

MATHEMATICS AS A BARRIER OR AN OPPORTUNITY: TRANSFORMATION OF APPROACHES TO FIRST-YEAR STUDENTS' PREPARATION FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

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Abstract. The article explores the challenges of first-year STEM students' mathematical preparation in Ukraine, framing them within the context of key Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 8 (Decent Work), SDG 9 (Innovation and Infrastructure), and SDG 10 (Reduced Inequalities). The insufficient level of mathematical literacy among school graduates, evidenced by both international assessments (PISA 2022) and the National Multi-Subject Test (NMT), creates substantial difficulties for the transition to higher education. An analysis of survey responses from 135 educators across 35 universities revealed widespread challenges, including students' inability to work with formulas, perform transformations, construct and interpret graphs, carry out mathematical proofs, formulate conclusions, and apply mathematical knowledge to practical tasks. Key problematic areas of the school curriculum are functions, mathematical analysis, stochastics, and plane geometry. It is argued that these gaps hinder the development of analytical, critical, and systems thinking – competencies crucial for sustainable development. The study concludes that systemic changes are needed including revising school curricula, implementing first-year adaptation programs, developing digital and interactive learning formats, integrating interdisciplinary and contextual learning, placing greater emphasis on the value-oriented dimension of education, and fostering educational partnerships between schools and universities. The importance of cultivating motivation, autonomy, reflection, and a value-based attitude toward mathematics is emphasized. The authors conclude that with adequate support, mathematics can become not a barrier but a resource for developing key competencies for sustainable development.

Keywords: mathematical preparation, STEM education, sustainable development goals, first-year students, bridging courses, learning losses.

1. INTRODUCTION

Education is not only a key factor in achieving the Sustainable Development Goals (SDGs), but also a driving force for the transformations needed to build a sustainable future. Numerous findings (Leal Filho et al., 2018; Shulla et al., 2020) emphasize that educational institutions play a central role in shaping a generation capable of implementing sustainable development objectives across various sectors of society. High-quality mathematical education is particularly important in this process. Mathematics forms the foundation for developing analytical reasoning, data processing skills, mathematical modeling, and informed decision-making. These competencies are essential for advancing the SDGs.

At the same time, challenges in mathematics education within the context of expanding STEM education significantly affect the potential to achieve several Sustainable Development Goals. A low level of mathematical preparedness among students (especially in their first year of higher education institutions) limits their ability to effectively master other STEM subjects. This negatively impacts the quality of education, as defined in SDG 4. In particular, gaps in basic mathematical knowledge hinder students' adaptation to university curricula. This contradicts Target 4.3, which aims to ensure equal access to quality higher education. As a result, graduates are not always prepared for successful employment in high-tech sectors, which are the focus of SDG 9. This, in turn, slows down the development of innovation, scientific research, and industry. It undermines the implementation of Target 9.5, which seeks to enhance a country's research and industrial capacity (Kopeika & Zvirgzdina, 2020).

A low level of mathematical preparedness limits students' opportunities for professional growth. It often leads to a loss of motivation to learn and, in some cases, to academic dropout. This hinders progress toward Target 8.6 of SDG 8, which aims to reduce the share of youth who are not in education, employment, or training. Universities, in turn, face the need to compensate for learning gaps. These gaps are especially pronounced among students from diverse social and regional backgrounds. This issue is closely related to SDG 10, which calls for reducing educational inequality.

In this context, providing high-quality mathematical education for students in STEM fields is a critically important condition for the successful achievement of the Sustainable Development Goals (Nugroho et al., 2022). At the same time, the low level of mathematical preparedness among school graduates in Ukraine is evidenced by the results of the international PISA 2022 assessment. Ukraine ranked 41st out of 47 participating countries, with an average score of 441. This is 31 points below the OECD average of 472. This gap corresponds to a learning lag of approximately one and a half academic years. Moreover, only 58% of Ukrainian students reached the baseline proficiency level in mathematical literacy, which is significantly lower than the OECD average of 69% (Organisation for Economic Co-operation and Development (OECD), 2023).

A similar trend is evident in the results of the National Multidisciplinary Test (NMT) 2024. Nearly 40% of Ukrainian test-takers demonstrated a low level of mathematical knowledge. About 47% performed at the intermediate level, while only 13% achieved a high level (Ukrainian Center for Educational Quality Assessment (UCEQA), 2024). These results highlight a sharp gap between the requirements of school and university-level mathematics education. The transition to higher education institutions is accompanied by increased academic workload, a greater volume of independent study, and a higher level of abstraction in mathematics courses. Under these conditions, first-year students in STEM programs often struggle to master the material. This, in turn, negatively affects their academic performance and learning motivation.

These challenges underscore the need for a systematic investigation of the problems related to the mathematical preparation of first-year students, viewed through the lens of sustainable societal development. The aim of this article is to identify the key issues in the mathematical preparation of first-year students enrolled in STEM programs, to analyse these issues in the context of the Sustainable Development Goals, and to outline pathways for transforming educational approaches in light of global and national educational trends.

