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The Impact of Interdisciplinary Instruction on the Development of Meta-subject Skills among Primary School Learners: An Experimental Study in Kazakhstan

Zhuldyzai Abdrash
Zhanibekov university
Asel Yesnazar
asel.esnazar@mail.ru

Zhanibekov university
Gulnar Chinibayeva
Zh. Tashenev University
Nurzhamal Ablyazimova
M. Auezov South Kazakhstan University
Akbota Rakhym
Zhanibekov university

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THE IMPACT OF INTERDISCIPLINARY INSTRUCTION ON THE DEVELOPMENT OF META-SUBJECT SKILLS AMONG PRIMARY SCHOOL LEARNERS: AN EXPERIMENTAL STUDY IN KAZAKHSTAN

ABSTRACT

Interdisciplinary teaching effectively develops meta-subject skills in primary school learners by enhancing cognitive, critical, analytical, communicative, and regulatory skills. This study aims to organize the primary education process based on interdisciplinary connections and to examine the formation of meta-subject skills among learners. To achieve this goal, an author-developed educational program grounded in interdisciplinary integration was designed and implemented.

The study was conducted in general education schools of the Republic of Kazakhstan and included three stages: diagnostic, formative, and control. A quasi-experimental design with pre/post-test measurements was employed, involving control and experimental groups. In the experimental class, the educational process was implemented using the specially developed interdisciplinary program, while the control class followed the traditional curriculum.

The collected data were analyzed using the Shapiro–Wilk test to assess the normality of distribution and the Mann–Whitney U test to determine differences between groups. The pre-test results showed that the control and experimental groups had comparable initial levels of meta-subject skills. After the formative stage, a significant improvement was observed in the experimental group. Statistically significant differences between the experimental and control groups confirmed the effectiveness of the interdisciplinary teaching approach.

The findings demonstrate that interdisciplinary teaching positively influences the development of meta-subject skills in primary school learners. The implemented program contributed to improving the quality of the educational process and supported the development of students' universal learning skills. The results confirm the reliability and validity of the study

and highlight the importance of widely integrating interdisciplinary teaching into primary education practice.

Keywords: Interdisciplinary teaching, meta-subject skills, primary education, transversal competencies, quasi-experimental design, Kazakhstan.

1. INTRODUCTION

The current education system is developing in the context of global change. The expansion of digitalization, the growing volume of information, new forms of social interaction, and rapid technological developments are changing the demands placed on students' learning processes. Therefore, in primary education, it is important not only to provide students with subject-specific knowledge but also to create conditions in which they can apply what they have learned in different academic and real-life situations. In this regard, the development of meta-subject competencies has become one of the important priorities of contemporary primary education. This requirement is also reflected in the State Compulsory Standard of Primary Education of the Republic of Kazakhstan (SCSE, 2025). The Standard links the expected learning outcomes of primary school students with such abilities as applying knowledge in new situations, analyzing information, regulating their own learning activities, identifying connections between subjects, and using knowledge to solve practical problems. From this perspective, meta-subject competencies represent an important educational outcome because they reflect not only students' acquisition of knowledge but also their ability to apply it across different contexts.

A distinctive feature of 21st-century skills is their interdisciplinary and activity-based nature, as well as their potential for application across different contexts. Such skills are developed primarily through practical activities undertaken in the learning process and cannot be adequately assessed through traditional testing formats alone (Efremova et al., 2020). Therefore, in primary education, integrating learning content and strengthening meaningful

connections between subjects are particularly important for developing students' analytical thinking, communication and collaboration skills, creativity, and capacity for reflection.

According to teachers, interdisciplinary connections enable primary school education to present learning content as an integrated whole and create opportunities for students to combine knowledge acquired from different subjects, compare and analyze information, and apply it in various learning situations (Cohen et al., 2024). These possibilities of interdisciplinary instruction are also reflected in the study by Yang et al. (2025). Drawing on the Source–Knowledge–Use (SKU) principle, the authors propose an instructional framework that connects knowledge from the humanities, sciences, and technology. Rather than treating knowledge as ready-made information, the study emphasizes the relationship between understanding where knowledge originates, acquiring its scientific content, and applying it in concrete situations. The authors illustrate this approach through the Humanities–Science–Technology Model using fuzzy mathematics as an example. Such an organization of learning allows students to connect information obtained from different fields and apply it to new situations.

Within the Kazakhstani research and educational context, the theoretical and methodological foundations of meta-subject and interdisciplinary instruction have also been gradually developing. Zhumabayeva et al. (2019) examined the integration of a meta-subject approach with interdisciplinary connections in primary education and demonstrated the potential of tasks combining the content of Kazakh language, mathematics, and natural sciences to develop cognitive, communicative, and regulatory learning activities. Zhumabayeva et al. (2021) incorporated the meta-subject approach into the preparation of future primary school teachers and described the outcomes of a specialized course focused on interdisciplinary connections, universal learning activities, reflection, and problem solving. This line of research was further developed from the perspective of teachers' professional

preparation by Rysbayeva et al. (2023), who examined the pedagogical conditions for teaching primary education subjects from a meta-subject perspective and analyzed the outcomes of a specialized seminar for teachers. In addition, Karashash et al. (2022) examined the outcomes of specialized training aimed at developing the meta-competence of primary school teachers. Turysbayeva and Turalbayeva (2024) also emphasized the importance of formative assessment, feedback, reflection, and universal learning activities in developing meta-subject outcomes among primary school students.

Taken together, these studies indicate that important foundations have been established in Kazakhstan for understanding the theoretical basis of the meta-subject approach, preparing teachers, and developing methodological conditions for achieving meta-subject outcomes. However, most of these studies have focused on the theoretical and methodological justification of the meta-subject approach, teacher preparation, or the conditions for organizing the learning process. The direct experimental comparison of the effects of interdisciplinary instruction on different components of primary school students' meta-subject skills remains insufficiently explored and requires further empirical investigation. In the context of the ongoing renewal of primary education content, there is therefore a need to examine systematically the mechanisms through which interdisciplinary connections may contribute to the development of meta-subject skills.

The aim of this study is to determine the extent to which interdisciplinary instruction contributes to the development of meta-subject skills among primary school students in Kazakhstan. Accordingly, the study seeks to answer the following research question: What effect does interdisciplinary instruction have on the development of meta-subject skills among primary school students?

The findings of the study are expected to identify effective ways of implementing interdisciplinary approaches, contribute to the improvement of primary school learning

content, and provide a basis for developing research-informed and practical recommendations for the purposeful development of meta-subject skills.

2. LITERATURE REVIEW

2.1. Interdisciplinary Instruction in Primary Education

Interdisciplinary instruction is regarded as an important approach to organizing the educational process, as it is based on establishing connections between different areas of knowledge. Rather than presenting school subjects as isolated domains of knowledge, this approach enables learners to identify relationships between concepts, apply knowledge beyond individual subject boundaries, and understand educational content as an interconnected whole. In the context of education in Kazakhstan, interdisciplinary instruction is aimed at developing learners' communicative, cognitive, and practical abilities through the integration of different subjects. The methodological guidelines developed by the Y. Altynsarin National Academy of Education also identify communication, interactive technologies, collaboration between learners and teachers, and the practical application of knowledge as important components of interdisciplinary instruction (Methodological Guidelines on the Use of Modern Methods and Technologies of Teaching within Interdisciplinary Instruction, 2023).

