Enhancing Inclusive Computer Science Education through Project-Based Learning

Aitkul Yersultanova[1], Nursaule Karelkhan[1,*], Meruert Serik[1], Liza Naviy[2], and Saule Murzina[3]

[1]Faculty of Information Technology, L.N. Gumilyov, Eurasian National University, Astana, Kazakhstan
[2]Department of Pedagogy and Psychology, Sh. Ualikhanov Kokshetau University, Kokshetau, Kazakhstan
[3]Office for the Development and Implementation of Educational Programs, Academy of Public Administration under the President of the Republic of Kazakhstan, Kokshetau, Kazakhstan
Email: aitkul.yersultanova@mail.ru (A.Y.); 801205450700@enu.kz (N.K.); serik_meruerts@mail.ru (M.S.); liza731028@mail.ru (L.N.); saule_murzina@mail.ru (S.M.)
*Corresponding author
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***Abstract*—The rising number of pupils with Special Educational Needs (SEN) and the underutilization of creative teaching strategies pose challenges to the integration of inclusive education in primary schools. The purpose of this research is to assess how well Project-Based Learning (PBL) teaches computer science in inclusive classroom environments. An inclusive pedagogical model was created by integrating interactive exercises, teaching aids, and digital learning materials. 151 Kazakhstani elementary school pupils participated in the study; they were split into two groups: one that used PBL as an experimental strategy and the other that used conventional techniques. Three components—motivation, content comprehension, and technical skills—were evaluated using a structured questionnaire to gather data. PBL has a positive effect on inclusive digital learning, as evidenced by statistical analysis showing significant improvements in the experimental group across all components. Future work will focus on scaling this model to other subjects and educational levels, as well as enhancing accessibility features for pupils with various types of disabilities.**

***Keywords*—inclusive education, computer science, project-based learning, learning platform**

I. Introduction

The United Nations recognizes inclusion as a fundamental element of modern education policy, essential for achieving sustainable development in both the present and the future. This framework highlights the responsibility of countries to provide equitable, high-quality learning opportunities for all pupils and to ensure that educational systems promote lifelong learning without discrimination or exclusion [1]. Multiple international organizations and policy frameworks advocate for the adoption of comprehensive public measures and systemic educational practices aimed at establishing a unified foundation of learning opportunities accessible to all pupils [2]. This issue exists in many countries around the world. Morris and Henderson provided several pieces of evidence in his study: The results show that over 77 % of Jamaican schools are inaccessible to children with disabilities, and 90 % of children with disabilities are not equipped with modern technologies that would help them learn.

This challenge is observed in many countries worldwide. Research evidence indicates that in certain regions, such as Jamaica, more than three-quarters of schools remain physically inaccessible to pupils with disabilities, and the vast majority lack access to modern assistive technologies essential for learning. These shortcomings in technological infrastructure are closely linked to broader issues of accessibility within the education system [3]. Other studies, examining the progress of inclusive education—an approach that ensures all pupils, regardless of their abilities, disabilities, or backgrounds, have equal access to quality education in mainstream learning environments—in contexts such as Portugal, report substantial advancements over the past two decades, particularly in expanding access and implementing supportive measures. Nevertheless, notable gaps persist in the systematic collection of data and the generation of knowledge necessary to inform policy and practice, highlighting the continued need for the development and improvement of educational programs to fully achieve the objectives of inclusive education and ensure equal opportunities for all pupils [4].

The provision of specific conditions for pupils with special educational needs remains a cornerstone of inclusive education. This includes the creation and implementation of adapted curricula, differentiated teaching methods, and the integration of appropriate technical resources, as well as the delivery of psychological, pedagogical, and social support, in accordance with the national standards established by the Ministry of Education of the Republic of Kazakhstan [5]. By the start of 2023, the number of children with special educational needs in the Republic of Kazakhstan had risen to 188,000 (up from 175,000 at the start of 2022), with 132,699 of these children being of school age. The annual increase in such children averages 3% (in 2020, there were 161,000 children, and in 2021, the number rose to 175,000). By the beginning of 2023, 99 special schools had been established in the country, alongside 92 Psychological, Medical and Pedagogical Consultation/Committee (PMPC), 208 psychological and pedagogical correction rooms, 14 rehabilitation centers, and 10 autism centers. Additionally, schools boast more than 640 inclusion support rooms and over 1600 speech therapy centers. A total of 17,771 children with disabilities are studying in special organisations under specialised educational programs [6]. Consequently, inclusive education for children with special educational needs continues to be a significant issue in Kazakhstan. The increasing number of these children necessitates a rise in the number of specialised institutions, enhancements in infrastructure and resources, and a more equitable distribution of support throughout the country. Education has yet to develop systems that ensure independent learning tailored to each student's characteristics and needs, including

