Current Challenges and Solutions in Physics Education

Presentation on Key Issues and Proposals

Assoc. Prof. Dr. Fabien Kunis
Faculty of Physics, Sofia University “St. Kliment Ohridski”

Objectives of the Presentation

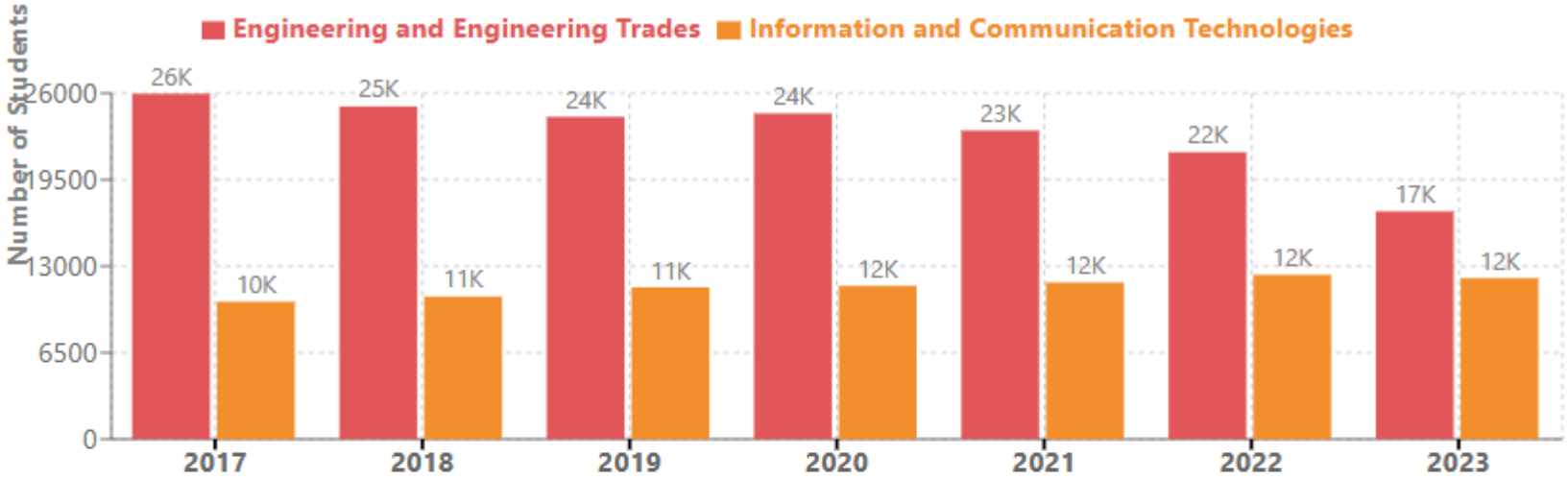
To outline the main challenges in physics and science education.

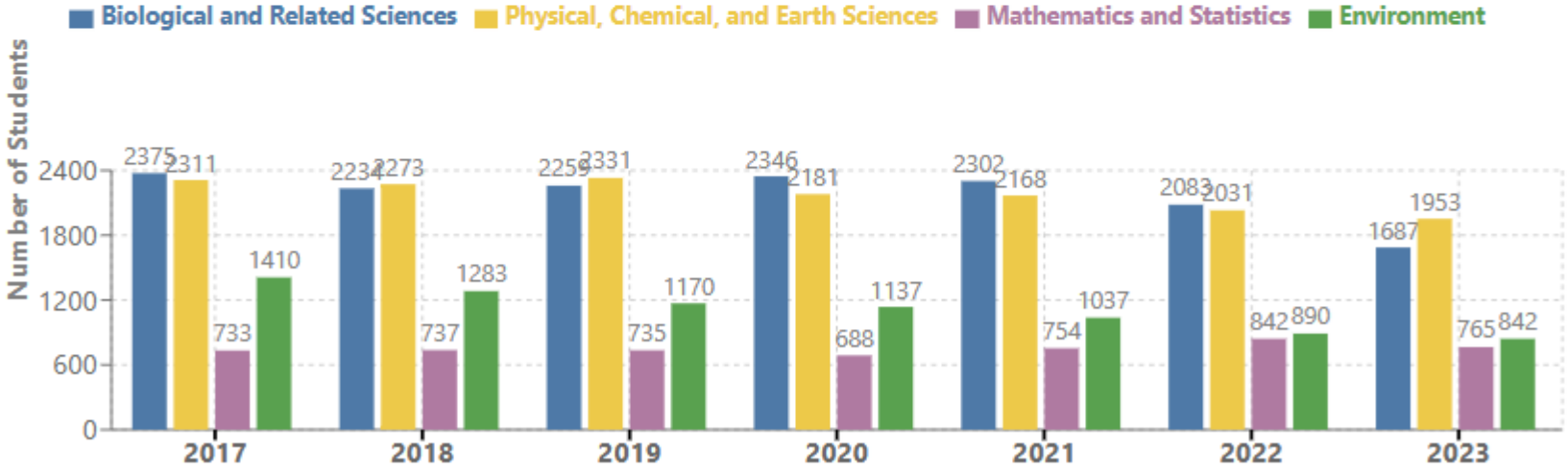
To propose possible solutions for overcoming these challenges.

