Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Educators' use of artificial intelligence to prepare and implement inquiry tasks in primary education

Oksana Onopriienko
National Academy of Educational Sciences of Ukraine
Inna Lipchevska
linla@ukr.net

National Academy of Educational Sciences of Ukraine

Research Article

Keywords: artificial intelligence, primary education, inquiry-based learning, inquiry tasks, digital instructional means, teaching practices

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11447940/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Despite growing research on artificial intelligence (AI) in education, its use to prepare and implement inquiry tasks in primary schools remains underexplored. This study aims to characterize educators' use of AI to prepare and implement inquiry tasks in primary education, identify its pedagogical purposes and ways of use, and examine its association with the frequency of digital instructional means use and the breadth of reported positive experiences. A cross-sectional online survey involved 9,314 primary school educators in Ukraine. AI-use status could be determined unambiguously for 8,560 respondents. Inductive qualitative content analysis covered 2,674 open-ended responses providing additional information about AI use. Differences in the frequency and breadth of digital instructional means use between respondents reporting AI use and those reporting non-use were examined using Mann–Whitney U tests. Among respondents with a determinate status, 63.9% reported using AI to prepare or implement inquiry tasks. Developing and selecting instructional materials was the most frequently mentioned purpose in the responses analyzed (68.2%), with examples spanning all five phases of the inquiry cycle. Direct pupil interaction with AI was mentioned in 88 responses (3.3%). Respondents who reported using AI also reported more frequent use of digital instructional means and positive experiences of such use for a wider range of pedagogical purposes, although effect sizes were small (r_{rb} = 0.128 and 0.156, respectively). The findings extend empirical evidence on AI use in primary education and identify priorities for supporting teachers in designing inquiry tasks and guiding pupils' interaction with AI.

1 Introduction

Inquiry-based learning (IBL) actively engages pupils in exploring phenomena and processes by asking questions, generating hypotheses, conducting investigations, interpreting data and justifying conclusions. In primary education, this approach enables pupils to develop inquiry skills progressively, in ways appropriate to their age. In their synthesis of inquiry-based learning models, Pedaste et al. [1] identified five interrelated phases of the inquiry cycle: orientation, conceptualization, investigation, conclusion and discussion. An individual inquiry task may involve one or more of the corresponding activities without necessarily encompassing the full inquiry cycle.

Preparing inquiry tasks is an important part of implementing inquiry-based learning. Teachers determine the learning objectives, select problem situations, formulate questions and instructions, and plan how pupils will conduct investigations and present their findings. During task implementation, teachers guide pupils' activities, provide support and facilitate discussion of the conclusions. Teachers' professional judgement remains important when artificial intelligence (AI) is used. Lee's systematic review [2] showed that, in AI-based instruction, information from intelligent systems acquires pedagogical value through teachers' interpretation and translation of that information into instructional actions. AI use in inquiry-based learning may therefore involve both task preparation and the organization of pupils' work on the tasks.

Advances in AI have broadened the scope for technological support for teaching. Martin et al.'s systematic review [3], covering studies published between 2017 and 2022, showed that various AI technologies were used in school education before generative tools became widespread. The emergence of widely accessible generative systems has created further opportunities to develop instructional materials, support learning interactions and conduct assessment. An and James [4] identified six main areas of use: idea generation, lesson planning, developing and revising instructional materials, assessment, communication, and organizing learning activities. However, the rapid development of these technologies makes it necessary to interpret findings in relation to when the studies were conducted. Marsalek and Teplá [5] illustrate this point by comparing surveys of Czech teachers conducted in 2023 and 2025. Over that period, the proportion of respondents who had attended at least one AI training session increased from 13% to 69%. In 2025, 78.9% also reported using AI to prepare for teaching.

Studies involving educators across school levels have examined professional uses of generative AI. Cheah et al. [6] investigated the practices of 89 teachers, including 27 primary school teachers, and found that generative AI was used more often for lesson preparation, assessment and administrative tasks than in direct instructional interactions with pupils. Drawing on a survey of 131 educators, Nadelson et al. [7] described professional uses of AI and related concerns without reporting primary education findings separately. Keppler et al. [8] examined 24 teachers' interactions with ChatGPT, including those of four primary school teachers, and identified ways of using the tool that ranged from obtaining ready-made materials to collaboratively refining pedagogical ideas.

How teachers interact with AI tools is an important aspect of their pedagogical use. Song et al. [9] examined the practices of 22 educators, including eight primary school teachers, to describe generative AI integration processes and the factors influencing them. In a study involving 17 teachers working with Grades 8–12, ElSayary et al. [10] showed the importance of refining prompts to generative models and revising their outputs during lesson planning.

Another strand of research addresses the conditions and constraints surrounding AI use in teaching and learning. Blundell et al. [11] studied 44 Australian teachers, including ten working in primary education and one working across primary and secondary education. Their findings highlighted the importance of pupils' age and readiness, alongside potential risks, in teachers' decisions about involving children in generative AI use. Filiz et al. [12], whose sample of 66 participants included 33 primary school teachers, examined psychological and pedagogical factors influencing AI integration, alongside technical, operational and ethical challenges. Aguilar-Cruz and Salas-Pilco [13] surveyed 190 educators, including 52 primary school teachers, about access to AI technologies, opportunities for professional development and ethical aspects of AI use. Petraki et al. [14] analyzed Australian teachers' readiness for and adoption of generative AI in their practice. Synthesizing 20 studies of teacher professional development, Shenoy and Saarela [15] argued for combining technical skills in generative AI use with pedagogical approaches to integration, critical evaluation of outputs and attention to ethical issues. It is worth noting that the review did not report the representation of primary school teachers separately.

Relationships between educators' digital preparedness and AI use have mainly been examined through measures of digital competence, attitudes towards the technology and its acceptance. Using data from 445 educators, including 120 primary school teachers, Galindo-Domínguez et al. [16] found a positive association between digital competence and attitudes towards AI. López-Costa et al. [17] examined 372 secondary school teachers and identified the importance of AI knowledge and data literacy for AI adoption. In a survey of 221 teachers, Zhao and Yang [18] found that intentions to use generative AI were positively associated with evaluations of tool performance and external support factors, and negatively associated with perceived risks. These studies identify different factors in teachers' acceptance of AI. To understand its place in teaching practice, however, it is also important to establish whether AI use for specific instructional purposes is associated with teachers' overall frequency and breadth of digital instructional means use.