their psychological and pedagogical support and social adaptation. Additionally, flexible curricula for further education have not been established, and there is a shortage of personnel as well as teaching and methodological resources for inclusive education within mainstream educational institutions.

Information and Communication Technology (ICT) has been highlighted as a tool for communication and inclusion for children with disabilities, but from research it appears that implementation of technology in children's everyday lives (e.g. in school) is difficult [7]. The application of a Project-Based Learning (PBL) approach—an instructional method in which pupils gain knowledge and skills by working for an extended period of time to investigate and respond to complex questions, problems, or challenges—in the educational process enables pupils to actively seek answers to their own questions, with teachers facilitating and guiding this inquiry-based engagement [8]. Empirical evidence demonstrates that implementing PBL in junior high school information technology classes, within the framework of STEM education—an interdisciplinary instructional approach that integrates science, technology, engineering, and mathematics to develop holistic problem-solving and innovation skills—promotes the integration of knowledge from multiple subject areas to address and resolve real-life problems. This approach enhances pupils' ability to comprehend and effectively apply the knowledge they acquire [9].

In this context, PBL emerges as a promising approach that enhances inclusive education by fostering student engagement, promoting individualized learning experiences, and developing essential competencies necessary for social and academic success. PBL fosters active participation in the learning process of Computer Science for students of varying abilities through hands-on, collaborative projects, thereby building critical thinking skills and enhancing problem-solving capabilities. This makes education more accessible and effective for all learners, as it enables students to learn through real-world experiences and apply their knowledge in practical situations.

The research aim is to explore the specific features and effectiveness of Project-Based Learning in teaching Computer Science within the framework of Inclusive Education in schools.

To achieve this goal, the following tasks were established:

- Examine the experience of PBL and research within the context of inclusive education;
- Develop and implement a PBL to teaching Computer Science in an inclusive educational setting;
- Evaluate the effectiveness of PBL in Computer Science as part of inclusive education.

II. Literature Review

To identify the features of the PBL method in inclusive education, it is necessary to consider its essence and its development processes. First, the existing approaches and results of scientific research and practical experience of implementing project-based learning in inclusive education were analysed. The stages of analysis are data collection, literature review, etc. Current teaching methods and resources, including tools, projects, and interactive tasks, are considered for PBL.

Inclusive education in Kazakhstan presents a number of challenges for researchers, particularly in relation to the integration of innovative teaching methods. Addressing these challenges requires the coordinated efforts of all stakeholders to develop and implement a comprehensive and sustainable approach [10]. International experience demonstrates that mobile learning models grounded in digital inclusion frameworks can increase motivation, interest, and confidence, while simultaneously providing practical digital training and assessment opportunities in remote or underserved communities [11]. Other studies have shown that the promotion of inclusive practices is significantly influenced by each country's educational policy, with some contexts offering strong support and others presenting more restrictive conditions [12].

Evidence from research on Project-Based Learning (PBL) indicates that guided PBL models can substantially improve pupil engagement and conceptual understanding of subject matter [13]. Further investigations support the use of PBL, in combination with design thinking principles, to enhance STEM education in resource-limited settings. For instance, visual programming environments such as Scratch have been successfully applied during prototyping stages to develop computational thinking skills in inclusive classrooms [14]. Studies conducted by both domestic and international scholars consistently confirm the effectiveness of PBL in inclusive education due to its pupil-centered and teacher-supported nature [15].

Innovative approaches also include the integration of widely accessible technologies—such as mobile devices and free photogrammetry applications—into learning activities. These resources enable pupils to engage in reality-based digitization projects that are both challenging and motivating, aligning with the principles of Challenge-Based Learning (CBL) [16]. For the effective implementation of PBL in teaching Computer Science within inclusive settings, it is necessary to assess pupils' initial knowledge levels, adapt content to individual needs, and employ interactive, project-oriented tasks.