2. THEORETICAL BACKGROUND

In the context of achieving the Sustainable Development Goals (SDGs), mathematics education plays a dual role: it serves both as a tool for developing a society's scientific and technological potential and as a means of reducing social and educational inequalities. Mathematics is not only an integral part of STEM education but also a foundation for building the competencies necessary to address the complex, interdisciplinary challenges of sustainable development (Makramalla et al., 2025). Accordingly,

strengthening the mathematical component in both school and higher education is considered a priority area of educational policy in many countries (United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017). In this context, Ukraine has recognised the need for systemic changes to improve the quality of mathematics education. One of the most important modern reforms is the implementation of the specialized senior school model. This model allows students to study mathematics in greater depth, especially those aiming for STEM fields. It is expected that this change will support more informed choices in learning pathways, increase student motivation, and reduce the gap between school and higher education levels (Ministry of Education and Science of Ukraine, 2024).

The findings emphasize that the transition from school to university-level mathematics education presents significant challenges. These include a mismatch between the content and complexity of school and university curricula, insufficient development of abstract thinking, and low academic motivation among first-year students (Gueudet & Thomas, 2020). Researchers highlight the importance of mathematical adaptation, defined as a first-year student's ability to successfully engage with university-level mathematics of high cognitive complexity. Studies show that the first year of study is critical for developing students' confidence in their mathematical abilities (Middleton et al., 2023).

An important aspect is the issue of inequality in mathematical preparation among students from diverse educational and socio-economic backgrounds. For example, the OECD (2020) highlights significant gaps in mathematics achievement between urban and rural students. These disparities subsequently affect academic success in higher education institutions. Such gaps tend to deepen amid ongoing transformations in the educational environment and the growing importance of independent learning. At the same time, although the digitalization of mathematics education has the potential to personalize learning and expand educational opportunities, it often exacerbates existing inequalities. According to the PISA 2022 report (OECD, 2023), students from disadvantaged socio-economic backgrounds are much less likely to have access to a computer with an internet connection at home. This limits their opportunities for online learning and completing homework assignments. This situation is especially critical for learning mathematics, which requires regular practice, access to interactive tools, and timely feedback (Rudenko et al., 2025).

A distinct body of research focuses on pedagogical strategies aimed at bridging educational gaps in mathematics. For example, Cancado et al. (2018) analyse the effectiveness of mathematics courses designed for academic leveling. Other scholars emphasize the integration of digital resources and adaptive learning to individualize mathematical instruction (Rincon-Flores et al., 2024). Studies on the preparation of future STEM professionals also highlight the need to transform approaches to mathematics teaching in higher education. In particular, they advocate for the implementation of problem-based learning, the use of interdisciplinary tasks, and modeling activities that connect mathematical content to real-world challenges of sustainable development (OECD, 2017).

Thus, contemporary scholarly sources emphasize the systemic nature of the challenges related to mathematical preparation in the context of sustainable development. Addressing this issue requires not only a revision of curriculum content and teaching methods but also the adaptation of the educational environment to meet the needs of diverse groups of learners. It is within this framework that the results of a study on university educators' subjective assessments of first-year STEM students' mathematical readiness in Ukraine should be considered.

3. METHODOLOGY AND DATA

To identify the current state of the problem concerning the mathematical preparation of STEM students in Ukrainian universities, which hinders the successful mastery of professionally oriented disciplines, an online survey of university educators was conducted in December 2024 (<https://forms.gle/McySUq2qkLNCWxXN8>). The study employed both quantitative and qualitative data collection methods, focusing on educators' subjective assessments of first-year students' preparedness,

identification of common knowledge gaps, and suggestions for possible solutions.

A total of 135 educators of STEM disciplines from 35 higher education institutions in Ukraine participated in the study. The age distribution of respondents was as follows: 0.7% were aged 20-30, 23% were 31-40, 31.9% were 41-50, 24.4% were 51-60, and 20% were over 61 years old. In terms of academic rank, 20.7% were lecturers, 62.2% associate professors, and 17% full professors. Regarding teaching experience, the vast majority (88.1%) had over 10 years of experience, 8.1% had between 6 and 10 years, and only 3.7% had up to 5 years. Thus, the sample represents a highly experienced academic community, providing a solid basis for a well-founded assessment of trends in students' mathematical preparation.

The questionnaire, developed using Google Forms, included both closed and open-ended questions. Among them were items related to: teaching subjects within STEM fields; subjective assessment of students' level of mathematical preparation; common gaps in knowledge and skills; the connection between these problems and external factors (such as changes in school curricula, socio-economic conditions, martial law, and features of the admissions process); the need for additional resources or support; suggestions for improving mathematical preparation.

The open-ended questions allowed respondents to express their own views on the causes of students' knowledge gaps, provide practical recommendations, and share personal experiences related to students' adaptation to the demands of university-level mathematics courses.

The study was conducted in full compliance with the principles of academic ethics. Participation by educators was entirely voluntary, with the right to withdraw at any stage or skip specific questions without any consequences. Respondents' anonymity and the confidentiality of all responses were ensured. Data collection, storage, and analysis were carried out in accordance with the provisions of the European Union's General Data Protection Regulation (GDPR, 2016/679) (European Parliament and Council, 2016), the ethical principles outlined in Guidelines for the Ethics of Science and Technology (UNESCO, 2005), and the Ethical Guidelines of the European Educational Research Association (European Educational Research Association (EERA, 2011).

All collected data were aggregated for the purpose of trend analysis, with no possibility of identifying individual respondents. The methodological approach enabled a systematic interpretation of both general assessments and specific issues characteristic of particular educational contexts.