Structure of Higher Education in Bulgaria

Degree Level	Duration of Study	Required Credits	Description
Professional Bachelor	Minimum 3 years	≥ 180 ECTS	Provides specialized professional training in specific fields. Offered by colleges or specialized higher education institutions.
Bachelor	Minimum 4 years	≥ 240 ECTS	Offers broad theoretical education in a chosen specialty. Conducted at universities or specialized higher education institutions.
Master	1-2 years post-Bachelor or 5 years post-secondary education	≥ 60 ECTS post-Bachelor or ≥ 300 ECTS total	Delivers advanced specialized training. Programs may follow a Bachelor's degree or be integrated from secondary education.
Doctor (Ph.D.)	Minimum 3 years	≥ 180 ECTS	Focuses on research and dissertation work. Requires a prior Master's degree.

Students


Engineering and Engineering Trades
Information and Communication Technologies
Number of Students
26000
19500
13000
6500
0
26K
10K
25K
11K
24K
11K
24K
12K
23K
12K
22K
12K
17K
12K
2017
2018
2019
2020
2021
2022
2023


Biological and Related Sciences
Physical, Chemical, and Earth Sciences
Mathematics and Statistics
Environment
Number of Students
2400
1800
1200
600
0
2375
2311
733
1410
2234
2273
737
1283
2259
2331
735
1170
2346
2181
688
1137
2302
2168
754
1037
2083
2031
842
890
1687
1953
765
842
2017
2018
2019
2020
2021
2022
2023

Students

	STUDENTS ENROLLED BY EDUCATIONAL-QUALIFICATION DEGREE											
	Biological and related sciences		Environment		Physical, Chemical, and Earth Sciences		Mathematics and statistics		Information and Communication Technologies (ICTs)		Engineering and engineering trades	
	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's
2017/2018	1943	432	1229	181	1774	537	635	98	8510	1824	21068	4892
2018/2019	1943	291	1075	208	1737	536	621	116	8859	1858	20603	4401
2019/2020	1961	298	1002	168	1770	561	618	117	9420	1988	19998	4226
2020/2021	1998	348	969	168	1707	474	584	104	9664	1860	20126	4358
2021/2022	1958	344	880	157	1720	448	631	123	9864	1910	19202	3995
2022/2023	1718	365	765	125	1585	446	742	100	10590	1766	17945	3618
2023/2024	1384	303	695	147	1541	412	693	72	10598	1502	14473	2652

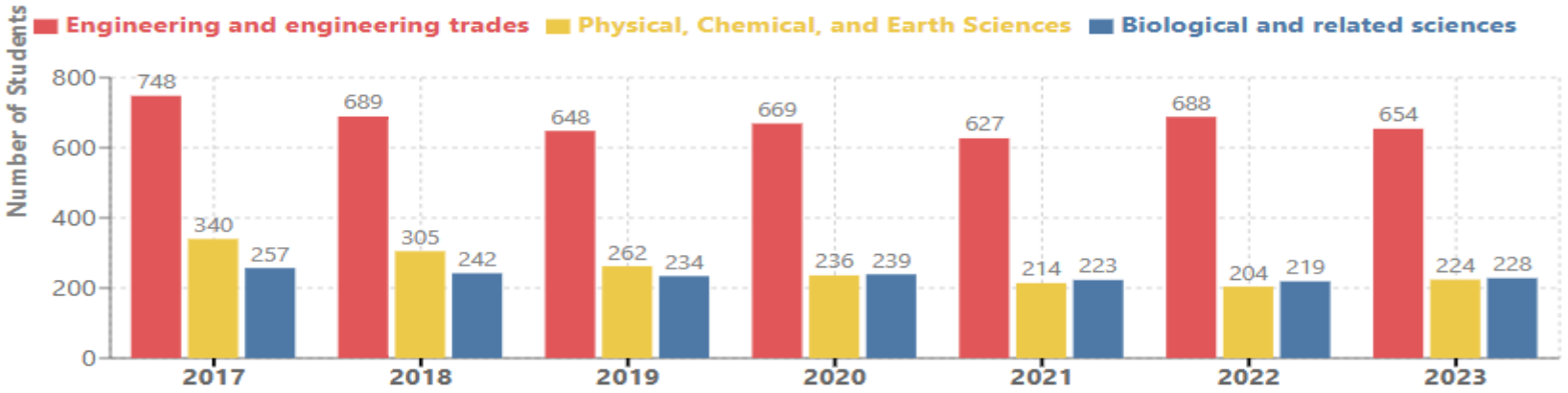
Key Insights:

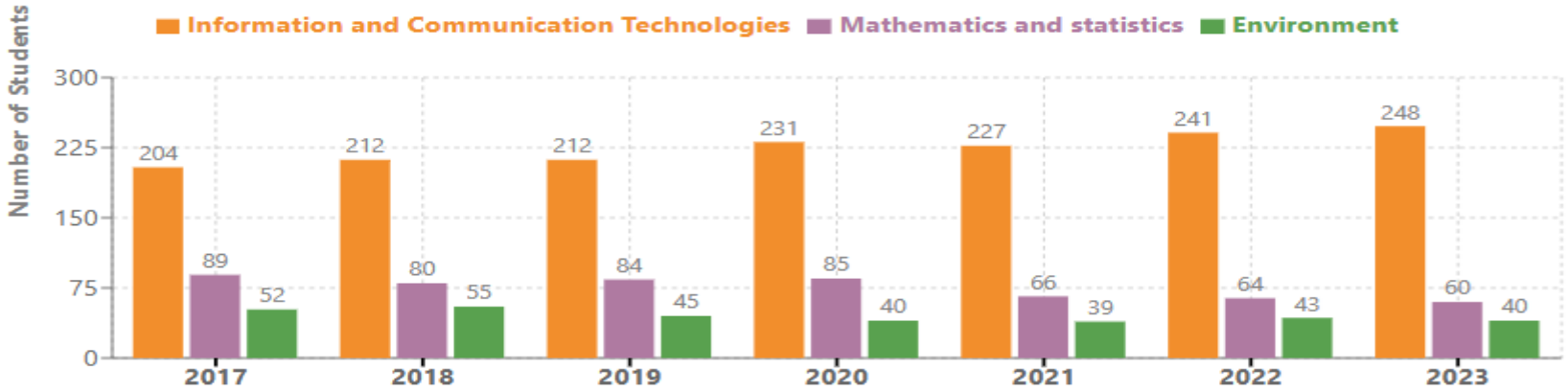
- Physical, Chemical, and Earth Sciences shows a gradual decline of 15% since 2017
- Engineering enrollment has declined by 34% since 2017
- ICT shows steady growth (+17% overall)
- Mathematics and Statistics is the most stable field
- Environment field shows consistent decline

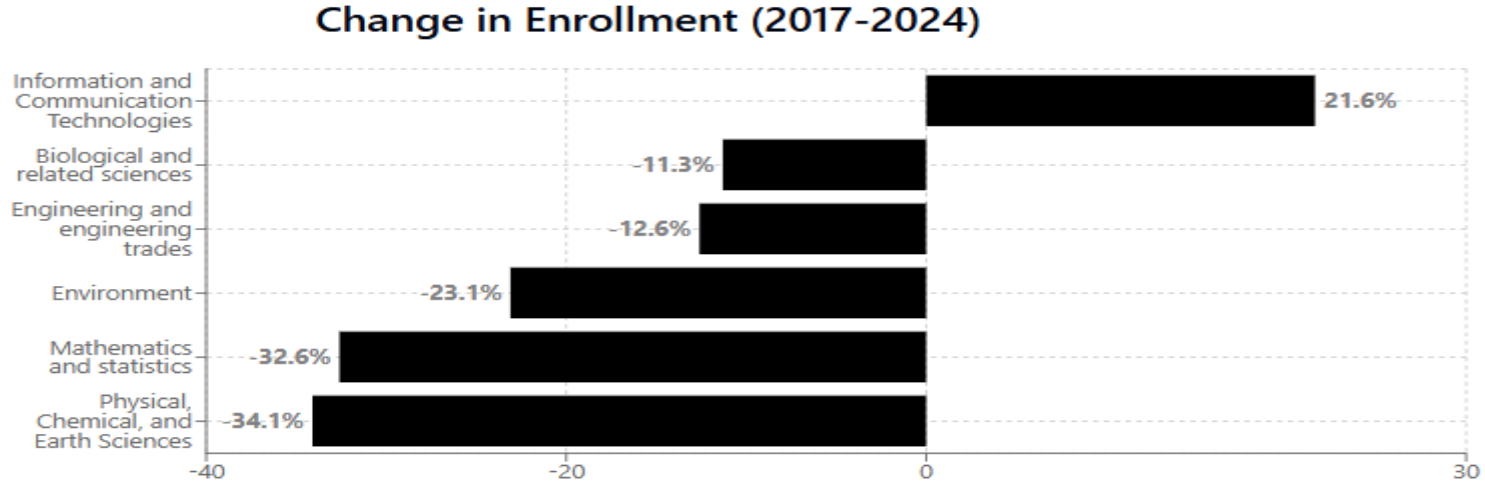
Sofia University "St. Kliment Ohridski", Faculty of Physics:

- **Total Bachelor's Students:** 445
- **Total Master's Students:** 167
- **Total Enrolled Students:** 612

STUDENTS ENROLLED AT DOCTORAL LEVEL





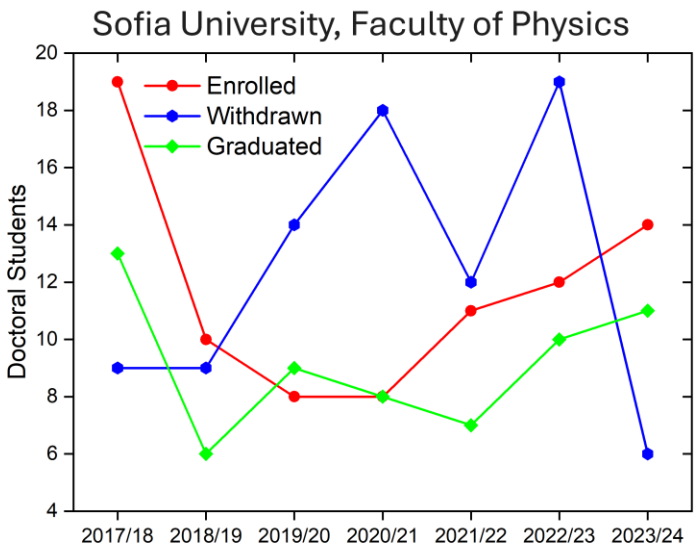


STUDENTS ENROLLED AT DOCTORAL LEVEL

	STUDENTS ENROLLED AT DOCTORAL LEVEL					
	Biological and related sciences	Environment	Physical, Chemical, and Earth Sciences	Mathematics and statistics	Information and Communication Technologies (ICTs)	Engineering and engineering trades
2017/2018	257	52	340	89	204	748
2018/2019	242	55	305	80	212	689
2019/2020	234	45	262	84	212	648
2020/2021	239	40	236	85	231	669
2021/2022	223	39	214	66	227	627
2022/2023	219	43	204	64	241	688
2023/2024	228	40	224	60	248	654

Key Insights:

- Physical, Chemical and Earth Sciences has seen the largest decline (-34%), dropping from 340 to 224 doctoral students
- ICT has shown the strongest growth (+21.6%), increasi from 204 to 248 students
- Engineering has declined by 12.6%, but remains the fi with the highest enrollment
- Mathematics enrollment has decreased by 32.6%
- All fields except ICT have experienced a net decline i doctoral enrollment



Structure of Secondary Education in Bulgaria

Educational Stage	Grades	Typical Age Range	Description
Primary Stage	1–4	7–10 years	Focuses on foundational skills in subjects like Bulgarian language, mathematics, and natural sciences.
Lower Secondary Stage	5–7	11–13 years	Builds upon primary education with a broader curriculum, including foreign languages, history, and geography.
Upper Secondary Stage	8–12	14–18 years	Divided into two phases:
			- *First High School Stage* (Grades 8–10): General education with options for specialized training.
			- *Second High School Stage* (Grades 11–12): Advanced specialized education preparing students for higher education or vocational paths.

Note: Completion of Grade 7 is marked by a Certificate for Basic Education, while successful completion of Grade 12 awards a Diploma of Secondary Education.