Digital platforms have also been developed to increase interactivity and functionality in online learning environments, facilitating inclusive communication and course management for pupils and educators, including those with sensory disabilities [17]. Nevertheless, findings suggest that although many pupils possess basic ICT skills for operating digital devices, they may lack the goal-oriented and self-directed competencies required to use these technologies effectively for learning purposes [18].

The review examined the features of the project-based learning method in inclusive education, analysing existing approaches, scientific research, and practical experiences of its implementation. It was found that the successful application of project-based learning requires a comprehensive approach, including data collection, literature analysis, the use of interactive tasks, and the individualization of the learning process. Furthermore, the review confirms that implementing project-based learning enhances student engagement and comprehension and can be effectively integrated into various educational contexts, including Computer Science and STEM education.

Experiences from other countries show that educational policies play a key role in developing inclusive practices, while modern technologies, such as mobile devices and visual programming, help increase student motivation.

To effectively apply project-based learning computer science in inclusive education, it is crucial to assess students' knowledge levels, adapt course content, and utilize digital platforms to improve accessibility and learning efficiency.

III. Materials and Methods

To evaluate the effectiveness of the Project-Based Learning (PBL) approach in inclusive computer science classes, a structured questionnaire was administered to 151 pupils from the experimental and control groups. The questionnaire consisted of 15 items, equally distributed among three components: Motivation, Content, and Technical. Each item was rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

Motivation component: Five items measured pupils' interest in teamwork, preference for interactive tasks, engagement in project activities, enjoyment of working with robotics kits, and preference for technology-assisted learning.

Content component: Five items assessed understanding of algorithms, clarity in robotics concepts, preferred types of project tasks, familiarity with robot types, and ability to describe steps in creating a simple Scratch game.

Technical component: Five items evaluated proficiency in using digital tools during lessons, understanding of Scratch programming, engagement with Lego Spike or EV3 Mindstorms tasks, ease of using robotics equipment, and preference for specific software.

The questionnaire was validated by three subject matter experts to ensure content validity. A pilot test with 20 pupils was conducted to refine item clarity and remove ambiguities. The internal consistency of each component was measured using Cronbach's alpha, which indicated good reliability: Motivation = 0.82, Content = 0.80, Technical = 0.84.

During the formative experiment, the responses were analyzed by calculating the percentage distribution of pupils' performance levels (low, average, high) for each component. Statistical analysis was conducted using the Chi-square test of independence to compare the experimental and control groups. The results demonstrated statistically significant improvements in the experimental group across all three components ($p < 0.05$), confirming the effectiveness of the PBL approach in enhancing motivation, content mastery, and technical skills in inclusive computer science education.

The pedagogical model "Enhancing Inclusive Computer Science Education Through Project-Based Learning"—a structured conceptual and methodological framework for organizing the educational process—was created as part of the second task. This framework is structured into three interrelated components—Content, Methodological, and Organizational (Fig. 1)—each designed to address specific aspects of implementing PBL in an inclusive primary school setting.

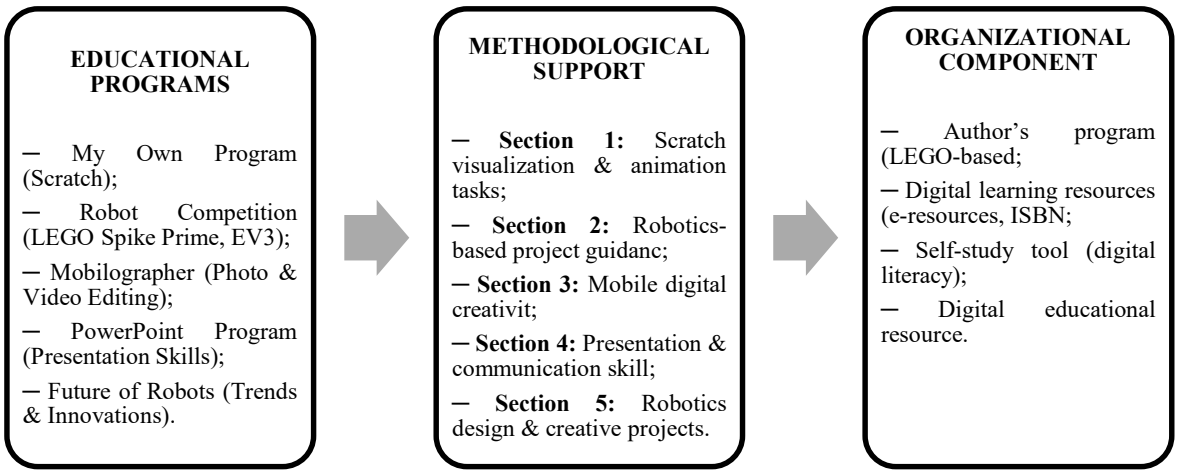


Fig. 1. Pedagogical model "Enhancing Inclusive Computer Science Education Through PBL".