Growing research interest in AI use in primary education is reflected in the bibliometric study by Abroto et al. [19], which covered 547 research articles indexed in Scopus between 2018 and 2025. The authors identified a gradual shift from general issues concerning digital technologies towards practical AI applications, including personalized learning and assessment. Lin and Tan [20] synthesized 84 empirical studies of generative AI in the education of children aged 3–18, mapping its goals, learning activities and roles. However, they did not disaggregate the findings by age group, making it impossible to determine the representation of primary education in the reviewed literature. Only four of the 30 studies in Alfarwan's review [21] concerned primary education; most addressed upper secondary education or pre-service teacher education. Among 45 empirical studies, Zhang et al. [22] identified 13 (28.9%) focusing on primary education and a further five (11.1%) covering both primary and secondary education. Overall, the literature indicates that AI use specifically to prepare and implement inquiry tasks in primary education remains underexplored. In particular, these studies do not establish how widespread this practice is among educators or provide a detailed account of why and how educators use AI for these tasks.

Focusing specifically on inquiry-based learning, Moundridou et al. [23] classified generative tools according to their potential functions and mapped them onto the phases of the inquiry cycle. These functions included generating instructional content, designing tasks, supporting learning activities and assessment. This classification describes potential uses of generative AI rather than the prevalence of corresponding teaching practices. In a systematic review of 24 empirical studies, Jiang et al. [24] examined ChatGPT use across stages of inquiry-based learning in STEAM education, including question formulation, investigation planning, problem-solving and reflection. None of the reviewed studies focused on primary school pupils. Moreover, the review primarily addressed learners' use of ChatGPT rather than educators' professional practices in preparing inquiry tasks. Khoueiry and Nabhan [25] directly examined AI use in a primary school pupil's inquiry-based learning through a case study of a ten-year-old child with dyslexia. They investigated ChatGPT-supported inquiry activities for learning English and recorded positive changes in selected learning indicators. However, a single case study cannot establish causal relationships or characterize the prevalence of these practices among primary school teachers.

Studies of lesson design have provided more specific accounts of the opportunities and limitations of generative AI for instructional design in primary education. Powell and Courchesne [26] analyzed the process of using ChatGPT to create a first-grade science lesson plan based on the 5E model. They showed that the tool could quickly generate and refine a lesson plan, although its outputs could include insufficiently specified components, questionable pedagogical choices and fabricated references. Kim [27] examined how participants in a university science methods course used generative AI to design lessons supporting environmental science agency: pupils' capacity to understand environmental issues and act on them. Participants used AI to deepen their own understanding of the subject matter, develop lesson components and integrate the relevant pedagogical goals, while checking and refining the generated suggestions.

Other studies in primary education have examined generative AI use for specific professional tasks. Rutherford et al. [28] investigated teachers' use of ChatGPT to develop mathematics lessons that support pupil motivation. Tan et al. [29] analyzed three primary school teachers' interactions with a large language model-based chatbot as they learned about the knowledge building approach and co-designed lessons. Their findings revealed differences in teacher–AI interaction, ranging from information seeking and clarification to collaborative refinement of pedagogical ideas. Giaouri and Charisi [30] examined ChatGPT use in developing individualized education programs in inclusive primary classrooms. Choi et al. [31] identified differences in teacher–AI interaction during student-centered lesson design according to teaching experience and AI proficiency.

Studies of specific instructional practices provide further insight into generative AI use in primary education. In a survey of 107 US teachers working in kindergarten through Grade 3 (K–3), Hall et al. [32] found that AI was used predominantly for professional tasks, including preparing instructional materials, visualizing content and differentiating instruction. Teachers also expressed concerns about younger pupils' direct use of AI. In a study involving three teacher teams in Malta, Calleja and Camilleri [33] examined changes in primary school teachers' perceptions of generative AI through lesson study.

These studies mainly describe teachers' use of generative AI to prepare and organize instruction. It is nevertheless important to distinguish teacher use from primary school pupils' direct interaction with AI tools. In UNESCO's guidance, Miao and Holmes [34] emphasize teacher oversight, critical verification of generated content and attention to the risks of AI use in education. Developing pupils' competencies for responsible interaction with these technologies is a related priority. UNESCO's framework [35] encompasses a human-centered mindset, ethics of AI, AI techniques and applications, and AI system design. The AI literacy framework developed by the OECD and the European Commission [36] emphasizes understanding how intelligent systems work, critically evaluating their outputs and using the technology responsibly. UNICEF's guidance [37] highlights the need to protect children's rights, safety and well-being in their interactions with AI. These documents provide guidance for responsible AI use in education but do not describe actual teaching practices. For the present study, this supports the need to identify how and for what pedagogical purposes primary school teachers use AI to prepare and implement inquiry tasks.

AI use to prepare and implement inquiry tasks should also be considered in the context of educators' broader digital practices. Research in primary education shows that digital tools serve different pedagogical purposes and support different types of learning activity. Alptekin and Taneri [38] found that primary school teachers in Turkey used digital tools more often to present instructional content than to support collaboration, work with data or assessment. Other studies have examined how digital tools support primary school pupils' active participation in learning: completing science tasks with interactive simulations (Diab et al. [39]), conducting experiments and developing scientific reasoning with interactive diagrams (van Eijck et al. [40]), solving mathematics problems collaboratively (Oikarinen et al. [41]), and creating digital stories (Ergül and Demirci Güler [42]). In a synthesis of 22 empirical studies in primary science education, Yun and Crippen [43] found that educational technologies were most often used to support observation and data interpretation during inquiry-based learning. Together, these studies show that frequency of digital tool use does not fully capture the diversity of learning activities supported. However, neither these studies nor those on digital competence and AI acceptance [16, 17] establish whether AI use to prepare and implement inquiry tasks is associated with these characteristics of educators' digital practices.

Previous research thus describes AI's potential for instructional design, teachers' uses of AI and the conditions for its integration into educational practice. However, educators' use of AI specifically to prepare and implement inquiry tasks in primary education remains underexplored. In particular, empirical evidence is lacking on the prevalence of this practice, the pedagogical purposes and uses reported by educators, and its association with the frequency and breadth of digital instructional means use.