4. RESULTS

The survey results reveal systemic problems in students' mathematical preparation that significantly affect the quality of learning in professionally oriented disciplines. The study confirmed that first-year students face numerous difficulties, which include both basic skills and higher-order cognitive abilities essential for successful learning in the context of modern university education.

4.1. Challenges in Acquiring Mathematical Skills

Respondents identified a range of difficulties faced by students, including: mathematical calculations (56.3%), the use of formulas (55.5%), construction and interpretation of graphs, diagrams, and figures (60%), understanding of basic mathematical concepts (57.7%), proving mathematical statements (68.8%), accurate use of mathematical language (65.2%), building mathematical models (68.9%), critical reasoning (65.9%), and establishing interdisciplinary connections (63%).

This wide spectrum of challenges indicates a lack of comprehensive school-level mathematical preparation, encompassing both theoretical components (concepts, statements, models) and practical skills (calculations, formulas, graphs). Of particular concern is the low level of mathematical language and argumentation skills, which hampers students' ability to communicate effectively in interdisciplinary contexts.

4.2. Problematic Topics in School Mathematics

Analysis of the survey results revealed that the content areas of greatest concern within the school mathematics curriculum are the functional-content line (63.7%) and the mathematical analysis line (64.4%). Significant difficulties arise with identity transformations of algebraic, exponential, logarithmic, and trigonometric expressions (60%). The stochastic line is also problematic (56.3%), affecting students' ability to work with data. Topics in plane geometry and basic numerical operations present challenges for about half of the students (55.6% and 49%, respectively).

These findings confirm the existence of substantial gaps in school-level mathematical preparation, which hinder a smooth transition to university-level mathematics. They also point to potential barriers in achieving the Sustainable Development Goals, particularly SDG 4 (Quality Education), SDG 8 (Decent Work), and SDG 9 (Industry, Innovation & Infrastructure).

4.3. Qualitative Analysis of Open-Ended Responses

The answers to the open-ended questions enabled the systematic organization of educators' perspectives on the causes of educational difficulties and possible ways to overcome them. These insights were categorized according to the Sustainable Development Goals (Fig. 1).

1. Ensuring Quality and Equitable Education (SDG 4, SDG 10). The vast majority of educators emphasize the low level of school mathematics preparation as the main barrier to successful learning. Students enter higher education institutions without a solid understanding of basic concepts. Their focus is on passing standardized exams rather than developing logical and mathematical reasoning skills. Educators suggest systemic changes for both schools and universities. For secondary education institutions, they recommend revising school curricula; ensuring daily mathematics instruction in senior secondary school; differentiating study profiles with a mathematical component; and raising standards for teacher training and accountability. For higher education institutions, the proposals include increasing classroom hours dedicated to mathematics; reducing group sizes for practical lessons; and providing institutional support for students with low initial competency levels.

2. Promoting Innovation in Education (SDG 9). Educators highlight the need to transition to modern teaching methods such as gamification, the use of digital simulators and platforms, and adaptive learning. These tools not only enhance motivation but also enable consideration of individual student learning trajectories. Particular attention in mathematical preparation should be given to data analysis and modeling of real-world processes; interdisciplinary thematic projects; and emphasizing the professional relevance of mathematical knowledge.

3. Addressing Educational Inequality (SDG 10). A significant number of respondents emphasize the heterogeneity of students' preparation levels. Therefore, they propose implementing adaptive learning platforms; refresher modules for foundational topics; and case-based learning tailored to students' initial competency levels.

4. Fostering Responsible Educatees (SDG 4, SDG 8). Some respondents highlight the need to develop students' learning autonomy, intrinsic motivation, and reflection. Accordingly, they propose problem-based learning formats; encouragement of independent inquiry; and a redefinition of mathematics as a tool for self-realization.

5. Educational Partnerships (SDG 17). Participants emphasize the need for horizontal integration between educational institutions. They propose aligning curricula between schools and universities; sharing analytical data; and establishing a system of leveling measures such as bridging courses, consultations, support groups, and involving senior students as tutors.