Research conducted in Kazakhstan indicates that interdisciplinary instruction can contribute to several aspects of primary school learners' development. Zhumabayeva and Amirkhanova (2021), examining interdisciplinary connections within the context of the updated educational content, emphasize that interdisciplinary instruction should not be limited to teaching subjects sequentially. Instead, the authors view interdisciplinary integration as a purposeful way of connecting subjects in accordance with learners' age characteristics and educational environment, as well as a means of renewing educational content. A similar position is presented by Saurykova et al. (2023), who identify the interaction between subjects, coordination of lesson content, methodological approaches, and teachers' creative activity as

important pedagogical conditions for interdisciplinary instruction. Their findings indicate that these conditions contribute to learners' cognitive, personal, and activity-based development.

Other studies conducted in Kazakhstan focus more specifically on the outcomes associated with interdisciplinary approaches. Kalelova et al. (2024) demonstrate that the use of interdisciplinary methods in history education can contribute to the development of critical thinking, analytical abilities, and communication skills. Research in teacher education also indicates that combining interdisciplinary integration with contextual learning, professional modelling, and digital technologies can support the development of analytical thinking and research skills (Sholpankulova et al., 2020). Bulshekbaeva et al. (2024) extend this perspective to social-emotional learning by examining changes in future teachers' self-awareness, social awareness, communication, and responsible decision-making skills. Similarly, Bostanov et al. (2025) found that interdisciplinary tasks used in STEM-oriented teacher education can contribute to the development of practical skills, research abilities, and complex problem-solving skills. Although these studies differ in terms of educational level and research context, they share a common finding: interdisciplinary instruction extends beyond the acquisition of subject-specific content by connecting knowledge with application, interaction, analysis, and problem solving.

Research in Kazakhstan has examined interdisciplinary instruction from several perspectives, including curriculum integration, cognitive development, communication, digital learning, social-emotional learning, and STEM education. However, these studies do not all address the same educational level or outcomes. Some focus on primary school learners, whereas others examine university students or future teachers. Therefore, although the developmental potential of interdisciplinary instruction is increasingly recognized, further empirical research is needed to determine its effects on specific learning outcomes among primary school learners.

2.2. Meta-subject Skills in Primary Education

Meta-subject skills can be understood as abilities that extend beyond individual school subjects and enable learners to organize, regulate, analyze, communicate, and apply knowledge across different learning situations. Their theoretical foundations are associated with developmental education, activity theory, and approaches aimed at developing metacognitive and universal learning activities. From this perspective, the development of meta-subject skills involves not only the acquisition of a certain amount of knowledge but also the formation of ways of acting with that knowledge.

The tradition of developmental education plays an important role in explaining the theoretical foundations of meta-subject skills. Drawing on the Elkonin–Davydov system, Rubtsov et al. (2024) consider independent formulation of learning tasks, identification of generalized methods, modelling, collective discussion, and reflection as important components of learning activity. These activities create conditions for developing universal cognitive tools, intellectual autonomy, and higher levels of understanding. Earlier empirical research by Rubtsov et al. (2019) also indicates that meta-subject skills can be developed through systematic corrective and developmental interventions and are associated with learners' cognitive activity, organization of learning activities, and ability to work with information.

Other studies examine the development of meta-subject skills from the perspective of instructional organization and pedagogical conditions. Basyuk and Melkov (2024) emphasize the importance of cognitive, social, and motivational components in the formation of meta-subject skills and highlight the need to develop research, communication, and creative activities, particularly when educational content is integrated across subjects. Korshunova et al. (2022) emphasize the importance of differentiated and modular instruction for developing cognitive, communicative, and research skills, with particular attention to learners' independent inquiry and active participation in the learning process. Khazhuev and Saidov (2024)

demonstrate that pedagogical games can support the development of communication, organizational activity, creativity, group interaction, and information-processing skills. Bezborodova and Zhuk (2022), in turn, emphasize the importance of integrating educational content and methodological tools and demonstrate the relationship between creative projects and interdisciplinary integration and learners' abilities to make independent decisions, analyze information, and engage in creative thinking.

The assessment of meta-subject skills also occupies an important place in this body of research. Gutorova (2021) considers meta-subject skills in terms of cognitive, communicative, and research components and proposes diagnostic criteria that can be used to monitor their development. Zaharova (2023) similarly emphasizes that the assessment of meta-subject abilities requires diagnostic procedures that correspond to the specific types of activity in which these abilities are manifested. Kabbassova et al. (2021) combine the CLIL (Content and Language Integrated Learning) approach, which integrates subject content with language learning, with metacognitive strategies and demonstrate the potential of integrated instruction to develop logical reasoning, information analysis, and other cognitive abilities.

Kazakhstani research has also increasingly focused on meta-subject skills from the perspective of primary education. Yesnazar et al. (2024) proposed a methodological system for STEM education that connects subject knowledge with scientific and technical skills, critical thinking, creativity, research, and project-based activities. In their subsequent study, Yesnazar et al. (2025) examined the practical and diagnostic aspects of this approach using the Draw-A-Scientist Test and specially developed integrated tasks. Zhumabayeva et al. (2021) focused on the meta-subject approach in the preparation of future primary school teachers, while Zhanazarova et al. (2024) examined the development of meta-subject abilities in the context of English-language instruction. These studies indicate that research on the development of meta-

subject skills through various forms of integration and learning activities has begun to gain attention in Kazakhstan.

2.3. Interdisciplinary Instruction as a Mechanism for Developing Meta-subject Skills

The relationship between interdisciplinary instruction and meta-subject skills is based on the assumption that universal ways of acting are developed when learners are required to apply knowledge from different subject areas within interconnected learning situations. In such situations, learners need to compare information, identify relationships between concepts, select relevant knowledge, solve problems, explain their reasoning, and apply previously acquired knowledge to new situations. Thus, interdisciplinary instruction can create learning conditions in which the cognitive, communicative, regulatory, and practical components of meta-subject skills are activated simultaneously.

The literature supports this relationship through several complementary perspectives. Abdurazakov et al. (2021) emphasize that interdisciplinary and meta-subject integration should not be reduced to the mechanical combination of subject content and identify the alignment of logical structures and methodological approaches as an important condition. Their analysis of mathematics and computer science demonstrates that combining different subject perspectives can reduce excessive formalism and create opportunities for developing learners' cognitive and information-processing abilities.

Alexandrova et al. (2021) similarly describe meta-subject skills as a universal system that extends beyond individual subject knowledge and includes cognitive, self-regulatory, and communicative activities. Their meta-subject technological model is based on coordinating interdisciplinary connections in lesson planning and creating conditions for inquiry, practical application, project-based activities, and independent learning. This perspective is also consistent with the findings of Poprygina and Voronina (2020). The authors demonstrate that

teaching meta-subject concepts through integrative tasks in primary school enables learners to identify relationships between subjects and develop a systematic understanding of knowledge.