This study aims to characterize educators' use of AI to prepare and implement inquiry tasks in primary education, identify the pedagogical purposes and ways of using AI, and examine its association with the frequency of digital instructional means use and the breadth of reported positive experiences of such use.

1.1 Research questions

RQ1. How prevalent is AI use to prepare and implement inquiry tasks in primary education?

RQ2. For what pedagogical purposes and in what ways do educators report using AI to prepare or implement inquiry tasks?

RQ3. How is reported AI use associated with the frequency of digital instructional means use and the number of pedagogical purposes for which educators report positive experiences of such use?

2 Methods

2.1 Research design and participants

This study draws on a cross-sectional online survey of primary school educators. Responses were collected using Google Forms between 6 April and 13 May 2026. The Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine distributed the survey link by official letter to the departments of education and science of regional state administrations and the Kyiv City State Administration, as well as to institutions providing postgraduate teacher education. These organizations, in turn, circulated the information among educators. Participation was self-selected.

The sample comprised 9,314 educators working with pupils in Grades 1–4. Most were primary school teachers: 9,073 respondents (97.4%) reported holding the relevant qualification, and 8,970 (96.3%) reported working in this role. Participants also included teaching assistants, computing teachers, after-school care educators and other staff working with primary school pupils. The term ‘primary school educators’ is therefore used throughout this article to refer collectively to the participants.

Respondents worked in 23 regions of Ukraine and the city of Kyiv, although regional representation was uneven.

2.2 Survey instrument

The questionnaire was entitled ‘Organizing Primary School Pupils’ Inquiry Activities in the New Ukrainian School’. This study used the open-ended item on AI use (Question 22), the item on frequency of digital instructional means use (Question 18) and the item on the learning activities in which these means were used (Question 19). The relevant questions and response options are provided in Section S1 of the supplementary information (Supplementary_Information.docx).

The draft questionnaire was developed through a review of research, regulatory documents, and curriculum and teaching guidance, taking account of primary school teaching practices and the study objectives. It was discussed at a meeting of the O. Ya. Savchenko Department of Primary Education at the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine. Researchers specializing in primary education reviewed the content and wording of the questions and response options. Before the main data collection, the questionnaire was piloted with practicing teachers from two general education schools. After completing it, participants provided feedback on the clarity of the questions and any need for clarification or additional content. They reported no comprehension difficulties and proposed no changes, so the questionnaire was used without revision.

The AI item concerned the preparation and implementation of inquiry tasks without restricting responses to a particular subject or curriculum area. Respondents were asked to indicate whether they used AI and, if so, to describe briefly how they used it. The responses therefore reflect self-reported practices.

2.3 Classification of AI-use status

Responses to the open-ended AI item were classified into three categories: reported AI use, reported non-use and indeterminate AI-use status. The first category comprised explicit statements of AI tool or

function use; the second comprised explicit statements of non-use. Blank, technical, irrelevant or ambiguous responses were assigned to the third category.

Prevalence was estimated among respondents whose AI use or non-use could be determined unambiguously and is reported as counts and percentages. The classification rules are provided in Section S2 of the supplementary information.

2.4 Qualitative content analysis of responses on AI use

To address RQ2, we analyzed open-ended responses on AI use. Of the 5,474 responses indicating AI use, 2,674 provided additional information about its use, including tool names, pedagogical purposes, activities or outputs, and were included in the qualitative analysis. Responses that merely confirmed use without providing additional information were excluded. A response did not need to contain information relevant to every coding dimension. Naming a tool alone was not sufficient to assign codes for pedagogical purposes, activities or product characteristics. The findings describe the information reported in this corpus and do not estimate the distribution of uses among all respondents who reported using AI.

We used inductive qualitative content analysis. An initial coding scheme was developed through pilot coding of 250 purposively selected responses representing diverse content. This established the main categories, their operational definitions, inclusion and exclusion criteria, and rules for distinguishing closely related cases. The scheme was refined iteratively as the full corpus was analyzed and recurring uses not covered by the initial categories were identified. The final codebook was applied to all responses.

The complete response was the unit of analysis, with categories assigned on the basis of meaning units within it. A response could receive multiple codes (multi-label coding). The main coding scheme captured only explicitly reported content, without inferring unstated purposes or capabilities of a named tool. For quantitative summaries, each category was recorded as a binary variable indicating its presence or absence in a response. Specific AI tools were recorded separately and only when explicitly named.

All 2,674 coded responses were also classified into four mutually exclusive categories: clear evidence of generative AI use; possible indications of generative AI use; clearly non-generative function; and insufficient information to determine the type of use. Classification was based on the tool name and/or an explicitly described action or output. Detailed rules are provided in Section S3 of the supplementary information.

To assess intercoder agreement, a second researcher independently coded a random 20% subsample (n = 535). Percentage agreement, unweighted Cohen's κ and Gwet's AC1 were calculated for each binary category in the main coding scheme. The same measures were calculated separately for the four-category variable describing evidence of generative AI use, using the same subsample. All four predefined categories were retained when calculating Gwet's AC1 for evidence of generative AI use. For

Gwet's AC1, 95% confidence intervals are reported. Operational coding rules and agreement statistics are provided in Section S3 of the supplementary information.

Final category frequencies were calculated from the first coder's codes; the second coder's independent coding was used to assess intercoder agreement. Counts and percentages were calculated using all 2,674 coded responses as the denominator. Percentages indicate the frequency with which characteristics were mentioned in this corpus, rather than their prevalence in educators' practice. Percentages in the main coding scheme could sum to more than 100% because responses could receive multiple codes. The four categories describing evidence of generative AI use were mutually exclusive and used the same denominator (n = 2,674).

2.5 Measures and analysis of digital instructional means use

This analysis included the 8,560 respondents whose AI-use status could be determined unambiguously. Two measures of digital instructional means use were examined: frequency and breadth.

Frequency was measured on a five-category ordinal scale: 'Never', 'Several times a month', 'Several times a week', 'Every day' and 'Every lesson'.

Breadth was defined as the number of pedagogical purposes for which respondents reported positive experiences of such use of digital instructional means. Seven purposes were included: motivating pupils; explaining and revisiting instructional content; discussion; interactive exercises; comparison and analysis; creating digital work; and assessment. For each purpose, 'Yes, I use them frequently' was coded as 1, while 'Yes, I use them occasionally' and 'No' were coded as 0. Summing the seven indicators yielded a score from 0 to 7. Because Question 19 concerned positive experiences, the measure reflects respondents' reports of such experiences rather than the full range of their digital instructional practices. A response of 'No' was not interpreted as unambiguous evidence of non-use. The full questions and scoring rules are provided in Sections S1 and S4 of the supplementary information.