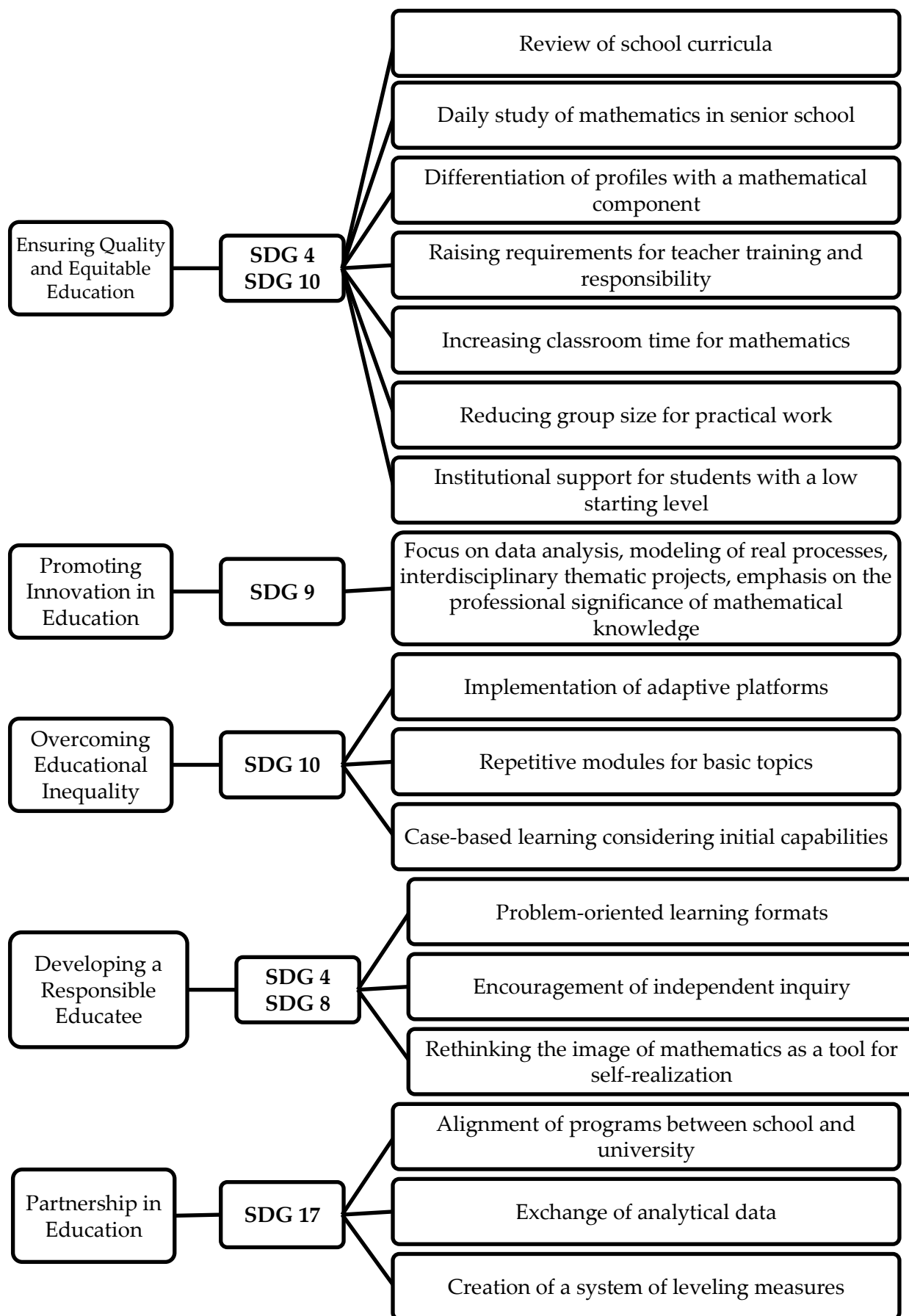


Fig. 1. Educators' Recommendations in the Context of SDG

Source: Own research

The proposed recommendations for improving mathematics education in schools and universities are based on the subjective assessments and practical experiences of the surveyed educators. While these suggestions may spark discussions regarding their practical implementation or resource availability, they reflect the views of educators identified in the study. They also highlight current directions for educational development in the context of the Sustainable Development Goals. It is important to note that these recommendations are not a universal solution. However, they can serve as a starting point for further discussion and adaptation to specific educational contexts. They can also serve as guidance for future experimental or pilot projects.

5. DISCUSSION

5.1. Mathematics and Sustainable Development: Conceptual Foundation

Mathematics education, as a component of STEM, plays a crucial role in achieving the Sustainable Development Goals (SDGs). In particular, it contributes to SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 10 (Reduced Inequalities). As noted by Loh et al. (2019), integrating STEM education with the context of sustainable development helps shape a value-oriented perspective on scientific and technological progress. In this context, mathematical training is not only a means of developing abstract reasoning. It also serves as a tool that enables future professionals to make informed decisions in complex social, economic, and environmental situations. Researchers also highlight the link between the level of mathematical competence and the ability to carry out practical tasks related to sustainable development (Lafuente-Lechuga et al., 2020). Mathematics, as a universal language of quantitative analysis and modeling, allows specialists from various fields to identify deep interconnections between processes, forecast outcomes, optimize resources, and assess risks. Therefore, the decline in students' mathematical preparedness threatens not only the quality of higher education but also the capacity of society to act sustainably.

5.2. Conceptual Competencies: What Mathematics Offers for a Sustainable Future

The current philosophy of mathematics education in the context of sustainable development focuses on building holistic competencies. These integrate knowledge, skills, values, and readiness for action. Widiati and Juandi (2019) highlight several crucial components: critical reasoning, systems reasoning, imagination, participation in decision-making, the capacity for interdisciplinary dialogue, and the ability to live and work in conditions of complexity. These competencies are directly linked to mathematical training. Mathematics fosters the ability to model, argue, analyse, search for patterns, and make predictions. Cebrián and Junyent (2015) identify additional key elements of sustainability competencies: future-oriented reasoning, contextualisation, reflection, interdisciplinary dialogue, and emotion management. All these elements are embedded in contemporary mathematics education through applied problems, project-based learning, instructional simulations, and interdisciplinary cases. Including such components in university mathematics courses not only enhances learning outcomes. It also cultivates a systemic and responsible attitude toward the profession and society.

5.3. International and National Trends in Students' Mathematical Preparation

The issue of first-year students' mathematical preparation is actively studied in the international context, particularly in relation to the transition from school to university education. Research shows that students often overestimate their level of mathematical knowledge, while university instructors tend to assess it more critically (Wandel et al., 2015; Harrington et al., 2016). This discrepancy is explained by the heterogeneity of the student population and the lack of unified approaches to developing mathematical competencies in secondary education.