Structure of Physics Education in Bulgaria

Educational Stage	Grade	Subject	Instructional Hours	Notes
Primary Stage	3rd	Man and Nature	32	Introduction to basic natural science concepts.
	4th	Man and Nature	68	Expansion of knowledge on natural phenomena.
Lower Secondary Stage	5th	Man and Nature	86	Further exploration of natural science concepts.
	6th	Man and Nature	86	Preparation for specialization into distinct scientific disciplines.
	7th	Physics and Astronomy	54	Focus on electrical, light, and sound phenomena, as well as basics of astronomy.
Upper Secondary Stage	8th	-	-	In most schools, natural sciences (physics, chemistry, biology) are not studied in this grade.
	9th	Physics and Astronomy	90	Covers topics such as electricity, magnetism, oscillations, and waves.
	10th	Physics and Astronomy	72	Continues with more complex concepts, preparing students for specialized education.
Upper Secondary Stage	11th	Specialized Physics Training	180	Only for students who have chosen the "Physics and Astronomy" profile. Others conclude their physics education after 10th grade. Approximately 1,000 students per academic year opt for this specialization.
	12th	Specialized Physics Training	155	In-depth study, preparing for higher education or specialized professions.

Note: In 11th and 12th grades, specialized physics training is available only to students who select this profile. For all other students, formal physics education concludes after the 10th grade.

PISA Performance: Bulgaria vs. OECD Average (2012–2022)

Year	Reading (Bulgaria)	Reading (OECD Average)	Difference	Mathematics (Bulgaria)	Mathematics (OECD Average)	Difference	Science (Bulgaria)	Science (OECD Average)	Difference
2012	436	496	-60	439	494	-55	446	501	-55
2015	432	493	-61	441	490	-49	446	493	-47
2018	420	487	-67	436	489	-53	424	489	-65
2022	404	476	-72	417	472	-55	421	485	-64

Key Observations:

•**Declining Performance:** Between 2012 and 2022, Bulgaria's scores in all three domains have shown a downward trend.

•**Below OECD Average:** Throughout this period, Bulgarian students consistently scored below the OECD average in reading, mathematics, and science.

•**Widening Gaps:** In 2022, the gap between Bulgaria and the OECD average was largest in reading (72 points), followed by science (64 points) and mathematics (55 points).

Problem 1: Absence of Natural Sciences in 8th Grade

- The majority of students do not study natural sciences in the 8th grade.
- In the 7th grade, the focus is primarily on preparation for the National External Assessment (NEA) in Bulgarian Language and Literature (BLL) and Mathematics.
- The second semester of the 7th grade is almost entirely dedicated to NEA preparation.
- This creates a "gap" of approximately a year and a half without systematic instruction in natural sciences.

Solution: Introducing Natural Sciences Education in 8th Grade

- Enhancing PISA Performance: Consistent study of natural sciences in the 8th grade provides continuous and in-depth learning, potentially leading to improved outcomes in international assessments like PISA.
- Developing Scientific Literacy: Early and uninterrupted exposure to natural sciences fosters scientific literacy, enabling students to comprehend and apply scientific concepts in daily life.
- Promoting Critical Thinking: Engaging with natural sciences cultivates skills in analysis, evaluation, and synthesis of information, forming the foundation for critical thinking and informed decision-making.
- Preparing for STEM Careers: Introducing natural sciences at an early stage motivates students to pursue education and careers in STEM fields (Science, Technology, Engineering, and Mathematics), which are vital for economic development and innovation.
- Bridging the Educational Gap: Incorporating natural sciences into the 8th-grade curriculum addresses the existing hiatus in instruction, ensuring a seamless transition and continuity in knowledge acquisition.

Problem 2: Limited Enrollment in "Physics" Profile after 10th Grade

- Data: Since 2022, approximately 1 000 students annually engage in specialized Physics and Astronomy (PA) training. Of these, about 5% opt to take the State Matura Exam (SME) in PA as their second mandatory exam.
- Causes: Insufficient interest and motivation among students, coupled with a lack of awareness regarding career opportunities in the field.
- Risk: Potential shortage of STEM professionals in the future, leading to diminished long-term competitiveness of the Bulgarian economy.

Year	Number of Students	Average Score (out of 100)
2022	44	48
2023	49	64
2024	59	54

Yearly Data for the Second Mandatory SME.
Source: Ministry of Education and Science (MES)

Possible Solution: Integrated General Education Subject in Natural Sciences for 11th and 12th Grades

- **Concept:** Develop a comprehensive subject for 11th and 12th grades that combines physics, chemistry, biology, and elements of other STEM disciplines.
- Structure of the Subject:
  - **Project-Based Learning:** Students engage in real-world projects, solve case studies, and apply knowledge from multiple disciplines.
  - **Teamwork and Presentations:** Fosters communication skills, teamwork, and critical thinking.
  - **Optimal Use of STEM Laboratories:** Ensures effective utilization of school STEM facilities.