Respondents reporting AI use and those reporting non-use were compared using two-sided Mann–Whitney U tests, given the ordinal frequency measure and the bounded, discrete breadth measure. Two-sided p-values were obtained using the asymptotic approximation with correction for ties. Distributions were summarized using the median and first and third quartiles. For frequency, percentages were also calculated for each response category. Effect sizes are reported as rank-biserial correlations (r_{rb}). The significance level was set at $\alpha = 0.05$.

3 Results and discussion

3.1 Prevalence of AI use

AI-use status could be determined unambiguously for 8,560 of the 9,314 responses (91.9%). Of these respondents, 5,474 (63.9%) reported using AI to prepare or implement inquiry tasks, whereas 3,086 (36.1%) reported not using it for these purposes. The remaining 754 responses (8.1% of all responses) did not provide sufficient information to determine AI-use status and were excluded from the prevalence estimate. Explicit reports of AI use accounted for 58.8% of the full sample.

AI use to prepare and implement inquiry tasks was therefore common among the primary school educators surveyed. This finding extends research on AI use across a broader range of teachers' professional tasks, including preparing instructional materials, lesson planning and teaching [6, 7, 20, 21]. Notably, even within this narrower area of practice, nearly two-thirds of respondents with a determinate status reported using AI.

3.2 Pedagogical purposes and ways of using AI

To address RQ2, we analyzed 2,674 open-ended responses providing additional information about AI use to prepare or implement inquiry tasks. The analysis covered pedagogical purposes, use by educators and pupils, evidence of generative AI use, types of materials created and additional characteristics reported by respondents (Table 1).

Table 1
Characteristics of reported AI use to prepare and implement inquiry tasks (*n* = 2,674)

Analytical dimension	**Category**	***n***	**%**
Purposes of AI use	Developing and selecting instructional materials	1,824	68.2
	Adaptation / differentiation / individualization / personalization of learning	417	15.6
	Information search and retrieval	313	11.7
	Instructional planning and design	275	10.3
	Support for assessment and feedback	233	8.7
	Support for information analysis	175	6.5
AI user	Use by educators	2,663	99.6
	Direct pupil use	88	3.3
Evidence of generative AI use	Clear evidence of generative AI use	1,674	62.6
	Possible indications of generative AI use	384	14.4
	Clearly non-generative function	1	< 0.1
	Insufficient information to determine the type of use	615	23.0
Material created	Textual materials	890	33.3
	Visual materials	593	22.2
	Audiovisual materials	51	1.9
	Audio materials	16	0.6
Interactivity	Interactive materials	97	3.6
Additional context / reported outcomes	Pupil motivation and interest	314	11.7
	Time savings and preparation efficiency	250	9.3
	Critical verification of AI outputs	38	1.4
	Special educational needs and inclusive contexts	15	0.6

Note. Responses could receive multiple codes within the main coding scheme, so percentages may sum to more than 100%. The categories describing evidence of generative AI use are mutually exclusive. All percentages use the 2,674 coded responses as the denominator.

Developing and selecting instructional materials, tasks and resources was the most frequently mentioned purpose (68.2%). Other purposes, including adapting materials, instructional planning, supporting assessment, and finding and analyzing information, were mentioned less often. A single response could encompass several purposes. For example, one respondent described using AI to find ideas for inquiry tasks, formulate questions and hypotheses, create materials, adapt tasks to pupils' levels and develop interactive exercises (Response 6316).

The predominance of instructional material preparation is consistent with earlier research on educators' professional practices. Cheah et al. [6] and Keppler et al. [8] also documented generative AI use for lesson planning and creating instructional resources. Our open-ended item enabled a more detailed examination of these practices in primary education.

Responses included examples of AI-assisted preparation of materials corresponding to each of Pedaste et al.'s [1] five phases of inquiry-based learning: orientation, conceptualization, investigation, conclusion and discussion. These examples show how materials prepared with AI may support specific inquiry activities among primary school pupils.

For the orientation phase, educators used AI to create problem situations and learning scenarios that encourage pupils to investigate. One respondent, for example, provided the prompt: 'Come up with a short story about a squirrel who needs to share some nuts, so that there is a need to investigate ways of making the number 8' (Response 4445). Another educator suggested preparing a 'mathematical investigation' in which pupils search for a 'missing number' by exploring the relationship between addition and subtraction (Response 2171). Teachers also used AI to create 'real-life scenarios that call for a particular mathematical topic' (Response 4854).

For the conceptualization phase, AI was used to prepare inquiry questions, possible hypotheses and tasks involving pattern identification. Respondent 1939, for instance, described preparing the task 'Why does snow melt?', selecting 'simple hypotheses and ideas for discussion with pupils', and developing possible observations and experiments for first-grade pupils. Another educator reported using AI to create problem situations and select 'possible questions to help formulate hypotheses' (Response 2593). Examples also included questions that encourage pupils to identify patterns (Response 941) and refine their hypotheses, such as 'what happens if the condition is changed' (Response 5559).

For the investigation phase, educators used AI to develop instructions, step-by-step procedures, observation sheets and materials for recording results. Examples included 'cards for group or individual investigations with a step-by-step procedure' (Response 7850), 'tables for recording pupils' observations' (Response 2256), and procedures for measuring objects in the surrounding environment (Response 1911). Some educators used AI to prepare differentiated support. Respondent 2314, for example, described creating three levels of hint cards: a guiding question, a visual diagram or model, and instructions for the first step.

For the conclusion phase, educators prepared sentence starters and supporting questions. Respondent 5981 gave the examples ‘I noticed that if the first addend …, then the sum …’ and ‘My experiment proved that …’. Other teachers reported using AI to prepare questions that help pupils draw conclusions (Response 7112) and prompts that anticipate pupils’ questions (Response 7307).