The impact of educational reforms on students' mathematical performance has been confirmed in

findings by Aruvee et al. (2019). The introduction of new testing formats and changes in the structure of school education can significantly affect the initial level of students' knowledge. Other statistically significant factors influencing success in first-year mathematics courses include student motivation, class attendance, and prior academic preparation (Li et al., 2013; Gupta et al., 2006). These courses are critical for student retention in STEM (Donovan & Suresh-Menon, 2024).

Recent studies highlight a global trend of declining interest among young people in science and mathematics subjects. This trend has led to a decrease in enrollment in these fields (Buturlina et al., 2021). Before mathematics became a compulsory subject in 2021, Ukraine showed a negative trend in the number of students choosing it for the national external assessment (ZNO), indicating systemic challenges in mathematics education.

5.4. Ukrainian Realities: The Gap Between School and Higher Education

Data from a faculty survey conducted in December 2024 confirm the existence of significant gaps in the mathematical preparation of first-year students. These findings are fully consistent with the results of the National Multi-Subject Test (NMT) in 2023 and 2024. For example, only 44% of test-takers were able to factor a quadratic expression. Just 25% correctly translated a function graph. At the same time, 60.9% of university educators reported that students struggle with understanding functions. More than 65% pointed to difficulties with mathematical proofs, modeling, and critical reasoning.

Knowledge in both plane and solid geometry also shows significant deficiencies. Only one-third of students can successfully solve spatial problems. Meanwhile, 52.5% of educators rate students' preparation in this area as critically low. This is further supported by reports on secondary education. School teachers also express doubts about the quality of learning during periods of remote instruction. According to Burda et al. (2023), only 55.3% of teachers are confident that students have mastered algebra, and even fewer believe they have adequately learned geometry.

Such gaps between school and university preparation create a systemic barrier to students' adaptation to academic-level expectations. This barrier is not only educational but also socio-economic, as it hinders equal access to quality higher education (SDG 4 and SDG 10).

5.5. Interventions and Strategies to Support Mathematical Preparation

At the international level, a range of pedagogical interventions has been developed to address the mathematical gaps between secondary school and university. Among the most common strategies are: diagnostic entrance tests, targeted refresher courses covering foundational material, first-semester bridging programs, tutoring support, and summer preparatory courses (Basitere & Ivala, 2015; Abumandour, 2022). Such programs are often mandatory for students who perform poorly on entry-level assessments.

Short-term intensive courses and bridge programs have also shown positive results. These initiatives often incorporate elements of formative assessment, differentiation, and personalized learning pathways. Harrington et al. (2016) report an increase in academic success rates of up to 80% among participants of such programs. When combined with active instructional support, such as mentoring, consultations, and workshops, these interventions significantly enhance students' academic performance.

Innovative approaches now include the use of online resources, MOOCs, adaptive learning software, and intelligent platforms that support students in working at their own pace and addressing individual learning gaps. Preez et al. (2008) emphasize the importance of early diagnostics and targeted intervention during the first weeks of study. The experience of Jacobs and Pretorius (2016) demonstrated the effectiveness of workshops focused on developing soft skills, such as reflection, goal-setting, and problem-solving, when integrated with mathematics modules.

An important way to address the identified problems is through ongoing changes in Ukrainian educational policy. In particular, there is a transition to specialized senior secondary schools (Ministry of

Education and Science of Ukraine, 2024). This reform aims to provide greater differentiation in learning based on students' interests and abilities. It has the potential to strengthen the mathematical preparation of future STEM students. Creating classes with an advanced focus on mathematics and natural sciences allows students to concentrate on developing critical and systems thinking. It also enhances skills in data handling and mathematical modeling. These are the competencies that educators have reported as lacking. Therefore, implementing the concept of specialized schools can be seen as a key state instrument for reducing the gap between school and university mathematics education. It can also contribute to achieving SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities).

5.6. Rethinking Approaches to Mathematical Preparation

Improving the quality of mathematical preparation requires a fundamental rethinking of pedagogical approaches. In particular, it is essential to address the discrepancy between students' and instructors' perceptions of students' mathematical readiness (Wandel et al., 2015). This calls for work with both groups: enhancing students' self-reflection and increasing educators' diagnostic sensitivity.

As early as the 1990s, Leitzel (1991) emphasized the need to strengthen the foundations of mathematical preparation for pre-service teachers. In today's context, this means not only reinforcing subject-specific knowledge and skills but also actively integrating digital tools, interactive platforms, and mathematics-oriented software (Colonna & Easley, 2011). The use of adaptive learning, gamification, project-based activities, and modeling enables the transformation of mathematics from an "abstract discipline" into a tool for personal and professional development.

5.7. Theoretical Generalizations and Connection to Research Findings

The conducted study confirmed the systemic nature of difficulties in the mathematical preparation of first-year STEM students. These difficulties affect both academic success and students' ability to actively participate in building a sustainable society. The problems identified by educators, such as deficits in modeling skills, challenges in formulating mathematical statements, limited understanding of functions and algebraic transformations, among others, align with the diagnostic results of the National Multi-Subject Test (NMT) and international research findings (Bingolbali & Monaghan, 2008; Cook & Fukawa-Connelly, 2016). Thus, the issue of mathematical preparedness is not solely a national challenge but part of a global trend. This trend demands a systemic response at the levels of content, methodology, organization, and culture of mathematical education. Implementing adaptive, interdisciplinary, and value-oriented approaches to mathematics teaching allows for the integration of academic achievement with the cultivation of responsible citizens capable of acting in the interest of sustainable societal development. The integration of sustainable development competencies, such as systems reasoning, critical analysis, decision-making, and interdisciplinarity, into the content and process of first-year mathematics education can make this course not only preparatory and developmental but also transformational. As research shows (Widiati & Juandi, 2019; Cebrián & Junyent, 2015), the combination of conceptual and practical dimensions, along with logical and value-based approaches, forms the foundation for a new paradigm of mathematics education in the 21st century.