The relationship between interdisciplinary instruction and transferable skills can also be observed in studies conducted in broader educational contexts. Makhachashvili and Semenist (2023) consider meta-subject and transdisciplinary approaches as responses to technological and social changes and emphasize their role in connecting educational content, skills, communication, and digital learning environments. In their interdisciplinary study on climate literacy assessment, Martin et al. (2025) integrate knowledge, information and communication skills, knowledge evaluation, and decision-making across natural sciences, social sciences, technology, and the humanities. Although these studies are not limited specifically to primary education, they reinforce the broader principle that moving beyond disciplinary boundaries supports learners' ability to integrate and apply knowledge in complex situations.

Taken together, these studies indicate that there is a theoretically grounded relationship between interdisciplinary instruction and meta-subject skills. Interdisciplinary learning encourages learners to move beyond reproducing isolated subject knowledge by establishing connections, integrating different types of information, expressing their ideas, regulating their own activities, and applying knowledge to practical or unfamiliar tasks.

2.4. Assessment of Meta-subject Skills and Research Gap

The assessment of meta-subject skills needs to take into account the different types of activity through which these skills are manifested. The literature reviewed above indicates that cognitive abilities, communication and collaboration, self-regulation, information processing, and the practical application of knowledge represent important dimensions of meta-subject development. Therefore, assessment should not be limited to learners' ability to reproduce subject knowledge but should also consider how they think, interact with others, organize their activities, and apply their knowledge.

Several diagnostic approaches described in the literature illustrate this multidimensional perspective. The “Identifying Essential Features” method developed by Rubinstein (1999) is designed to assess learners’ ability to distinguish essential from non-essential features and therefore provides information about their logical and cognitive operations. The “Gloves” method proposed by Zuckerman (1993) focuses on communication and collaboration and requires learners to coordinate their actions, reach agreement, justify their decisions, and take another person’s ideas into account. These approaches demonstrate that different components of meta-subject skills may require different types of diagnostic tasks.

The synthesis of the reviewed literature allows three conclusions to be drawn that are particularly relevant to the present study. First, interdisciplinary instruction is associated with knowledge integration, practical application, communication, analysis, and problem solving. Second, meta-subject skills represent a multidimensional system of abilities that extends beyond individual subject knowledge and includes cognitive, communicative, regulatory, research, and creative components. Third, although previous studies have proposed various methodological approaches to the development and assessment of these skills, they differ considerably in terms of educational contexts, learner groups, and measured outcomes.

Nevertheless, a specific empirical gap remains. Research conducted in Kazakhstan has addressed interdisciplinary instruction, curriculum integration, STEM-oriented education, and the development of meta-subject skills; however, these areas have often been examined separately or across different educational groups. The reviewed literature provides limited direct experimental evidence demonstrating the extent to which systematic interdisciplinary instruction contributes to the development of meta-subject skills among primary school learners.

The present study is intended to address this gap. By comparing learners’ outcomes before and after the intervention and analyzing the performance of the relevant groups, the

study seeks to provide empirical evidence on the extent to which interdisciplinary instruction contributes to the development of meta-subject skills in primary education.

3. RESEARCH METHODS

3.1. Framework

The framework for developing meta-subject skills among primary school learners through interdisciplinary instruction comprises the following stages:

- Problem identification
- Information search and collection
- Comparison and establishing connections
- Knowledge integration and application
- Problem-solving
- Analysis of results and drawing conclusions
- Reflection and self-assessment

First, learners identify a learning problem and gather relevant information from different subject areas. They then compare the information obtained, identify connections between subjects, and integrate their knowledge to complete practical tasks. Subsequently, learners solve the problem, analyze the results obtained, and draw conclusions. In the final stage, they reflect on their learning activities and evaluate their own performance.

This framework is designed to systematically develop learners' meta-subject skills by enhancing their cognitive, regulatory, and communicative universal learning activities through interdisciplinary instruction.

3.2. Research Design

To address the research question comprehensively, the study was organized into several interrelated stages. Before the main diagnostic phase, a pilot test was conducted using a set of 10 interdisciplinary tasks developed by the authors. The pilot study involved 48 learners. Its

purpose was to preliminarily assess the clarity of the tasks, their appropriateness for the learners' age group, their level of difficulty, and their practical applicability, as well as to identify areas requiring refinement. Based on the pilot-test findings and recommendations provided by academic supervisors and experienced primary school teachers, minor revisions were made to the wording of the tasks and their corresponding instructions.

To assess the internal consistency of the task set, Cronbach's alpha coefficient (Cronbach, 1951) was calculated. The analysis yielded a Cronbach's alpha value of 0.769 for the 10 tasks (Table 1).

Table 1. Internal Consistency of the 10 Author-Developed Interdisciplinary Tasks

Reliability Statistics	
Cronbach's alpha	Number of items
,769	10

This result indicates an acceptable level of internal consistency for the task set and provides an initial estimate of the reliability of the author-developed assessment instrument. However, internal consistency alone does not establish the validity of an instrument. Therefore, the content relevance of the tasks was also considered during their development and expert review. The research design, structured in accordance with the research question, is presented in Table 2.

Table 2. Research Design

Group	**Sample size**	**Class**	**Instructional approach**	**Diagnostic instruments**	**Statistical tests**

Control group	27	CG 1	Traditional instruction	"Identifying Essential Features" method (Rubinstein, 1999); "Gloves" method (Zuckerman, 1993); 10 Author-Developed Interdisciplinary Tasks.	Shapiro–Wilk test (1965); Mann–Whitney U test (1975)
	29	CG 2			
Experimental group	28	EG 1	Elective course "The Bridge of Knowledge: A Journey	"Identifying Essential Features" method (Rubinstein, 1999); "Gloves"	Shapiro–Wilk test (1965); Mann–Whitney

	28	EG 2	Across Disciplines”	method (Zuckerman, 1993); 10 Author-Developed Interdisciplinary Tasks	U test (1975)

The purpose of data analysis was to identify key patterns, trends, and relationships within the research context. Data were collected from primary school learners enrolled in a state general education school in the city of Shymkent, Kazakhstan.

3.3. Research Sample

The study was conducted among third-grade learners at two school-lyceums in Shymkent, Kazakhstan. The inclusion of two schools was intended to broaden the range of educational contexts represented in the study and to enable a comparative examination of the effectiveness of interdisciplinary instruction across different school settings. To protect the confidentiality of the participating educational institutions, they were designated School A and School B. Across the primary education levels of these two schools, more than 1,500 pupils are enrolled, and over 50 primary school teachers are employed.

With the consent of parents and school administrations, a total of 112 learners participated in the study. School A contributed 55 learners, comprising 29 boys and 26 girls, while School B contributed 57 learners, including 30 girls and 27 boys. At each school, one control class and one experimental class were selected for participation in the study.