For the discussion phase, which also includes reflection, educators used AI to prepare questions for self-assessment and justification. Respondent 744 provided the examples ‘Have I checked my result?’, ‘Have I recorded my observations?’ and ‘Can I explain how I did it?’. Another teacher used the questions ‘Have I formulated a hypothesis?’ and ‘Have I tested it using three examples?’ (Response 2256). According to Respondent 4854, such checklists ‘encourage pupils to reflect not on the result, but on how they arrived at it’. A further example involved creating ‘detective texts’ containing deliberate factual errors that pupils were to identify and explain with reference to their textbook or prior knowledge (Response 6812).

These examples complement Jiang et al.’s [24] synthesis of ChatGPT use across inquiry-based learning phases. Our data specify ways in which AI may support educators in preparing inquiry tasks in primary education.

The vast majority of responses described educators’ own use of AI (99.6%). This pattern is consistent with Cheah et al.’s [6] finding that generative AI was used more frequently for lesson preparation than in direct instructional interactions.

Alongside AI use for preparing inquiry tasks, educators reported involving AI directly in primary school pupils’ learning activities. Of the 2,674 textual responses analyzed, 88 mentioned pupil use of AI. Among these respondents, 12 taught Grade 1, 18 taught Grade 2, 35 taught Grade 3 and 35 taught Grade 4. Seven educators taught more than one grade, so these groups overlap. Examples of such interaction were thus reported across all primary grades but occurred more often in responses from Grade 3 and Grade 4 teachers. This distribution describes the composition of the identified subgroup rather than the prevalence of these practices among all educators.

One way of incorporating AI into learning activities was through joint interaction under teacher guidance. Educators displayed the tool on a classroom screen, formulated spoken or written prompts and discussed its responses with pupils (Responses 1565 and 4274). Respondent 4972, for example, described using ChatGPT as an ‘expert’ to check the conjecture that the sum of two odd numbers is always even. The AI prompt requested an explanation using examples accessible to second-grade pupils. Another educator reported using AI to simulate a conversation with Taras Shevchenko, who addressed the children and answered their questions about his poems (Response 6372). Suggested scenarios also included role-play in which AI could represent a historical figure, an animal or a planet, and pupils could ask it inquiry questions (Response 7197).

Pupils’ degree of autonomy in these interactions varied. In some cases, they formulated their own prompts, searched for information and discussed the outputs. Respondent 1180 noted that children asked AI questions that interested them and expressed their own views when they disagreed with its

answers. Another teacher invited pupils to use AI on their own smartphones to find answers to inquiry questions and critically evaluate the information obtained (Response 5167). Respondent 3806 reported inquiry activities in computing lessons in which pupils compared information from AI with Google search results. In all these examples, interaction with the technology remained part of teacher-organized learning activities.

Of particular interest were reports of using AI to check hypotheses, compare results and draw conclusions. One educator stated: 'We may turn to artificial intelligence, but only to compare the result of our own investigation with the result of an investigation by artificial intelligence' (Response 928). Another One described the activities in which pupils examined ChatGPT's answers to questions, compared them and drew conclusions (Response 6996). Respondent 7416 suggested that pupils use AI to check their own hypotheses and explanations, treating it 'as a tool for discussion rather than the "final truth"'. This respondent also reported creating interactive situations in which pupils formulated AI prompts and evaluated the accuracy and completeness of the responses. These examples show that, in some teaching practices, AI responses became a subject of discussion and critical examination rather than merely a source of ready-made information. However, comparing them with pupils' hypotheses or findings does not replace verification using other sources or forms of evidence.

Other responses described the use of AI in working with information and data. An educator using Gemini described the following activities: 'We collect data, verify information, check true and false statements, complete tables and create charts' (Response 7228). Respondent 9124 reported co-creating inquiry tasks with pupils, selecting illustrations and verifying information, giving the example of an investigation into food additives. These accounts illustrate how AI use can be combined with different cognitive activities, although they do not always establish which activities pupils performed independently.

A further area involved investigating AI's own capabilities. Respondent 1923 reported that pupils used AI to compose poems, entered sequences of commands and compared 'who performs better: pupils or AI', as well as testing the tool's ability to recognize emotions. Unlike using AI to find information or complete learning tasks, these activities involve investigating the capabilities and limitations of the technology itself. This relates to the development of AI literacy, whose importance is set out in the UNESCO framework [35] and the OECD and European Commission framework [36]. UNESCO [34] and UNICEF [37] also emphasize teacher oversight, age-appropriate use and children's safety.

Overall, educators' responses describe varied ways of involving AI in primary school pupils' learning activities: formulating questions, finding and critically evaluating information, checking hypotheses, comparing results, working with data and investigating the technology itself. Across these examples, teachers play a central role in setting learning tasks, organizing interaction and discussing outcomes. However, some responses present possible scenarios rather than accounts of implemented practices. The available data do not establish how regularly AI was used in these ways, pupils' degree of autonomy or the effects on learning outcomes. They nevertheless identify primary school pupils' direct interaction with AI as a promising area for further research on teaching practices and AI literacy development.

A further aspect of the findings concerns the type of AI used. The coded responses predominantly described practices involving generative AI. Marsalek and Teplá [5] likewise found that generative tools played a prominent role in teachers' broader AI use. ChatGPT and Gemini were the tools most frequently named by our respondents.

Among materials created with AI, textual and visual materials were mentioned most frequently, whereas audiovisual and audio materials were much less common. This is consistent with Hall et al.'s [32] findings on teachers' use of AI to create instructional materials, illustrations and presentations. Educators' reports of time savings also accord with that study, while reports of support for pupil motivation relate to Rutherford et al.'s findings [28]. Current generative tools offer a wider range of possibilities, including creating and adapting multimedia content, animations, interactive visualizations, digital models and instructional simulations. Materials that enable pupils to observe changes in objects and phenomena, model processes, and generate and test hypotheses are of particular interest for inquiry in primary education. Broadening AI use to develop such materials is therefore a promising direction for improving teaching practice, supported by relevant professional learning for teachers.

Critical verification of AI outputs was also mentioned infrequently. Respondent 1146, for example, noted that a chatbot is not a wholly reliable source and may provide incorrect information. Some responses nevertheless described deliberate efforts to involve pupils in checking generated content. These included lessons in which pupils selected a topic and gathered information before they 'generated, discussed, evaluated, checked and refined the proposed material' (Response 7591). Choi et al. [31] also emphasize the importance of teachers checking and refining generated materials.