The Content part of the model includes the content of the textbook "Computer Science" for the 4th grade. It is developed on the basis of the state mandatory standard of basic secondary education and the updated content of education (1 hour per week, 34 hours per year). The program is based on the project-oriented teaching method. It consists of five sections, each of which is a set of teaching methods aimed at developing specific skills and competencies (Table 1). The first part is devoted to the development of individual programs and includes individual and group training, as well as feedback and assessment. The second part considers the method of designing robotic competitions, which includes individual practical exercises, teamwork and feedback methods. The third part is devoted to the method of designing mobile photo and video cameras and includes practical classes, master classes, as well as feedback and assessment. The fourth part introduces students to PowerPoint through an interactive method, including group projects and feedback. Finally, in the fifth part, the perspective of robots is presented through the design method and includes game scenarios, simulations and practical exercises.

The Methodological part of the model includes activities that are most suitable for use in an inclusive classroom, considering all students' needs. Based on the analysis of the data and results obtained, recommendations were formulated to improve the educational process and further use of a set of tasks in computer science in inclusive education.

The methodological stage of the model consists of:

1) Teaching Aid: Collection of Practical Tasks for the 4th-Grade Inclusive Class;
2) Interactive learning—an instructional method based on active engagement of pupils with learning materials, the

teacher, and peers through technology-enhanced activities: Collection of Practical Tasks for the 4th-Grade Inclusive Class;

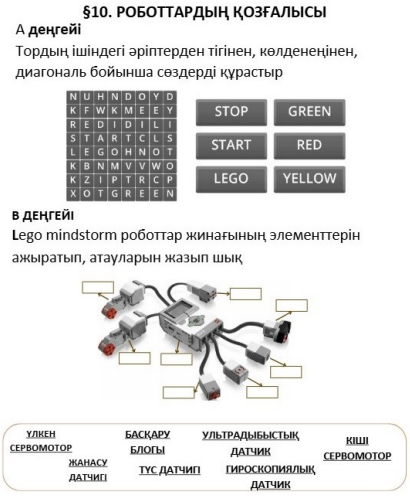
3) Digital educational resources—electronic, multimedia, and interactive materials designed to support and enhance the learning process: Project-Based Learning in Robotics in an Inclusive Group.

Table 1. The program "The Worlds of Color Code: Scratch and Robotics"

No.	Section topics	Teaching methods and techniques	Number of hours
1	PART I. SCRATCH program	Project learning method: learn coding skills by creating animations, games, and interactive projects in Scratch. Teamwork: develops creative and communication skills through coding. Feedback: students correct programming errors by analyzing completed projects.	8
2	PART II. Robot racing	Project method: develops algorithmic and engineering thinking skills by programming robots and preparing them for competitions. Practical training: students independently build and program a robot. Teamwork: improves cooperation and leadership skills through teamwork.	7
3	PART III. Mobilograph	Project method: through photo and video shooting, students develop creative thinking skills. Practical classes: learning to use camera settings. Feedback: as a result, students ' visual communication skills are improved.	4
4	PART IV. Introduction to PowerPoint	Project method: learns to convey information visually by preparing a presentation. Teamwork: develops cooperation and responsibility skills through joint projects. Feedback: develops skills in presenting information visually and intelligibly.	7
5	PART V. The Future of Robots	Project method: improves technical skills by creating models of future robots and programming them. Modeling: builds models of robots. Feedback: develops logical thinking skills by controlling robots in a game.	8

The first methodological section presents a teaching manual: a set of practical tasks for the IV-inclusive class (Fig. 2) [19]. This manual is compiled using the project-oriented teaching method of digital literacy in inclusive education. The collection of level and author tasks has been recommended for use in the primary grades of general education schools. The educational and methodological manual "Collection of Practical Tasks for the IV-inclusive Class" serves as an effective educational resource for developing digital literacy within the inclusive education system. This collection helps improve elementary school students' reading skills, logical thinking abilities, and digital competencies through a project-oriented teaching approach. Using the "Teaching Aid: Collection of Practical Tasks for the 4th-Grade Inclusive Class" was considered at a meeting of the city Expert Council and included in the educational process in schools-gymnasiums No. 87 and No. 65 of Astana, as well as in general Secondary School No. 2 in the village of Koyandy, Akmola region.