The study's results indicate that first-year mathematical preparation can serve either as a barrier or an opportunity for achieving the Sustainable Development Goals, depending on how the educational process is organized. The identified gaps in students' knowledge and skills call for a rethinking of mathematics' role within the education system and for the implementation of targeted support measures. Therefore, first-year mathematics education is not only a means of addressing learning losses but also a key tool for shaping competent, responsible, and action-ready citizens aligned with the strategic goals of sustainable societal development.

6. CONCLUSIONS

The conducted study provided a deeper understanding of the systemic problems in the mathematical preparation of first-year STEM students within the context of achieving the Sustainable Development Goals. The results justify the assertion that the insufficient level of mathematical knowledge and skills, evident both in external assessments (PISA, NMT) and in instructors' observations, represents a key barrier to realizing the principles of quality, equitable, and inclusive education (SDG 4). It also hinders progress toward promoting decent work and economic growth (SDG 8), developing innovative industry (SDG 9), reducing educational inequalities (SDG 10), and strengthening partnerships in education (SDG 17).

Mathematics serves both as a barrier and a potential resource. With appropriate transformation of teaching approaches, it can become a powerful tool for developing systems reasoning, analytical skills, mathematical literacy, and students' readiness to participate actively in building a sustainable society. Currently, students face challenges ranging from basic mathematical knowledge (numbers, identity transformations, functions) to higher-order skills (proving statements, mathematical modeling, critical analysis, and proficient use of mathematical language). This situation reflects not only the fragmented nature of mathematical preparation but also the lack of a holistic vision of mathematics as a tool for understanding and action.

Educators unanimously emphasize the need to update both the school and university components of mathematics education. The main directions for transformation include: revising school curricula to focus on developing reasoning skills rather than solely preparing for standardized tests; implementing adaptive and compensatory measures during the first year of higher education; increasing the role of innovative and interactive teaching methods; differentiating learning pathways based on students' initial proficiency levels; and establishing inter-institutional partnerships among schools, universities, and other educational stakeholders.

A promising direction for future research is monitoring the effectiveness of educational reforms in Ukraine. In particular, this includes the transition to specialized senior secondary schools and its impact on the mathematical readiness of applicants for university studies. This systemic change has the potential to deliberately strengthen the mathematical competencies of future STEM students.

Effectively addressing the challenges of mathematical preparation for STEM students will enable mathematics to be viewed not as a barrier, but as a powerful tool for realizing students' individual potential in achieving global sustainable development goals.

7. LIMITATIONS

1. The study is based on expert evaluations from 135 STEM educators across 35 Ukrainian universities. Although the sample is geographically broad within the Ukrainian context, it does not encompass all stakeholders, which could provide a more comprehensive picture of the issues in mathematical preparation.

2. The research focuses specifically on the preparation of STEM students; therefore, its results cannot be directly extrapolated to humanities or socio-economic disciplines.

3. The educator survey involved subjective judgments regarding students' mathematical preparedness, which may reflect not only the actual state but also the respondents' expectations, biases, or personal experiences.

4. Data from the National Multi-Subject Test (NMT) were used for comparison with survey results; however, these data were not specifically adapted to assess readiness for studying STEM disciplines in higher education institutions.

5. The study analyses the initial level of mathematical preparation of first-year students without considering the dynamics of their development throughout their higher education studies.