Respondents also rarely mentioned adapting tasks for pupils with special educational needs. This area nevertheless has considerable potential, as illustrated by Giaouri and Charisi's [30] study of ChatGPT use for individualized educational planning in inclusive primary education.

Overall, the findings point to opportunities to broaden educators' uses of AI and further develop the corresponding aspect of their professional competence.

3.3 Frequency and breadth of digital instructional means use

To address RQ3, we compared digital instructional means use among the 8,560 respondents whose AI-use status could be determined unambiguously. Of these, 5,474 reported using AI to prepare or implement inquiry tasks and 3,086 reported non-use. The comparison covered two measures: frequency of digital instructional means use and breadth, defined as the number of pedagogical purposes for which educators reported positive experiences (Table 2).

Table 2
Frequency and breadth of digital instructional means use by reported AI-use status

Measure	Reported non-use (*n* = 3,086)	Reported AI use (*n* = 5,474)	Mann–Whitney U	*p*	r_{rb}
Frequency of digital instructional means use	Median: Every day; *Q1*: Several times a week; *Q3*: Every lesson	Median: Every day; *Q1*: Several times a week; *Q3*: Every lesson	7.37×10^6	< 0.001	0.128
Breadth of digital instructional means use	4 (*Q1–Q3* = 2–6)	5 (*Q1–Q3* = 3–7)	7.13×10^6	< 0.001	0.156

Note. *Q1* and *Q3* denote the first and third quartiles; r_{rb} denotes the rank-biserial correlation. Breadth is reported as the median (*Q1–Q3*) and represents the number of pedagogical purposes for which positive experiences of frequent use were reported by selecting 'Yes, I use them frequently' in Question 19 (range: 0–7).

The median frequency category was 'Every day' in both groups, and the first and third quartiles were also identical. The response distributions nevertheless differed significantly ($p < 0.001$). Specifically, 35.0% of respondents reporting AI use used digital instructional means in every lesson, compared with 26.3% of those reporting non-use. The effect size was small ($r_{rb} = 0.128$). Full response distributions are provided in Supplementary Table S5.

Differences were also found in the breadth of reported positive experiences of frequent use. Among respondents reporting AI use, the median number of pedagogical purposes for which such experiences were reported was five of seven, compared with four among those reporting non-use. This difference was also statistically significant ($p < 0.001$), although the effect size remained small ($r_{rb} = 0.156$).

Educators who reported using AI to prepare or implement inquiry tasks thus reported somewhat more frequent use of digital instructional means and positive experiences of such use for more pedagogical purposes. However, the differences were small, which was somewhat unexpected. A stronger association might have been anticipated because frequency and breadth of digital instructional means use reflect educators' engagement in digital practices. The findings suggest that even regular and varied use of digital instructional means does not necessarily coincide with AI use to prepare and implement inquiry tasks. Such AI use may therefore be associated with other characteristics of educators' professional practice, which warrant further investigation.

4 Conclusions

The findings indicate that AI use to prepare and implement inquiry tasks was common among the primary school educators surveyed in Ukraine. The study's contribution lies in specifying professional practices of AI use in the context of primary school pupils' inquiry-based learning, an area underrepresented in previous empirical research. Combining quantitative analysis of a large set of

responses with qualitative content analysis made it possible to describe not only the prevalence of reported AI use but also its pedagogical purposes, reported uses and association with teachers' broader digital practices.

In the substantive responses analyzed, educators' use of AI to develop and select instructional materials predominated. Respondents' examples nevertheless showed that such materials may support different phases of the inquiry cycle, from identifying a problem and formulating hypothesis to organizing an investigation, justifying conclusions and reflecting on the process. This clarifies AI's potential as a tool for instructional design whose use extends beyond generating content. Realizing this potential, however, depends on teachers' professional judgement.

The identification of examples of primary school pupils' direct interaction with AI was another important finding, although these practices were mentioned relatively rarely. They involved not only consulting AI as a source of information but also critically evaluating its responses, comparing results and investigating the technology itself. This opens possibilities for combining inquiry-based learning with AI literacy development, an issue of particular relevance to international discussions of digital education. Involving primary school pupils in these activities nevertheless requires attention to their age, teacher guidance, and safe and responsible interaction with the technology.

Differences in the frequency of digital instructional means use and the breadth of reported positive experiences of such use between educators reporting AI use for inquiry tasks and those reporting non-use were statistically significant but small. This finding suggests that frequent use of digital instructional means and positive experiences across a range of pedagogical purposes does not necessarily coincide with AI use for these pedagogical purposes. Understanding the digitalization of education therefore requires examining not only the intensity of technology use but also the specific pedagogical tasks, ways of using technology and conditions of use.

The findings may inform teacher professional development programs, teaching guidance and priorities for AI integration in primary education. Promising directions include developing teachers' skills in designing inquiry tasks with AI, creating multimedia and interactive instructional materials, providing differentiated pupil support and critically evaluating generated content. Particular attention should be given to developing pedagogically grounded ways of involving primary school pupils in AI interaction. More broadly, the study extends international empirical evidence on AI use in primary education and highlights the need to assess its integration primarily in terms of instructional purpose rather than technology adoption alone.

Interpretation of the findings is limited by self-selected survey participation, uneven regional representation and reliance on self-reported data. In addition, the qualitative analysis included only responses providing additional information about AI use, and some accounts described possible scenarios rather than confirmed practices. The study did not involve direct observation of learning activities, assessment of the quality of generated materials or evaluation of the effects of AI use on pupils' learning outcomes. Future research should examine actual AI use in primary classrooms, its

pedagogical quality and its effectiveness in developing pupils' inquiry skills. Further priorities include examining educators' professional preparedness to use AI and comparing practices across educational contexts.

Declarations

Author contributions

Oksana Onopriienko: Conceptualization; Supervision; Validation, including independent coding of a subsample of responses as the second coder; Project administration; Writing – review & editing.

Inna Lipchevska: Conceptualization; Methodology; Investigation; Formal analysis; Data curation; Writing – original draft; Writing – review & editing.

Funding

The study was conducted as preparatory work for the planned research project 'Didactic and Methodological Foundations for Developing Primary School Pupils' Inquiry Competence' at the O. Ya. Savchenko Department of Primary Education, Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine. No specific grants or other targeted funding were received for this study.