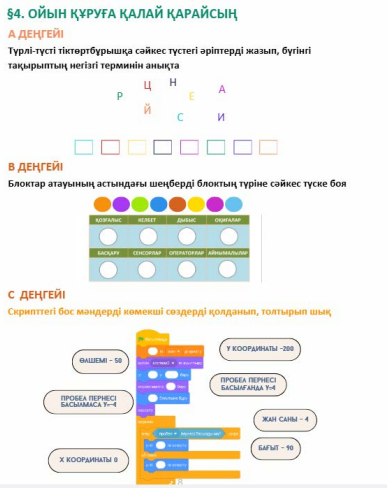
Additionally, there is the Interactive Learning Aid: "Collection of Practical Tasks for the IV-inclusive Class". Fig. 2 depicts the platform's theoretical section, while Fig. 3 illustrates simplified level-based tasks.



Note: The figure shows an interactive digital resource for teaching robot motion. The top part includes virtual control buttons (STOP, START, GREEN, RED, YELLOW, LEGO), while the bottom part presents a labeled LEGO EV3 robot diagram for identifying its sensors and motors.

Fig. 2. Theoretical page of the interactive learning aid: "Collection of Practical Tasks for the IV-inclusive Class".

The main idea of the platform is to provide students with access to interactive tasks based on material from a computer science textbook for primary school. All tasks from the textbook are integrated into the platform, creating opportunities to consolidate students' knowledge and skills through interactive educational materials. The platform's main advantages are its accessibility, interactivity and adaptability. Learners can develop their knowledge independently by completing assignments on the platform and receiving direct feedback. Thanks to interactive elements, students can effectively learn the material, and the adaptive capabilities of the platform allow you to customize tasks to the individual needs of each student.



Note: The tasks are divided by levels. Level A asks to match letters to colored blocks. Level B involves categorizing buttons by function (movement, control, sensing, etc.).

Fig. 3. Simplified level-based tasks of the interactive learning aid: "Collection of Practical Tasks for the IV-inclusive Class".

In addition to the Interactive Learning Aid, the Digital educational resource "Project-oriented teaching of robotics, an interdisciplinary field concerned with the design, construction, and application of robots, in an inclusive group [20]. The proposed computer program is compiled by the Computer Science curriculum. It is designed using project-oriented learning technology for inclusive groups. It consists of 6 digital educational resources, including theoretical materials, a video with the project results, and control questions (Fig. 4). The program is designed for

students and teachers of the robotics selection course.

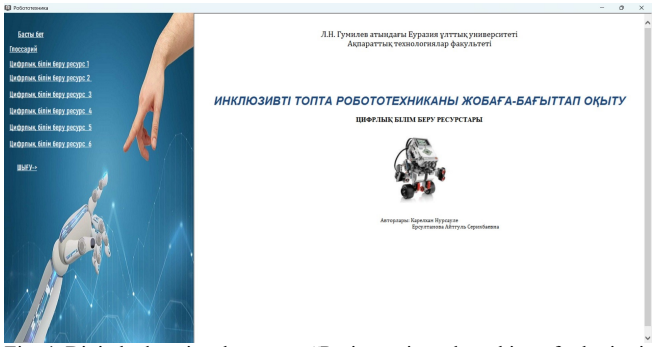


Fig. 4. Digital educational resource "Project-oriented teaching of robotics in an inclusive group".