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REFERENCES

- [1] Leal Filho, W., Pallant, E., Enete, A., Richter, B., & Brandli, L. L. (2018). Planning and implementing sustainability in higher education institutions: An overview of the difficulties and potentials. *International Journal of Sustainable Development & World Ecology*, 25(8), 713–721. <https://doi.org/10.1080/13504509.2018.1461707>
- [2] Shulla, K., Filho, W. L., Lardjane, S., Sommer, J. H., & Borgemeister, C. (2020). Sustainable development education in the context of the 2030 Agenda for Sustainable Development. *International Journal of Sustainable Development & World Ecology*, 27(5), 458–468. <https://doi.org/10.1080/13504509.2020.1721378>
- [3] Kopeika, E., & Zvirgzdina, L. (2020). Skills and competencies in mathematics of engineering students in the context of sustainable development. *19th International Scientific Conference Engineering for Rural Development*, Jelgava, 20–22.05.2020, 1255–1261. <https://doi.org/10.22616/ERDev.2020.19.TF303>
- [4] Nugroho, O., Juwita, S., & Febrianti, N. (2022). STEM Education Planning Based on Contextual Issues Sustainable Development Goals (SDGs). *Pedagonal: Jurnal Ilmiah Pendidikan*, 6(2), 159–168. <https://doi.org/10.55215/pedagonal.v6i2.5554>
- [5] OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. OECD Publishing, Paris. <https://doi.org/10.1787/53f23881-en>
- [6] Ukrainian Center for Educational Quality Assessment. (2024). Official report on the results of the NMT in 2024. URL: <https://surl.lj/csouv.c>. (in Ukr.)
- [7] Makramalla, M., Coles, A., le Roux, K., & Wagner, D. (2025). Mathematics education for sustainable futures: A strengths-based survey of the field to invite further research action. *Educational Studies in Mathematics*, 119, 535–556. <https://doi.org/10.1007/s10649-025-10389-x>
- [8] UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. URL: <https://surl.li/dgwujs>
- [9] Ministry of Education and Science of Ukraine. (2024). Conceptual Foundations for Reforming Profile-Based Secondary Education (Academic Lyceums). URL: <https://surl.li/uyzyhu> (in Ukr.)
- [10] Gueudet, G., & Thomas, M.O.J. (2020). Secondary-Tertiary Transition in Mathematics Education. In: Lerman, S. (eds) *Encyclopedia of Mathematics Education*. Springer, Cham. https://doi.org/10.1007/978-3-030-15789-0_100026
- [11] Middleton, J. A., Wiezel, A., Jansen, A., & Smith, E. P. (2023). Tracing mathematics engagement in the first year of high school: relationships between prior experience, observed support, and task-level emotion and motivation. *ZDM Mathematics Education*, 55, 427–445. <https://doi.org/10.1007/s11858-022-01432-9>
- [12] OECD (2020). *The Digital Divide in Education: How Schools Can Support Students at Risk of Exclusion*. URL: <https://surl.li/fbubgm>
- [13] Rudenko, Y., Drushlyak, M., Naboka, O., Proshkin, V., & Semenikhina, O. (2025). Development of Youth Information Hygiene Skills: The Gap Between the Self-Assessment and Real State. In: Smyrnova-Trybulska, E., Chen, NS., Kommers, P., Morze, N. (Eds) *E-Learning and Enhancing Soft Skills*. Springer, Cham. https://doi.org/10.1007/978-3-031-82243-8_5

- [14] Cancado, L., Reisel, J. R., & Walker, C. M. (2018). Impacts of a Summer Bridge Program in Engineering on Student Retention and Graduation. *Journal of STEM Education: Innovations and Research*, 19(2). URL: <https://surl.lt/hfhkeb>
- [15] Rincon-Flores, E. G., Castano, L., Guerrero Solis, S. L. et al. (2024). Improving the learning-teaching process through an adaptive learning strategy. *Smart Learning Environments*. 11, 27. <https://doi.org/10.1186/s40561-024-00314-9>
- [16] OECD. (2017). *Harnessing Spatial Thinking to Support STEM Learning*. URL: <https://surli.cc/iexneo>
- [17] European Parliament and Council. (2016). *Regulation (EU) 2016/679 (General Data Protection Regulation – GDPR)*. URL: <https://surl.li/vqgrzm>
- [18] UNESCO. (2005). *Universal Declaration on Bioethics and Human Rights*. URL: <https://surl.lu/adripx>
- [19] European Educational Research Association (EERA). (2011). *Ethical Guidelines for Educational Research*. URL: <https://surli.cc/vvwkhk>
- [20] Loh, S. L., Pang, V., & Lajium, D. (2019). The planning of integrated STEM education based on standards and contextual issues of the Sustainable Development Goals. *Journal of Nusantara Studies*, 4(1), 300–315. <https://doi.org/10.24200/jonus.vol4iss1pp300-315>
- [21] Lafuente-Lechuga, M., Cifuentes-Faura, J., & Faura-Martínez, Ú. (2020). Mathematics applied to the economy and sustainable development goals: A necessary relationship of dependence. *Education Sciences*, 10(11), 339. <https://doi.org/10.3390/educsci10110339>
- [22] Widiati, I., & Juandi, D. (2019). Philosophy of mathematics education for sustainable development. *Journal of Physics: Conference Series*, 1157, 022128. <https://doi.org/10.1088/1742-6596/1157/2/022128>
- [23] Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability*, 7(3), 2768–2786. <https://doi.org/10.3390/su7032768>
- [24] Wandel, A. P., Robinson, C., Abdulla, S. A., Dalby, T., Frederiks, A., & Galligan, L. (2015). Students' mathematical preparation: Differences in staff and student perceptions. *International Journal of Innovation in Science and Mathematics Education*, 23(1), 1–15. URL: <https://surl.li/rklnaf>
- [25] Harrington, M. A., Lloyd, A., Smolinski, T., & Shahin, M. (2016). Closing the gap: First year success in college mathematics at an HBCU. *Journal of the Scholarship of Teaching and Learning*, 16(5), 92–106. URL: <https://surli.cc/fydmpc>
- [26] Aruvee, E., Kaminskienė, J., & Rimkuviene, D. (2019). Mathematical readiness assessment for first-year students. In: *International Conference on Education and New Developments*. <https://doi.org/10.36315/2019v2end056>
- [27] Li, K. Y., Zelenka, R., Buonaguidi, L., et al. (2013). Readiness, behavior, and foundational mathematics course success. *Journal of Developmental Education*, 37(1), 14–24. URL: <https://surl.li/jtrn>
- [28] Gupta, S., Harris, D. E., Carrier, N. M., & Caron, P. G. (2006). Predictors of student success in entry-level undergraduate mathematics courses. *College Student Journal*, 40(1), 97–108. URL: <https://surl.li/outocd>
- [29] Donovan, D., & Suresh-Menon, D. (2024). Student recruitment and retention improvements through success in first-year mathematics: A multi-faceted approach. In: *Collaborative Network for Engineering & Computing Diversity (CoNECD)*, Arlington, V. A. <https://doi.org/10.18260/1-2--45480>
- [30] Buturlina, O., Dovhal, S., Hryhorov, H., Lysokolenko, T., & Palahuta, V. (2021). STEM education in Ukraine in the context of sustainable development. *European Journal of Sustainable Development*, 10(1), 323. <https://doi.org/10.14207/ejsd.2021.v10n1p323>
- [31] Burda, M. I., Vasyliieva, D. V., & Tarasenkova, N. A. (2023). Mechanisms of addressing/compensating for learning losses (mathematics education domain). In O.M. Topuzov (Eds.), *Diagnosis and compensation of learning losses in general secondary education in Ukraine: methodological recommendations* (pp. 100–121). Kyiv: Pedahohichna Dumka. <https://doi.org/10.32405/978-966-644-736-7-2023-190>. (in Ukr.)
- [32] Basitere, M. M., & Ivala, E. N. (2015). Mitigating the mathematical knowledge gap between high school and first year university chemical engineering mathematics course. *Electronic Journal of e-Learning*, 13(1), 68–83. URL: <https://surl.li/qobqah>
- [33] Abumandour, E.-S. T. (2022), Applying e-learning system for engineering education – challenges and obstacles. *Journal of Research in Innovative Teaching & Learning*, 15(2), 150-169. <https://doi.org/10.1108/JRIT-06-2021-0048>.
- [34] Preez, J. D., Steyn, T., & Owen, R. H. (2008). Mathematical preparedness for tertiary mathematics: A need for focused intervention in the first year? *Perspectives in Education*, 26(1), 49–62. URL: <https://surl.lt/fjfhia>