Data availability

The data underlying this study are not currently publicly available. The authors plan to deposit the dataset in an open repository after preparing it for public release. Until then, the data are available from the corresponding author upon reasonable request.

Ethics approval

In accordance with the institutional research ethics requirements of the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine, this anonymous, voluntary, minimal-risk educational survey did not require prior separate ethics committee approval. This determination was confirmed by the Institute's Ethics Committee (Decision No. 10/1, dated 29 October 2026). The study was conducted in accordance with the Ethical Guidelines for Educational Research (BERA, 2024) and the European Code of Conduct for Research Integrity (ALLEA, 2023).

Consent to participate

All participants were aged 18 years or older. They were informed of the study's purpose, its anonymous nature and the voluntary nature of participation. Informed consent to participate was implied by voluntary completion and submission of the online questionnaire.

Consent to publish

Not applicable. The manuscript presents aggregated survey results and anonymized excerpts from open-ended responses. No information identifying individual participants is included.

Competing interests

The authors declare no competing interests.

Declaration of generative AI use

During manuscript preparation, the authors used OpenAI ChatGPT (GPT-5.6) for language and style editing, translation support, and identification of potentially relevant research sources for the literature review. All outputs were checked by the authors; Inna Lipchevska verified the accuracy of the English version. The authors confirm the originality and accuracy of the final text and take full responsibility for the article and its references.

Authors' information

Oksana Onopriienko holds a Doctor of Sciences degree in Education and is a Corresponding Member of the National Academy of Educational Sciences of Ukraine. She is Acting Deputy Director of the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine and Chief Researcher in its O. Ya. Savchenko Department of Primary Education. Her research interests include the theory and practice of primary education, assessment and monitoring of primary school pupils' attainment, mathematics education, and the organization of pupils' project and inquiry activities.

Inna Lipchevska holds a PhD in Education and is a Senior Researcher in the O. Ya. Savchenko Department of Primary Education at the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine. Her research interests include digital education and media literacy, visualization in education, primary school didactics and primary teacher education.

References

1. Pedaste M, Mäeots M, Siiman LA, de Jong T, van Riesen SAN, Kamp ET, Manoli CC, Zacharia ZC, Tsourlidaki E. Phases of inquiry-based learning: Definitions and the inquiry cycle. Educ Res Rev. 2015;14:47–61. https://doi.org/10.1016/j.edurev.2015.02.003.
2. Lee H. Teacher intervention in K-12 AI-based instruction: A systematic review of processes, strategies, and effects. Smart Learn Environ. 2026;13:35. https://doi.org/10.1186/s40561-026-00461-1.
3. Martin F, Zhuang M, Schaefer D. Systematic review of research on artificial intelligence in K-12 education (2017–2022). Comput Educ Artif Intell. 2024;6:100195. https://doi.org/10.1016/j.caeai.2023.100195.
4. An Y, James S. Generative AI integration in K-12 settings: Teachers' perceptions and levels of integration. TechTrends. 2025;69:1304–17. https://doi.org/10.1007/s11528-025-01114-9.

5. Marsalek R, Teplá M. Is AI inevitable? Development of attitudes and practices of Czech teachers between 2023 and 2025. Educ Sci. 2026;16(2):335. https://doi.org/10.3390/educsci16020335.
6. Cheah YH, Lu J, Kim J. Integrating generative artificial intelligence in K-12 education: Examining teachers' preparedness, practices, and barriers. Comput Educ Artif Intell. 2025;8:100363. https://doi.org/10.1016/j.caeai.2025.100363.
7. Nadelson LS, Walthall B, Faidley EW, Filer J. Generative artificial intelligence in teaching and learning: Concerns, practices, and supporting students use. J Educ Res. 2025;118(6):535–46. https://doi.org/10.1080/00220671.2025.2511229.
8. Keppler S, Sinchaisri WP, Snyder C. Making ChatGPT work for me. Proc ACM Hum Comput Interact. 2025;9(2):CSCW128. https://doi.org/10.1145/3711026.
9. Song Z, Qin J, Jin F, Cheung WM, Lin CH. A case study of teachers' generative artificial intelligence integration processes and factors influencing them. Teach Teach Educ. 2025;165:105157. https://doi.org/10.1016/j.tate.2025.105157.
10. ElSayary A, Kuhail MA, Hojeij Z. Examining the role of prompt engineering in utilizing generative AI tools for lesson planning: Insights from teachers' experiences and perceptions. Hum Behav Emerg Technol. 2025;2025:9986139. https://doi.org/10.1155/hbe2/9986139.
11. Blundell CN, Mukherjee M, Nykvist S. Adopting generative AI in K-12 teaching and learning: Australian teachers' actions through the lens of innovation theory. Educ Inf Technol. 2025;30:24009–28. https://doi.org/10.1007/s10639-025-13699-y.
12. Filiz O, Kaya MH, Adiguzel T, Teachers. Understanding the factors influencing AI integration in K-12 education. Educ Inf Technol. 2025;30:17931–67. https://doi.org/10.1007/s10639-025-13463-2.
13. Aguilar-Cruz PJ, Salas-Pilco SZ. Teachers' perceptions of artificial intelligence in Colombia: AI technological access, AI teacher professional development and AI ethical awareness. Technol Pedagog Educ. 2025;34(2):219–38. https://doi.org/10.1080/1475939X.2025.2451865.
14. Petraki E, Chapman BL, Ross AS. Readiness and adoption of generative AI in K-12 education: Perspectives from Australian teachers. Educ Inf Technol. 2026;31:7305–28. https://doi.org/10.1007/s10639-026-14061-6.
15. Shenoy P, Saarela M. A critical review and actionable framework for integrating generative AI into teacher professional development. Discov Educ. 2026;5:570. https://doi.org/10.1007/s44217-026-01579-7.
16. Galindo-Domínguez H, Delgado N, Campo L, Losada D. Relationship between teachers' digital competence and attitudes towards artificial intelligence in education. Int J Educ Res. 2024;126:102381. https://doi.org/10.1016/j.ijer.2024.102381.
17. López-Costa M, Donate-Beby B, Cabrera-Lanzo N, Maina MF. Understanding AI adoption among secondary education teachers: A PLS-SEM approach. Comput Educ Artif Intell. 2025;8:100416. https://doi.org/10.1016/j.caeai.2025.100416.
18. Zhao J, Yang X. Understanding K-12 teachers' adoption of generative AI through an integrated technology acceptance and perceived risk framework. Discov Educ. 2026;5:592.

https://doi.org/10.1007/s44217-026-01611-w.