Expected Outcomes:

- **Enhanced Understanding:** Improved comprehension of the interconnections between various scientific fields.
- **Increased Interest and Practical Preparation:** Heightened enthusiasm and better practical readiness for future STEM specializations..

Possible Solutions: Encouraging Interest and Providing Support

- Encouraging Interest:
  - Promote career opportunities in the sciences.
  - Organize extracurricular activities, laboratory visits, and tours of innovative companies..
- Support for Teachers:
  - Enhance qualifications and facilitate the sharing of best practices.

Problem 3: Lack of a Mandatory State Exam in Mathematics or Natural Sciences

- **Issue:** Currently, Bulgaria does not require students to take a mandatory State Matura Exam (SME) in Mathematics or Natural Sciences.
- **Why is this a problem?**
- **Lower student motivation:** Without a compulsory exam, many students put less effort into studying mathematics and sciences, treating them as secondary subjects.
- **Declining STEM proficiency:** A lack of emphasis on mathematics and science in final assessments contributes to weaker knowledge in these areas, affecting students' readiness for STEM-related university programs.
- **Impact on PISA performance:** Countries with stronger mathematics and science education tend to perform better in international assessments like PISA.
- **Limited career opportunities:** The absence of a mandatory STEM-related exam reduces the number of students prepared for technical and scientific careers, which are crucial for economic growth and innovation.

Solution: Introducing a Mandatory Mathematics Exam in 12th Grade

- Enhancing PISA Performance: A compulsory final exam in mathematics would ensure consistent engagement with the subject throughout high school, leading to better results in international assessments like PISA.
- Improving Scientific Literacy: Mathematics is fundamental to logical reasoning, data interpretation, and problem-solving—skills essential for scientific literacy in the modern world.
- Developing Critical Thinking: Studying mathematics at an advanced level fosters analytical skills, structured thinking, and the ability to evaluate complex problems—crucial competencies for decision-making in any field.
- Preparing for STEM Careers: A mandatory math exam would encourage more students to pursue careers in Science, Technology, Engineering, and Mathematics (STEM), areas that are in high demand globally.

Solution: Introducing a Mandatory Mathematics Exam in 12th Grade

- Better Prepared University Students: Many university programs, including economics, engineering, and natural sciences, require strong mathematical skills. Ensuring all graduates complete a mathematics exam would lead to better-prepared students for higher education.
- Boosting Business and Technological Development: Strong mathematical skills are key for technological innovation, economic competitiveness, and workforce readiness. Countries that emphasize mathematics education produce more engineers, data scientists, and tech professionals, driving business growth and national development.
- **Eliminating the Ineffective National External Assessment in 10th Grade:** The National External Assessment (NEA) in **Bulgarian Language and Literature** and **Mathematics** after 10th grade has proven to be an inefficient use of the system's resources. The exam does not yield meaningful results or insights that contribute to improving students' educational trajectories. Removing this assessment would allow for better allocation of resources towards strengthening final examinations, such as a compulsory mathematics exam in 12th grade.

Conclusion

- **Systematic Approach:** Reforms should be implemented as part of a comprehensive strategy, encompassing curriculum development, teaching methodologies, exam formats, and teacher qualification programs.
- **Collaboration:** Effective change requires joint efforts from the Ministry of Education, schools, parents, employers, and the non-governmental sector to ensure a holistic and sustainable impact.
- **Future Outlook:** By providing a well-structured and up-to-date education in physics and natural sciences, we can nurture the next generation of scientists, innovators, and engineers who will drive societal and economic progress.
- **Investing in Education = Investing in the Future**
  Strengthening STEM education, ensuring continuity in science instruction, and making mathematics a core requirement will empower students with the skills needed for the 21st-century workforce.
- **Long-Term Impact:**
  Countries that prioritize science and mathematics education consistently lead in technological advancements, innovation, and economic growth. Bulgaria has the opportunity to elevate its educational system to better prepare students for the challenges of tomorrow.
- **Call to Action:**
  The time for change is now. By implementing strategic reforms, fostering scientific curiosity, and providing students with the right tools, we can create a future where Bulgaria thrives as a leader in education, research, and innovation.