- [35] Jacobs, M. B., & Pretorius, E. (2016). First-year seminar intervention: Enhancing first-year mathematics performance at the University of Johannesburg. *Journal of Student Affairs in Africa*, 4(1), 77-86. <https://doi.org/10.14426/jsaa.v4i1.146>
- [36] Leitzel, J. R. (1991). A call for change: Recommendations for the mathematical preparation of teachers of mathematics. *Mathematical Association of America*. <https://eric.ed.gov/?id=ED412109>
- [37] Colonna, F., & Easley, G. R. (2011). Hints on how to improve mathematics instruction. *Journal of e-Learning and Knowledge Society*, 7(3), 7–20. URL: <https://surl.li/twvkfn>
- [38] Bingolbali, E., & Monaghan, J. (2008). Concept image revisited. *Educational Studies in Mathematics*, 68(1), 19–35. <https://doi.org/10.1007/s10649-007-9112-2>
- [39] Cook, S. A., & Fukawa-Connelly, T. (2016). The incoming statistical knowledge of undergraduate majors in a department of mathematics and statistics. *International Journal of Mathematical Education in Science and Technology*, 47(2), 167–184. <https://doi.org/10.1080/0020739X.2015.1060642>

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Друшляк Марина, Лукашова Тетяна, Шамония Володимир, Семеніхіна Олена. Математика як бар'єр чи можливість: трансформація підходів до підготовки першокурсників для досягнення цілей сталого розвитку. *Журнал Прикарпатського університету імені Василя Стефаника*, 13 (1) (2026), 115-128.

У статті представлено результати дослідження проблеми математичної підготовки студентів першого курсу STEM-спеціальностей в Україні крізь призму ключових Цілей сталого розвитку (ЦСР), зокрема ЦСР 4 (Якісна освіта), ЦСР 8 (Гідна праця), ЦСР 9 (Інновації та інфраструктура) та ЦСР 10 (Зменшення нерівності). Недостатній рівень математичної грамотності серед випускників шкіл, підтверджений як міжнародними оцінюваннями (PISA 2022), так і Національним мультипредметним тестом (НМТ), створює суттєві труднощі

при переході до навчання у закладах вищої освіти. Аналіз відповідей 135 викладачів із 35 університетів виявив значні проблеми, серед яких: нездатність студентів працювати з формулами, виконувати перетворення, будувати й читати графіки, проводити математичні доведення, формулювати висновки і застосовувати математичні знання до практичних завдань. До ключових проблемних розділів шкільного курсу математики належать: функціональна змістова лінія, математичний аналіз, стохастика та планіметрія. Стверджується, що ці прогалини перешкоджають розвитку аналітичного, критичного та системного мислення, саме тих компетентностей, які є критично важливими для сталого розвитку. Зроблено висновок про необхідність системних змін на всіх етапах освіти, зокрема: перегляд шкільних навчальних програм, впровадження адаптаційних програм для першокурсників, розвиток цифрових та інтерактивних форматів навчання, інтеграція міждисциплінарного і контекстного навчання, посилення ціннісного аспекту освіти та сприяння партнерству між закладами загальної середньої освіти та університетами. Особливу увагу приділено розвитку мотивації, автономії, рефлексії та ціннісного ставлення до математики. Автори роблять висновок, що за наявності належної підтримки математика може стати не бар'єром, а ресурсом для розвитку ключових компетентностей, необхідних для сталого розвитку.

Ключові слова: математична підготовка, STEM-освіта, цілі сталого розвитку, студенти-першокурсники, адаптаційні курси, освітні втрати.