19. Abroto A, Maemonah M, Machali I. Mapping artificial intelligence research in primary education: a bibliometric study. Discov Educ. 2026;5:824. https://doi.org/10.1007/s44217-026-02012-9.
20. Lin X, Tan H. A systematic review of generative AI in K–12: Mapping goals, activities, roles, and outcomes via the 3P model. Systems. 2025;13(10):840. https://doi.org/10.3390/systems13100840.
21. Alfarwan A, Generative. AI use in K-12 education: A systematic review. Front Educ. 2025;10:1647573. https://doi.org/10.3389/feduc.2025.1647573.
22. Zhang T, Lai YC, Yu PLH. Generative artificial intelligence in K-12 education: A systematic review. Res Pract Technol Enhanc Learn. 2026;21:034. https://doi.org/10.58459/rptel.2026.21034.
23. Moundridou M, Matzakos N, Doukakis S. Generative AI tools as educators' assistants: Designing and implementing inquiry-based lesson plans. Comput Educ Artif Intell. 2024;7:100277. https://doi.org/10.1016/j.caeai.2024.100277.
24. Jiang H, Li Y, Chugh R, Xin Y, Cheng H. The AI-powered co-inquirer: A systematic review of ChatGPT for inquiry-based learning in STEAM education. Int J STEM Educ. 2026;13:42. https://doi.org/10.1186/s40594-026-00628-9.
25. Khoueiry J, Nabhan R. AI enhanced inquiry based learning for English language development in a dyslexic learner a mixed methods case study from Lebanon. Discov Educ. 2026;5:1027. https://doi.org/10.1007/s44217-026-01911-1.
26. Powell W, Courchesne S. Opportunities and risks involved in using ChatGPT to create first grade science lesson plans. PLoS ONE. 2024;19(6):e0305337. https://doi.org/10.1371/journal.pone.0305337.
27. Kim WJ. Teachers' use of generative artificial intelligence for designing science lessons in support of environmental science agency. Res Sci Educ. 2026;56:203–22. https://doi.org/10.1007/s11165-025-10262-0.
28. Rutherford T, Rodrigues A, Duque-Baird S, Veng S, Mykyta-Chomsky R, Cao Y, Chisholm K, Bergwall E. I just think it is the way of the future: Teachers' use of ChatGPT to develop motivationally-supportive math lessons. Comput Educ Artif Intell. 2025;8:100367. https://doi.org/10.1016/j.caeai.2025.100367.
29. Tan SC, Tan YY, Yuan G, Teo CL, Dai L. A pragmatic study of teacher dialogues with a large language model-based AI chatbot. Linguist Educ. 2026;93:101541. https://doi.org/10.1016/j.linged.2026.101541.
30. Giaouri S, Charisi M. Enhancing IEP design in inclusive primary settings through ChatGPT: A mixed-methods study with special educators. Educ Sci. 2025;15(8):1065. https://doi.org/10.3390/educsci15081065.
31. Choi S, Jeong S, Park S, Kim Y, Han I. Analyzing teacher–AI interaction patterns across teacher experience and AI proficiency in student-centered lesson design. Teach Teach Educ. 2026;169:105266. https://doi.org/10.1016/j.tate.2025.105266.

32. Hall AH, Gao Q, White K. Exploring K-3 teachers' uses, perceived benefits, and challenges of generative AI in early writing instruction. Early Child Educ J. 2026;54:4863–73. https://doi.org/10.1007/s10643-026-02183-y.
33. Calleja J, Camilleri P. Primary school teachers' perceptions towards the use of generative AI in teaching using lesson study. Int J Lesson Learn Stud. 2025;14(3):237–52. https://doi.org/10.1108/IJLLS-11-2024-0268.
34. Miao F, Holmes W. Guidance for generative AI in education and research. Paris: UNESCO; 2023. https://doi.org/10.54675/EWZM9535.
35. Miao F, Shiohira K, Lao N. AI competency framework for students. Paris: UNESCO; 2024. https://doi.org/10.54675/JKJB9835.
36. OECD, European Commission. Empowering learners for the age of AI: An AI literacy framework for primary and secondary education. Paris: OECD Publishing; 2026. https://doi.org/10.1787/65cd27d4-en.
37. UNICEF Innocenti – Global Office of Research and Foresight. UNICEF guidance on AI and children 3.0. Florence. UNICEF Innocenti; 2025. https://www.unicef.org/innocenti/media/11991/file/UNICEF-Innocenti-Guidance-on-AI-and-Children-3-2025.pdf.
38. Alptekin Z, Taneri A. Technology integration in pedagogical processes: Digital competence and teaching practices of primary school teachers in Turkey. Discov Educ. 2025;4:351. https://doi.org/10.1007/s44217-025-00646-9.
39. Diab H, Daher W, Rayan B, Issa N, Rayan A. Transforming science education in elementary schools: The power of PhET simulations in enhancing student learning. Multimodal Technol Interact. 2024;8(11):105. https://doi.org/10.3390/mti8110105.
40. van Eijck T, Bredeweg B, Holt J, Pijls M, Bouwer A, Hotze A, Louman E, Ouchchahd A, Sprinkhuizen M. Combining hands-on and minds-on learning with interactive diagrams in primary science education. Int J Sci Educ. 2025;47(18):2413–33. https://doi.org/10.1080/09500693.2024.2387225.
41. Oikarinen RM, Oikarinen JK, Havu-Nuutinen S, Pöntinen S. Students' collaboration in technology-enhanced reciprocal peer tutoring as an approach towards learning mathematics. Educ Inf Technol. 2022;27:7519–48. https://doi.org/10.1007/s10639-021-10799-3.
42. Ergül S, Demirci Güler MP. Primary school students' experiences in developing digital stories on environmental issues: An action research. Educ Inf Technol. 2026;31:4369–96. https://doi.org/10.1007/s10639-026-13966-6.
43. Yun M, Crippen KJ. The use of educational technology in inquiry-based elementary science education: A systematic review. Int J Sci Educ. 2024;46(12):1256–79. https://doi.org/10.1080/09500693.2023.2284689.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryInformation.docx