping educators' curriculum priorities and professional-development needs.

6. Conclusions

This exploratory comparative study examined curriculum priorities, AI-related competencies for primary school pupils, and professional-development needs among future and early-career educators in two Polish and Ukrainian institutional samples. Digital safety, foundational digital competencies, critical evaluation of AI-generated content, and awareness of AI-related risks emerged as important educational priorities. After Holm adjustment, no statistically significant between-sample differences were identified in curriculum-priority or AI-competency items. In contrast, Ukrainian respondents reported significantly higher

professional-development needs in robotics and STEAM education. These findings indicate overlapping descriptive priorities across the two samples without establishing cross-national equivalence.

The findings suggest that initial teacher education should integrate foundational AI concepts with critical evaluation, responsible AI use, digital safety, and developmentally appropriate practical activities. Professional preparation should also address context-specific needs, particularly in robotics and STEAM. The qualitative responses further support practice-oriented curriculum development, although conclusions concerning preferred training formats are limited by differences between the Polish and Ukrainian questionnaire versions.

Given the small, non-probability samples, differences in participants' professional experience, and the reliance on self-reported perceptions, the findings should not be generalised to national populations or interpreted as direct measures of AI competence. Future research should employ larger and more diverse samples, harmonised research instruments, and performance-based or longitudinal designs to evaluate the effectiveness of proposed curriculum innovations.

Supplementary Materials: The following supporting information can be downloaded at: (https://docs.google.com/forms/d/1bT3cWvS5ptI8A8KdRkF1dUKqMr3bucIQzmWe09JyOsE/preview) (accessed on 20 June 2026). Questionnaire: Preparing Future Primary School Teachers for AI-Enhanced Computer Science Education—A Comparative Study.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Commission of Ethics of the University of Silesia. Agreement Number: KEUS/O/40/01.25.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Participation was voluntary and anonymous, and all participants were informed about the purpose of the study and the use of the collected data for scientific research purposes.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. The dataset is not publicly available due to ethical and privacy considerations related to research involving human participants and the conditions under which informed consent was obtained.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
STEAM	Science, Technology, Engineering, Arts, and Mathematics
GenAI	Generative Artificial Intelligence
ICT	Information and Communication Technology

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