Both participating schools are public educational institutions, and their teaching and learning processes are organized in accordance with the state compulsory education standards

of the Republic of Kazakhstan. These shared educational requirements provide a common curricular context for examining the findings across the two school settings. The participants were aged 8–9 years.

The selection of third-grade learners was based on the developmental characteristics of this age group, including their emerging cognitive engagement, learning motivation, and the initial development of meta-subject skills. At the primary education stage, particular importance is attached to fostering learners' abilities to monitor their own learning activities, evaluate their performance, and regulate their learning processes (Eberhart et al., 2025; Bayard et al., 2021).

The control group was instructed according to the traditional subject-based curriculum. The experimental group participated in an author-designed elective course entitled "The Bridge of Knowledge: A Journey Across Disciplines", developed in accordance with the principles of interdisciplinary instruction. The program consisted of eight interdisciplinary thematic modules aimed at the purposeful development of learners' meta-subject skills, including comparison, analysis, information integration, logical reasoning, inquiry-based activities, and the identification of connections between academic subjects.

The elective sessions were conducted once a week over a period of eight lessons. All sessions were taught by a researcher–teacher who had received specialized training in interdisciplinary instructional methodologies, ensuring methodological consistency and uniform implementation of the intervention across both schools. The lessons were organized with the approval of school administrations and were adapted so as not to interfere with learners' core instructional schedule.

3.3. Research Instruments

Three main instruments were employed to assess primary school learners' meta-subject skills and their attitudes toward participation in interdisciplinary lessons.

3.3.1. “Gloves” Method (Zuckerman, 1993)

The Gloves method is used to assess learners’ communicative and collaborative skills. The task is conducted in a game-based format. Participants are divided into pairs, and each learner is given the outline of a single glove. The children are required to decorate the gloves so that they form a matching pair, first negotiating and agreeing on a common pattern. Each pair receives glove silhouettes and an identical set of colored pencils. A total of 10 minutes is allocated for completing the task.

This task is designed to elicit learners’ abilities to engage in dialogue, negotiate shared decisions, coordinate actions, and work toward a common goal.

Assessment Criteria:

- *Low level:* The glove patterns differ significantly or show no similarity at all. Learners do not attempt to negotiate and instead insist on their own individual ideas without considering their partner’s perspective.
- *Medium level:* Partial similarity is observed; some features (such as color or certain design elements) correspond, but noticeable differences remain. Negotiation is limited or inconsistent.
- *High level:* The gloves are identical or nearly identical in design. Learners actively discuss possible pattern options, reach agreement on coloring strategies, compare and coordinate their actions, engage in genuine collaborative work, and monitor the implementation of the jointly accepted idea.

3.3.2. “Identifying Essential Features” Method (Rubinstein, 1999)

The Identifying Essential Features method is designed to assess the level of logical thinking and the directionality and stability of reasoning processes. In this task, participants are presented with a set of words related to a given concept and are required to select the two most essential attributes. The objective is to identify generalized and meaningful characteristics

rather than specific or situational features. Within the context of the present study, this method enables the assessment of learners' meta-subject skills, particularly their ability to analyze and structure information. The test is widely used in educational psychology to diagnose individual differences in cognitive development. A total of 10 minutes is allocated for completing the task.

Procedure:

For each task, a target word is provided along with five associated words. Learners are instructed to select and underline the two correct (essential) words.

Test Materials:

1. Garden (plants, gardener, dog, fence, soil)
2. River (bank, fish, fisherman, fertile soil, water)
3. City (transport, buildings, population, street, bicycle)
4. Warehouse (hayloft, horses, roof, livestock, walls)
5. Cube (angles, drawing, edge, stone, wood)
6. Division (class, dividend, pencil, divisor, paper)
7. Circle (diameter, diamond, sample, roundness, stamp)
8. Reading (eyes, book, picture, stamp, word)
9. Newspaper (truth, supplements, telegrams, paper, editor)
10. Game (cards, players, penalties, punishment, rules)

Following task completion, the results are discussed with learners to determine whether they persist in incorrect responses and how they justify their choices. Analysis of these explanations provides additional insight into the level of development of learners' logical thinking.

Scoring Criteria:

- 0–50%: Low level
- 51–70%: Medium level

- 71–100%: High level

3.3.3. Author-Developed Set of Ten Interdisciplinary Tasks

To assess learners' cognitive, self-regulatory, communicative, and personal skills, a set of ten interdisciplinary tasks was developed specifically for the elective course "The Bridge of Knowledge: A Journey Across Disciplines." Each correctly completed task was awarded 1 point. Each task was allocated 3 minutes for completion, resulting in a total administration time of 30 minutes for all 10 tasks.

Table 3. Types of Interdisciplinary Tasks

No.	Task type	Interdisciplinary connection	Meta-subject skill	Score
1	Transferring information from one representational system to another	Kazakh Language, Mathematics	Cognitive	1
2	Identifying similarities and differences; making comparisons	Science, Kazakh Language	Cognitive	1
3	Gathering information and presenting it systematically	Kazakh Language, Literary Reading	Cognitive	1
4	Identifying an effective way to solve a problem	Kazakh Language, Science	Regulatory	1
5	Planning the sequence of actions required to solve a problem	Mathematics	Regulatory	1

6	Predicting the possible outcome of a given situation	Science	Regulatory	1
7	Checking one's work against specified criteria and correcting errors	Kazakh Language, Literary Reading	Regulatory	1
8	Explaining one's ideas based on a picture	Kazakh Language, Science	Communicative	1
9	Defending one's viewpoint and providing arguments to support an opinion	Kazakh Language, Literary Reading	Communicative	1
10	Asking and answering questions about learning materials	Kazakh Language, Mathematics	Communicative	1

Scoring Criteria:

- 8–10 points: High level
- 4–7 points: Medium level
- 0–3 points: Low level

3.4. Data Analysis

Statistical analysis was conducted to identify significant differences between the experimental and control groups at a significance level of $p < 0.05$. The normality of data distribution was assessed using the Shapiro–Wilk test (Shapiro & Wilk, 1965), which is considered reliable for small and medium sample sizes. When the assumption of normal distribution was met, group differences were examined using the Mann–Whitney U test (Mann & Whitney, 1947). All statistical analyses were performed using the SPSS 24.0 software package.

3.4.1 Stages of the Study

Diagnostic Stage:

At the initial stage, the baseline level of meta-subject skills among learners in both the control and experimental groups was assessed. For this purpose, preliminary diagnostic methods and interdisciplinary tasks were administered to evaluate learners' cognitive, communicative, self-regulatory, and personal skills. At the third-grade level, learners were familiar, within the framework of the general education curriculum, with topics such as vocabulary expansion, text comprehension, completion of simple text-based tasks, and creative thinking. This prior knowledge provided a foundation for the effective organization of interdisciplinary lessons and ensured learners' readiness to participate in the elective course.