The digital educational resource "Project-oriented teaching of robotics in an inclusive group" improves the learning process in inclusive robotics classes. Using these educational and methodological tools, students completed one project per chapter of the subject CS. Each project group comprised four children, including an inclusive one. For example, as a result of the project-oriented training method, our project centered on the topic "Development of a voice control system for household appliances for people with disabilities" based on the Arduino platform, an open-source hardware and software environment for developing electronic devices, widely used in education and research projects. Within the project's scope, we explored the possibility of voice control for lights and fans using a smartphone. The study's results demonstrated that voice control technologies can effectively enhance the daily lives of individuals with special needs. The devices utilised in the project:

- Arduino Nano / Uno-main microcontroller to control all actions;
- Bluetooth modules (HC-06)—used to receive voice commands from the smartphone to the microcontroller;
- Relay Module (5V)—used to turn the light and fan on and off;
- LED light is a light source that turns on and off by voice control;
- ventilator-a fan operated by voice control;
- power supply (Power Bank)—used to provide the device with a constant power supply; and C++, Android application APK software was used.

The student's creative abilities, logical thinking, and teamwork skills. Using interactive methods and multimedia technologies in the learning process increases students' motivation to learn and demonstrates the effectiveness of using digital educational resources. The gradual increase in the complexity of tasks in each educational section contributes to improving pupils' knowledge levels.

Statistical analysis was conducted using the Chi-square test of independence to compare the distribution of pupils across low, average, and high-performance levels between the experimental and control groups for each learning component. Results indicate statistically significant differences in all three components: Motivation ($\chi^2 = 23.28$, $p < 0.001$, Cramer's $V = 0.393$), Content ($\chi^2 = 32.86$, $p < 0.001$, Cramer's $V = 0.470$), and technical skills ($\chi^2 = 34.45$, $p < 0.001$, Cramer's $V = 0.478$). These findings provide strong evidence of the effectiveness of the PBL approach in enhancing pupil performance in inclusive computer science education (Fig. 5).

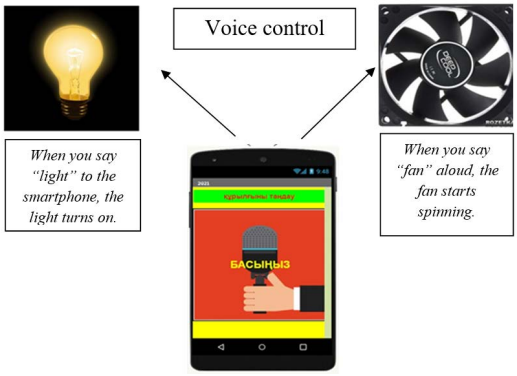


Fig. 5. The project "Development of a voice control system for household appliances for people with disabilities".

In the part Organization of the model to assess the effectiveness of the learning process, a questionnaire was developed to study the results of using the project-based learning method.

Table 2. The questionnaire questions are divided into three categories to assess the student's level

Motivation component	Content component	Technical component
Determining the increase in interest through project-oriented tasks.	Implement the project-based learning method, which assesses training effectiveness based on project tasks.	Determination of skills in using digital tools, effective use of digital technologies
1. Do you enjoy teamwork?	1. What is an algorithm?	1. What digital technologies do you use most often in one lesson?
2. Are you interested in using interactive tasks?	2. Which aspects of building robots are clear to you?	2. How well do you understand the Scratch programming language?
3. Is it engaging to complete the project tasks?	3. What types of project tasks do you prefer?	3. How engaging do you find completing tasks using Lego Spike or EV3 Mindstorms?
4. Do you like working with robotics builders?	4. What types of robots are you familiar with?	4. How easy is it to work with Lego Spike?
5. Do you prefer teaching with interactive tools?	5. What are the steps to create a simple game in Scratch?	5. What programs do you enjoy working with?

This questionnaire includes formative tests to assess students' motivation, content understanding, and technical and software skills. To clarify the effectiveness of PBL, questions were included that allowed students to determine their attitudes towards tasks, difficulties in combining theory and practice, and experience using digital resources. As a result, combining digital educational resources and project-based learning methods improves student learning performance, effectively organizing the educational process and implementing individualized approaches to learning (Table 2).

To ensure accessibility of the survey for all participants, including those with special educational needs, the questionnaire items presented in Table 2 were adapted for

clarity and simplicity. For students with visual impairments, audio support was integrated through screen-reader-compatible formats in the digital platform. Although the study did not directly involve non-verbal students with Autism Spectrum Disorder (ASD), we acknowledge that alternative communication tools—such as pictograms or symbol-based systems—should be considered in future iterations of the project to support wider inclusion and comprehension.