Formative Stage:

During the formative stage, the experimental group participated in the interdisciplinary elective course "The Bridge of Knowledge: A Journey Across Disciplines." The course included interdisciplinary tasks, project-based activities, and creative assignments specifically designed to foster learners' meta-subject skills. The thematic structure of the course comprised the following units: "Nature Laboratory: Observation and Listening," "Natural Environment Around Me: Prediction and Research," "Humans and Nature: A Dialogue of Responsibility," "Environmental Protection: From Idea to Action," "Light and Darkness: Understanding Natural Phenomena," "Light as a Good Deed and a Kind Word," "Understanding Darkness: Comparison and Conclusion," and "Distinguishing Good and Evil: Improving the Text." The content and thematic structure of the elective course are systematically presented in Table 4.

Table 4. Content of the Elective Course

No	Topic	Learning Outcome	Hours	Student Activity	Metasubject Skills

Section 1. Development of Metasubject Skills through Perception, Processing, and Presentation of Information					
Cross-cutting theme: Living Nature					
1	Nature Laboratory: Observation and Listening	Listens to a text about nature, identifies key information, and completes assigned tasks	1	Listening to the text	- Identifying key words - Formulating open and closed questions and responding to peers' questions - Identifying cause-and-effect relationships - Information perception and processing
2	Natural Environment Around Me: Prediction and Research	Predicts the content of the text using images and diagrams	1	Analyzing images and diagrams	- Predicting the topic of the text - Comparing predictions with factual information - Making assumptions - Analytical thinking - Working with visual data
3	Humans and Nature: A Dialogue of Responsibility	Understands the relationship between humans and nature and engages in dialogue	1	Role-playing activities based on scenarios	- Dialogue construction - Group discussion - Communication skills - Self-monitoring - Collaboratio

4	Environmental Protection: From Idea to Action	Constructs a coherent narrative on an environmental topic	1	Developing a plan	- Using key words - Creating presentations - Group discussion - Structuring information - Developing arguments - Decision-making
Section 2. Interdisciplinary Tasks Aimed at Developing Metasubject Skills					
Cross-cutting theme: Learn from the Good, Avoid the Bad (Light and Darkness)					
1	Light and Darkness: Understanding Natural Phenomena	Identifies text types and structural elements	1	Reading texts	- Distinguishing descriptive and narrative texts - Analyzing structural components - Systemic thinking - Classification - Text analysis
2	Light as a Good Deed and a Kind Word	Understands and describes the main topic and central idea	1	Analyzing literary texts	- Identifying the topic and main idea - Connecting with proverbs and sayings - Interpretation - Critical thinking
3	Understanding Darkness:	Writes a comparative descriptive text	1	Creating a plan	- Writing a comparative text using key words - Self-assessment

	Comparison and Conclusion				- Written communication - Modeling and comparison - Self-correction
4	Distinguishing Good and Evil: Improving the Text	Identifies and corrects errors in the text; applies language norms	1	Editing texts	- Correct use of forms of address and parenthetical words - Reflection - Self-assessment - Application of language norms

Assessment Stage:

At the final stage, post-tests and meta-subject tasks were re-administered in both the control and experimental groups. The obtained results enabled a comparative evaluation of changes in learners' meta-subject skills over the course of the intervention. This stage aimed to determine the effectiveness of interdisciplinary instruction and to identify the levels of development of learners' cognitive, communicative, self-regulatory, and personal skills.

The study was conducted during the first term of the 2025–2026 academic year. Sessions were held once a week, on Wednesdays.

4. RESULTS

4.1. Gloves Method (Zuckerman, 1993)

To assess primary school learners' abilities to interact, negotiate, exchange viewpoints, and make joint decisions, the Gloves method developed by G. A. Zuckerman (1993) was employed. This method focuses on paired activity and is designed to reveal learners' verbal communication, strategies for reaching agreement, and capacity for collaborative task

performance. Each pair's performance was evaluated according to predefined criteria and subsequently converted into quantitative indicators.

The analysis of learners' interactions demonstrated varying levels of communicative and collaborative skill, reflected in the degree of similarity between the jointly designed glove patterns, the quality of negotiation processes, and the coordination of actions. These indicators provided insight into learners' ability to engage in constructive dialogue, align individual perspectives, and achieve shared outcomes within an interdisciplinary learning context.

Examples of gloves collaboratively designed by learners are presented in Figure 1.



Figure 1. Examples of gloves collaboratively decorated by learners.

To determine the distributional characteristics of the obtained data, the Shapiro–Wilk test (Shapiro & Wilk, 1965) was applied (Table 5).

Table 5. Tests of Normality

	Group	Kolmogorov–Smirnov Statistic			Shapiro–Wilk Statistic		
		Statistic	df	Sig.	Statistic	df	Sig.
pre-test Gloves	,00	,156	56	,002	,927	56	,002
	1,00	,181	56	,000	,929	56	,003
post-test Gloves	,00	,215	56	,000	,906	56	,000
	1,00	,182	56	,000	,925	56	,002
*Note. Lilliefors significance correction							

The results indicated statistically significant deviations from a normal distribution in both groups at the pre-test and post-test stages ($p < 0.05$). Accordingly, the non-parametric Mann–Whitney U test (Mann & Whitney, 1947) was used to compare the independent groups.

The results of the Mann–Whitney U test obtained using SPSS are presented in Table 6.

Table 5. Mann–Whitney U Test Statistics

Statistic	**Pre-test Gloves**	**Post-test Gloves**
Mann–Whitney U	1506,500	564,000
Wilcoxon W	3102,500	2160,000
Z	-,363	-5,911
Asymp. Sig. (two-tailed)	,717	,000
**Note:* Grouping variable: Group		

At the pre-test stage, no statistically significant difference was found between the groups ((U = 1506.50), (Z = -0.363), (p = 0.717)). This indicates that the groups did not differ significantly in their initial performance on the diagnostic task.

However, comparison of the post-test results revealed a statistically significant difference between the groups ((U = 564.00), (Z = -5.911), ($p < 0.001$)). The experimental group had a higher mean rank (74.43) than the control group (38.57). Assuming that higher scores indicate a higher level of communicative skills, these findings suggest that the experimental group demonstrated better performance than the control group at the post-test stage.

The Wilcoxon signed-rank test (Wilcoxon, 1945) was used to assess changes between pre-test and post-test scores. The analysis was conducted on the full sample of 112 participants. The results revealed a statistically significant difference between the two measurement occasions ((Z = -7.138), ($p < 0.001$)).

Table 7. Wilcoxon Signed-Rank Test

Ranks

		N	Mean Rank	Sum of Ranks
Post-test Gloves - Pre-test Gloves	Negative Ranks	5[a]	14,00	70,00
	Positive Ranks	68[b]	38,69	2631,00
	Ties	39[c]		
	Total	112		
a. post-test Gloves < pre-test Gloves				
b. post-test Gloves > pre-test Gloves				
c. post-test Gloves = pre-test Gloves				

The rank analysis revealed that post-test scores increased for 68 participants, decreased for 5 participants, and remained unchanged for 39 participants (Table 7). These findings indicate a statistically significant change in the overall sample's performance on Zuckerman's Gloves diagnostic task.

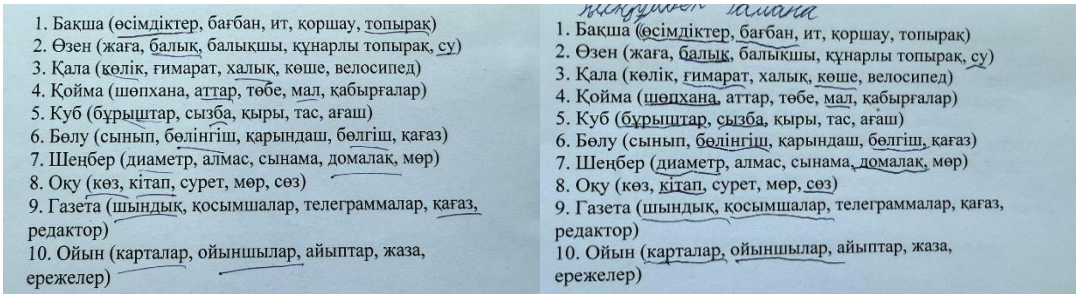
However, because the analysis was conducted on the combined results of both groups, the observed changes cannot be attributed exclusively to the effects of the pedagogical intervention. Further analyses conducted separately for the control and experimental groups are required to determine the nature and extent of changes within each group.

4.2. Identifying Essential Features Method (Rubinstein, 1999)

To assess learners' cognitive abilities and logical thinking, the Identifying Essential Features method developed by Rubinstein (1999) was employed. This method enables the evaluation of learners' capacity to distinguish essential characteristics of objects and phenomena, as well as their abilities to compare, abstract, and generalize information. It provides insight into the development of analytical thinking and the stability of reasoning processes, which are core components of meta-subject skill.

Figure 2 presents an example of learners' responses obtained through this method.

Kazakh version



English version

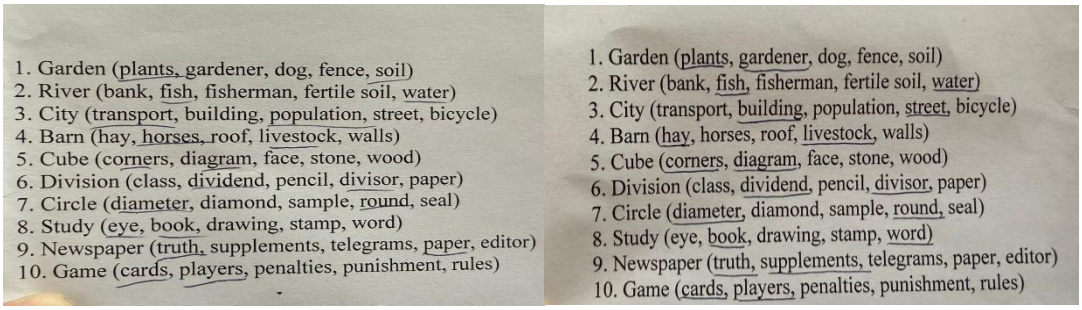


Figure 2. Example of a learner's response to the task.

Learners were presented with several concepts or objects and were required to identify their core, meaningful attributes. The obtained results were converted into a numerical scale and subjected to statistical analysis (Table 8).

Table 8. Shapiro–Wilk Test of Normality

	Group	Kolmogorov–Smirnov Statistic			Shapiro–Wilk Statistic		
		Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,00	,099	56	,200*	,967	56	,126
	1,00	,124	56	,032	,949	56	,019
Post-test	,00	,102	56	,200*	,976	56	,321
	1,00	,097	56	,200*	,972	56	,224
*Note. Lilliefors significance correction							

The results indicated that the experimental group's baseline scores did not deviate significantly from a normal distribution ((W = 0.967), (p = 0.126)). In contrast, the control group's baseline scores did not meet the assumption of normality ((W = 0.949), (p = 0.019)). At the post-test stage, no statistically significant deviations from normality were identified for

either the experimental group ((W = 0.976), (p = 0.321)) or the control group ((W = 0.972), (p = 0.224)).

Thus, statistically significant deviations from normality were not observed for three of the four indicators; however, the control group's baseline scores did not satisfy the assumption of normality. Given that the distributional characteristics were not consistent across all groups and measurement occasions, the non-parametric Mann–Whitney U test (Mann & Whitney, 1947) was considered appropriate for comparing the experimental and control groups, while the Wilcoxon signed-rank test (Wilcoxon, 1945) was used to compare pre-test and post-test scores within the same group.

The Mann–Whitney U test (Mann & Whitney, 1947), a non-parametric statistical procedure, was used to examine differences in cognitive and logical reasoning performance between the experimental and control groups at the pre-test and post-test stages (Table 9). The baseline diagnostic results revealed no statistically significant difference between the groups ((U = 1440.50), (Z = -0.746), (p = 0.456)). This indicates that no statistically significant difference in the diagnostic scores of the experimental and control groups was identified before the intervention.

Table 9. Mann–Whitney U Test Results

Statistic	Pre-test	Post-test
Mann–Whitney U	1440,500	742,000
Wilcoxon W	3036,500	2338,000
Z	-,746	-4,826
Asymp. Sig. (two-tailed)	,456	,000
**Note:* Grouping variable: Group		

The post-test results revealed a statistically significant difference between the groups ((U = 742.00), (Z = -4.826), (p < 0.001)). The experimental group had a mean rank of 71.25, compared with 41.75 for the control group. These findings indicate that the experimental group demonstrated higher post-test performance than the control group.

Table 10. Wilcoxon Signed-Rank Test

Ranks				
		N	Mean Rank	Sum of Ranks
Post-test - Pre-test	Negative Ranks	5 [a]	18,60	93,00
	Positive Ranks	93 [b]	51,16	4758,00
	Ties	14 [c]		
	Total	112		
a. Post-test < Pre-test				
b. Post-test > Pre-test				
c. Post-test = Pre-test				

To characterize changes between the pre-test and post-test measurements, an additional analysis was conducted using the results of all 112 learners. According to the rank statistics for the Wilcoxon signed-rank test (Wilcoxon, 1945), presented in Table 10, post-test scores were higher than pre-test scores for 93 learners, lower for 5 learners, and unchanged for 14 learners. Thus, an increase in post-test performance was observed among the majority of participants.

However, because these results combine data from both groups, the observed changes cannot be attributed exclusively to the effects of interdisciplinary instruction. To clarify the potential effect of the intervention, the Wilcoxon signed-rank test should be applied separately to the experimental and control groups, and the magnitude of change in the two groups should be compared.

4.3. Results of the Author-Developed Interdisciplinary Tasks

Prior to the main study, a pilot test was conducted using 10 author-developed interdisciplinary tasks designed to assess meta-subject skills. The pilot study involved 48 learners. Its purpose was to preliminarily evaluate the clarity of the task content and the internal consistency of the assessment instrument. Each task was scored dichotomously, with 1 point awarded for a correct response and 0 points for an incorrect response. The total score ranged from 0 to 10 points.