IV. Result and Discussion

To assess the efficacy Enhancing Inclusive Computer Science Education Through PBL, a questionnaire was distributed to all 151 participants once the experiment was finished (Table 3).

Table 3. Data from the participants of the experiment

School name	Experimental group	Control group	Number of participants
Gymnasium school №87	39	36	75
Gymnasium school №65 M. Zhumabayev	41	35	76
Total	80	71	151

Seventy-five students from School Gymnasium No. 87 in Astana and seventy-six students from School Gymnasium No. 65, named after M. Zhumabayev, participated in the study. Out of these students, eighty were assigned to the experimental group, while seventy-one were placed in the control group. The control group utilized only traditional teaching materials, whereas the experimental group studied using a different model as part of the experiment. At the end of the study, the results from both groups were compared through a questionnaire.

The results of the survey were analysed in three main categories: motivational, substantive, and technical. To evaluate the effectiveness of this model, we assessed the study's results by compiling survey questions based on the components presented in Table 2. This analysis was derived from Question 5 for each component.

Motivational Component: Classes were conducted in inclusive courses using the project-oriented training method, and at the final stage, a test was administered to measure motivation. According to the results of the motivational component, most students expressed interest in working within a group. They also responded positively to questions regarding the appeal of project tasks and interactive tools.

Content Component: basic concepts such as algorithms, robotics, and digital tools. Their interest in topics related to digital literacy has increased significantly, especially on platforms such as PowerPoint, Scratch.

Technical component: the technical skills component of the survey showed an increase in students' confidence in the use of digital tools, which showed a significant improvement in their ability to perform tasks with Scratch, Lego Spike, and EV3 Mindstorms, Arduino and others robot constructors and software. This is reflected in their responses.

The experimental group students achieved better results in motivation, content provision, and technical training than the control group. The results of the analysis of digital skills and the use of project-based learning technology in teaching affect students' motivation. These conclusions support the idea that introducing innovative technologies in the educational process will effectively increase students' interest and motivation to learn (Table 4 and Fig. 6).

Table 4. Results of formative experiment

Components	low level		average level		high level	
	Exper.gr	Contr.gr	Exper.gr	Contr.gr	Exper.gr	Contr.gr
	%	%	%	%	%	%
Motivation component	0.0	23.9	68.8	63.4	31.3	12.7
Content component	0.0	29.6	70.0	63.4	30.0	7.0
Technical component	1.3	33.8	72.5	60.6	26.3	5.6

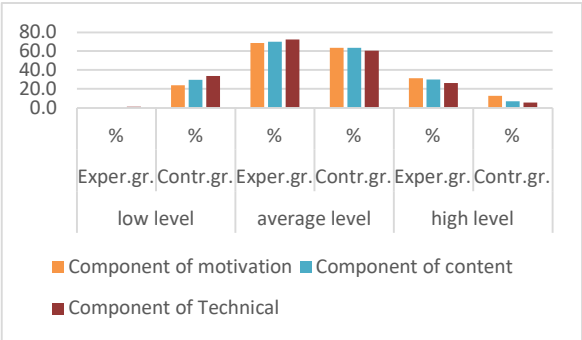


Fig. 6. Results of formative experiment.

Table 4 presents the distribution of pupils in the experimental (n = 80) and control (n = 71) groups across three performance levels—low, average, and high—for the Motivation, Content, and technical components. For the Motivation component, 0.0% of pupils in the experimental group were at the low level compared to 23.9% in the control group; 68.8% vs. 63.4% were at the average level, and 31.3% vs. 12.7% at the high level. For the Content component, 0.0% vs. 29.6% were at the low level, 70.0% vs. 63.4% at the average level, and 30.0% vs. 7.0% at the high level. For the Technical component, 1.3% vs. 33.8% were at the low level, 72.5% vs. 60.6% at the average level, and 26.3% vs. 5.6% at the high level. Statistical comparison using the Chi-square test of independence indicated significant differences between groups for all three components ($p < 0.05$), supporting the positive effect of the PBL approach in an inclusive learning environment.

Fig. 6 visualizes the comparative distribution of performance levels for the experimental and control groups across the Motivation, Content, and technical components. The data originate from the questionnaire analysis summarized in Table 4. The graphical representation highlights the higher percentage of pupils in the high-performance category within the experimental group, accompanied by a notable reduction in low-level performance compared to the control group. This pattern underscores the effectiveness of integrating project-based learning in inclusive computer science education.