The pilot-test data were analyzed using IBM SPSS Statistics. Reliability analysis was performed to assess the internal consistency of the task set, and Cronbach's alpha coefficient (Cronbach, 1951) was calculated. In addition, the content of the tasks was reviewed based on feedback from academic supervisors and experienced primary school teachers. Minor revisions were made to selected task statements and items in accordance with their recommendations. The pilot-test findings and expert feedback were taken into account when preparing the diagnostic tasks for use in the main study.

The distributional characteristics of the data were assessed using the Shapiro–Wilk test (Shapiro & Wilk, 1965; Table 11).

Table 11. Shapiro–Wilk Test of Normality

	Grou p	Kolmogorov–Smirnov Statistic			Shapiro–Wilk Statistic		
		Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,00	,172	56	,000	,935	56	,005
	1,00	,141	56	,007	,938	56	,006
Post-test	,00	,148	56	,004	,945	56	,013
	1,00	,157	56	,001	,953	56	,031
*Note. Lilliefors significance correction							

The results of the Shapiro–Wilk test (Shapiro & Wilk, 1965) indicated statistically significant deviations from normality for both groups at the pre-test stage: the experimental group ($W = 0.935$, $p = 0.005$) and the control group ($W = 0.938$, $p = 0.006$). At the post-test stage, statistically significant deviations from normality were also observed in the experimental group ($W = 0.945$, $p = 0.013$) and the control group ($W = 0.953$, $p = 0.031$). Since all significance values were below 0.05, the null hypothesis of normality was rejected for all four distributions. Accordingly, non-parametric statistical methods, specifically the Mann–Whitney U test (Mann & Whitney, 1947), were considered appropriate for assessing differences between the groups.

The results of the Mann–Whitney U test obtained using SPSS are presented in Table 12.

Table 12. Mann–Whitney U Test Results

Statistic	**Pre-test**	**Post-test**
Mann–Whitney U	1537,000	908,000
Wilcoxon W	3133,000	2504,000
Z	-,182	-3,873
Asymp. Sig. (two-tailed)	,856	,000
**Note:* Grouping variable: Class		

Ranks				
	Group	N	Mean Rank	Sum of Ranks
Pre-test	,00	56	57,05	3195,00
	1,00	56	55,95	3133,00
	Total	112		
Post-test	,00	56	68,29	3824,00
	1,00	56	44,71	2504,00
	Total	112		

According to the pre-test results, the experimental group had a mean rank of 57.05, whereas the control group had a mean rank of 55.95 (Table 12). The difference between the groups was not statistically significant ($U = 1537.00$, $Z = -0.182$, $p = 0.856$). This indicates that no statistically significant difference in the groups' diagnostic scores was identified at the beginning of the study.

At the post-test stage, the experimental group had a mean rank of 68.29, compared with 44.71 for the control group. The Mann–Whitney U test revealed a statistically significant difference between the groups ($U = 908.00$, $Z = -3.873$, $p < 0.001$). The higher mean rank of the experimental group indicates that its learners achieved higher post-test scores than those in the control group. The absence of a statistically significant difference at the pre-test stage and the advantage of the experimental group at the post-test stage suggest a potential positive effect of the interdisciplinary teaching approach. However, to strengthen conclusions regarding the effectiveness of the intervention, further analysis is needed of the changes between pre-test and

post-test scores within each group, as well as of the between-group difference in the magnitude of change.

To describe changes between the pre-test and post-test results, the ranks obtained from the Wilcoxon signed-rank test (Wilcoxon, 1945) were also examined (Table 13).

Table 13. Wilcoxon Signed-Rank Test

Ranks				
		N	Mean Rank	Sum of Ranks
Post-test - Pre-test	Negative Ranks	5 [a]	18,00	90,00
	Positive Ranks	78 [b]	43,54	3396,00
	Ties	29 [c]		
	Total	112		
a. Post-test < Pre-test				
b. Post-test > Pre-test				
c. Post-test = Pre-test				

Of the 112 learners, 78 showed an increase in their post-test scores compared with their pre-test scores, 5 showed a decrease, and 29 demonstrated no change. These results indicate positive changes in 69.6% of the learners, negative changes in 4.5%, and unchanged performance in 25.9%. However, these aggregate data combine the experimental and control groups. Therefore, to clarify the statistical significance of the observed changes and the potential effect of the interdisciplinary teaching approach, it is necessary to consider the Z and p values of the Wilcoxon signed-rank test, as well as the results of separate analyses of changes within each group.

5. DISCUSSION

5.1. Analysis of the Gloves Method (Zuckerman, 1993)

The results obtained using Zuckerman's (1993) Gloves method indicate a marked improvement in the quality of learners' interaction under conditions of interdisciplinary tasks, as well as the development of their abilities to organize collaborative activity and reach shared

decisions. These findings make it possible to conceptualize communicative activity not merely at the level of speech skills, but as a meta-subject form of organizing joint cognitive activity.

The obtained results are consistent with the conclusions of Minakova et al. (2019), who emphasize that the development of communicative skills plays a crucial role in regulating children's social behavior and is most effectively achieved within structured collaborative learning environments. In the present study, the problem-oriented nature of interdisciplinary tasks and their implementation in group formats encouraged learners to exchange viewpoints, consider their peers' perspectives, and justify their own positions. These outcomes suggest that a learning environment conducive to the development of communicative universal learning actions—key components of meta-subject skill—was successfully established.

Koneva and Karpushkina (2019) argue that insufficient development of communicative activity constrains joint planning and mutual understanding in the learning process. From this perspective, the findings of the present study demonstrate that such challenges can be progressively overcome through interdisciplinary tasks that are purposefully designed and systematically implemented. Moreover, the results highlight the importance of pedagogical support characterized by consistency and content coherence in fostering learners' communicative skills.

The findings of this study also align with the arguments advanced by Kostović-Vranješ and Vickov (2013), who identify interdisciplinary instruction in primary education as an effective mechanism for the formation of social and communicative experience. This convergence of results further confirms the universal potential of interdisciplinary approaches in the development of communicative meta-subject skills among primary school learners.

5.2. Analysis of the Results of the Identifying Essential Features Method (Rubinstein, 1999)

In the contemporary educational landscape, the influence of the digital environment is known to have a substantial impact on the structure of learners' thinking. Studies by Dutko and Belovol (2020) indicate that children who grow up in a digital environment often demonstrate insufficient development of verbal–logical thinking and experience difficulties with operations such as generalization, synthesis, and analysis. The authors associate this phenomenon with the predominance of visual–imaginal thinking.

These observations are consistent with the cognitive characteristics identified in the present study, as interdisciplinary tasks require learners to process information, provide justification, and engage in generalization. In this context, the application of Rubinstein's (1999) Identifying Essential Features method enabled an assessment of learners' abstract thinking, their ability to distinguish essential properties of objects, and their capacity to systematize information on a logical basis. The method provided a comprehensive examination of the development of core logical operations, including comparison, classification, generalization, and the identification of cause–effect relationships.

The obtained results are theoretically consistent with the findings of Makshantseva and Sabanin (2014). The authors emphasize the significant impact of the socio-economic and infrastructural environment on the cognitive development of students in urban and rural schools. The study showed that children in urban schools demonstrated higher performance in verbal-logical thinking, whereas rural students developed their cognitive skills within a broader "zone of proximal development" but did not reach the actual developmental level of their urban peers. These findings highlight the importance of adapting instructional content to students' verbal and figurative thinking abilities and implementing differentiated pedagogical strategies in educational practice.

Furthermore, the development of cognitive universal learning actions was manifested through meta-subject skills related to comparing, systematizing, and modeling information

across subject domains. This result is consistent with the conclusions of Perminov and Testov (2020), who conceptualize modeling as a methodological core of interdisciplinary instruction, and it further confirms the role of perceiving educational content as an integrated system in fostering scientific thinking.

5.3. Analysis of the Results of the Author-Developed Interdisciplinary Tasks

The implementation of interdisciplinary tasks revealed a clear formation of self-regulatory universal learning actions. Learners demonstrated the development of meta-subject skills related to planning activities, breaking work into stages, monitoring their own decisions, and making necessary adjustments. The systematic use of reflective questions enabled learners to consciously analyze their learning activities. This finding is consistent with the model proposed by Vesmanov et al. (2020), who conceptualize meta-subject skills as a system of purposefully organized activities.

The importance of metacognitive support observed in this study aligns with the conclusions of Narengaowa and Tungalag (2024), who emphasize that interdisciplinary tasks contribute to the development of primary school learners' meta-subject abilities in goal setting, learning management, and outcome evaluation.

Personal meta-subject skills were manifested through increased learning motivation, sustained cognitive interest, and more conscious engagement in learning activities. This process corresponds to Korol's (2025) philosophical and methodological conceptualization of interdisciplinary education as a dialogical space in which learners are positioned as active subjects who construct their own knowledge.

Research by Ye and Xu (2023) further supports these findings, demonstrating that interdisciplinary tasks are effective in developing learners' meta-subject skills and 4C skills (critical thinking, communication, creativity, and collaboration). Their study shows that, at the

secondary school level, interdisciplinary tasks significantly enhance learners' critical thinking and group interaction abilities.

Moreover, studies by Kuznetsova et al. (2022), as well as Gabidullina and Syrtsova (2003), highlight the role of interdisciplinary integration in enhancing functional literacy and cognitive engagement. They confirm that the use of interdisciplinary tasks facilitates the development of students' analytical thinking, problem-solving skills, and the ability to apply subject knowledge in practical contexts. These works theoretically reinforce the present findings and substantiate the motivational and personal-development potential of interdisciplinary approaches.

A comparative analysis of the empirical data obtained in this study and the results of prior research indicates that interdisciplinary instruction constitutes an effective pedagogical method for fostering meta-subject skills in the context of primary education. Interdisciplinary integration supports the interconnected development of learners' communicative, cognitive, self-regulatory, and personal skills, enabling the organization of the learning process as a meaningful, learner-centered, and cognitively enriched system.

5.4. Limitations of the Study

Several limitations were identified in the course of this study, which should be taken into account when interpreting the findings:

1. The Gloves method, the Identifying Essential Features method, and the author-developed interdisciplinary tasks used to assess communicative, cognitive, and meta-subject skills were based on specific criteria. Although these instruments provided clear and observable indicators of learners' skills, their external validity and applicability in other cultural or educational contexts may be limited.

2. The study was conducted exclusively with primary school learners in Kazakhstan. Consequently, the findings cannot be fully generalized to school systems in other countries or to diverse educational settings with different curricular, cultural, or institutional characteristics.

3. The interdisciplinary tasks and elective course were implemented over a single academic term (8 weeks). This relatively short duration does not allow for a comprehensive assessment of long-term effects. In longitudinal studies, the impact of interdisciplinary instruction on the development of meta-subject skills may differ in magnitude or trajectory.

4. Learners' initial levels of preparedness, individual personality traits, and motivation may have influenced the study outcomes. As it was not possible to fully control for these variables, some of the observed effects may partially reflect individual differences rather than the instructional intervention alone.

6. CONCLUSION

The results of the pedagogical experiment conducted to investigate the influence of interdisciplinary instruction on the development of meta-subject skills among primary school learners made it possible to address the research question.

The assessment conducted using Zuckerman's *Gloves* method revealed a statistically significant difference in post-test results between the experimental and control groups (Mann–Whitney U test: $U = 564.00$, $Z = -5.911$, $p < 0.001$). The experimental group had a higher mean rank than the control group (74.43 and 38.57, respectively). This finding indicates that learners in the experimental group demonstrated higher communicative performance, including skills related to collaborative interaction and reaching mutual agreement, under the interdisciplinary teaching approach.

The results obtained using Rubinstein's *Identifying Essential Features* method also revealed a statistically significant difference between the experimental and control groups ($U = 742.00$, $Z = -4.826$, $p < 0.001$). The experimental group had a mean rank of 71.25, compared

with 41.75 in the control group. This finding suggests that the experimental group performed better in cognitive and logical activities, such as identifying essential features and making comparisons.

The results of the author-developed interdisciplinary tasks likewise revealed a statistically significant difference between the groups at the post-test stage ($U = 908.00$, $Z = -3.873$, $p < 0.001$). The experimental group had a mean rank of 68.29, whereas the control group had a mean rank of 44.71. These findings indicate that the experimental group achieved higher results in the meta-subject skills assessed using the author-developed tasks.

No statistically significant differences were identified between the experimental and control groups in the initial measurements obtained using any of the three assessment instruments. However, at the post-test stage, the experimental group demonstrated statistically significantly higher scores than the control group. These findings support the possibility that the author-developed interdisciplinary course contributed to the development of meta-subject skills. Nevertheless, to assess the magnitude of the effect more precisely, changes between pre-test and post-test scores should be analysed separately for each group, and the magnitude of these changes should be compared between the groups.

The findings highlight the potential of systematically integrating interdisciplinary instruction into primary education. Results obtained using different assessment instruments suggest that the experimental group demonstrated higher levels of communicative, cognitive-logical, and other meta-subject skills assessed through the author-developed tasks. Future research should assess the regulatory and personal components using dedicated measurement instruments and examine the long-term sustainability of the observed outcomes.

DECLARATIONS

Ethics approval

This study was reviewed and approved by the Zhanibekov University Ethics Committee. The study was determined to involve no more than minimal risk to human participants. The research was conducted in accordance with the ethical principles applicable to research involving human participants.

Consent to Participate

Written informed consent to participate in the study was obtained from the parents or legal guardians of all participating primary school students prior to data collection. Participation was voluntary.

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Human Ethics and Consent to Participate declarations

The study was approved by the Zhanibekov University Ethics Committee, and appropriate consent procedures were followed prior to data collection.

Data Availability

The anonymized and de-identified dataset supporting the findings of this study, together with the research instruments, assessment tasks, scoring guidelines, and relevant statistical analysis materials, is provided as supplementary material for peer review. The shared materials do not contain personally identifiable information. These materials are made available for the purpose of verifying the study's methodology and findings.

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