The findings of this study are consistent with previous research demonstrating the benefits of project-based learning

in inclusive education contexts. For example, the guided PBL model has been shown to significantly enhance pupils' engagement and conceptual understanding [13], which aligns with our observation of increased motivation and technical competence in the experimental group. Similar approaches integrating PBL with design thinking principles in STEM subjects have improved problem-solving skills and promoted active participation [14], echoing the positive outcomes observed in our robotics-based projects. In contrast, while our results show substantial gains in all three components—motivation, content understanding, and technical skills—other studies indicate that infrastructural and accessibility barriers can still hinder full inclusion [3], suggesting that the effectiveness of PBL may be context-dependent. This comparison underscores that, although PBL is a robust methodology for enhancing inclusive computer science education, its success is closely linked to the availability of appropriate resources, teacher preparedness, and policy support.

The research findings confirmed the effectiveness of the proposed model for Enhancing Inclusive Computer Science Education Through Project-Based Learning and validated the accuracy of the scientific predictions made in this study. The results obtained, together with positive user feedback, demonstrate both the practical value and pedagogical relevance of the approach.

PBL has long been applied not only in computer science but also in mathematics, where numerous studies have proven its effectiveness. Robotics education, as a significant component of STEM education, has evolved from the basic "simple robot building" module [21]. It has been suggested that personalised learning can be delivered to both traditional and non-traditional learners through synchronous learning platforms, which recommend materials best suited to individual needs [22]. Çerkini *et al.* demonstrated that teachers with access to online learning resources exhibit greater confidence in teaching mathematics than those who do not integrate internet-based tools into their practice [23]. However, empirical research on inclusion remains limited, and there is no conclusive longitudinal evidence regarding the effectiveness of full inclusion [24]. One promising approach for advancing inclusive education is Universal Design for Learning, which enables teachers to develop adaptable learning materials for all pupils, including those with special educational needs [25].

V. Conclusion

Evidence also shows that pupils learning mathematics through PBL demonstrate faster and deeper mastery of material compared to those taught via traditional methods. Prior studies have indicated that PBL in mathematics fosters logical reasoning, creative problem-solving, and a deeper understanding of mathematical concepts. Furthermore, it enhances teamwork, independence, and the ability to apply theoretical knowledge in practice—making the learning process both effective and engaging.

This study offered a comprehensive analysis of the theoretical and practical foundations of project-based learning in the context of digital literacy for inclusive education. Digital educational resources and PBL methods developed using LEGO EV3 and SPIKE PRIME proved effective in developing the digital literacy of pupils with special educational needs. The main benefits of PBL identified include increased learning motivation, enhanced creativity and engineering skills, reinforcement of theoretical knowledge through hands-on projects, and the development of teamwork abilities. Additionally, robotics-based learning was shown to promote algorithmic thinking and problem-solving competence.

While the study demonstrated the effectiveness of the proposed model, the findings are derived from data collected in a limited number of schools, which may influence the generalizability of the results to other educational contexts. Furthermore, the study focused exclusively on primary school pupils in inclusive computer science classes, narrowing the applicability to similar educational settings. Future research should examine the implementation of this model across a broader range of schools, regions, and grade levels, as well as investigate its long-term effects on pupils' academic achievement, digital literacy, and social integration. In parallel, future work should prioritize enhancing teacher professional development to ensure that educators are fully prepared to apply PBL methodologies and digital tools effectively in inclusive classroom environments.

While the results of this study demonstrate the effectiveness of the proposed model in enhancing inclusive digital education, its applicability is primarily focused on pupils with mild to moderate learning difficulties and sensory impairments. Specifically, the research addressed the needs of students with visual impairments, Autism Spectrum Disorder (ASD), and general developmental delays. However, it does not encompass the full spectrum of neurological or behavioral disorders, such as severe non-verbal autism or complex physical disabilities requiring extensive assistive technologies. These limitations should be considered when generalizing the findings. Future studies should expand the model to include a broader range of disabilities and test its adaptability in diverse educational contexts.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N.K. conducted the literature review and developed digital resources. A.Y. conceptualized the study and finalized the manuscript. M.S. analyzed the data. L.N. assisted with methodology. S.M. contributed to the theoretical framework. All authors approved the final version.

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