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Symbiotic Relationships in Overcoming Challenges in Terms of Natural Sciences Education

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ABSTRACT

This brief investigation traces the formation of the educational system to its current stage. The data analyses are referred to the achieved results of the educational system. This study seeks perspectives from both teachers and students, aiming to comprehend the collective objectives in their symbiotic relationships. The ensuing report contemplates some of the most pressing challenges, linked to human methods of processing information and forming knowledge. Consequently, a practical 5-steps solution is unfolded. Attached are auxiliary materials which would facilitate the execution of a complex project-based training, ultimately resulting in the establishment of an innovative approach in Natural Sciences Education.

Keywords: symbiosis, education, PISA, assessment, innovations, Bulgarian students, natural sciences, industrial revolution; Bulgarian teachers; Project-Based Learning Approach, interdisciplinary practices.

INTRODUCTION

Symbiosis, as a biological term, describes "Interspecific interaction in which two species live together in a long-term association" [1]. Just as symbiosis in biology illustrates a mutualistic relationship where each organism provides for the other's survival, the state of the Bulgarian education system reflects a parallel dynamic. Similarly, as organisms rely on one another for essential resources, the education system and its participants – students, teachers, and society - depend on each other for the exchange of knowledge, skills, and societal progress. However, compared to any symbiotic relationship, when one partner fails to adequately meet the needs of the other, imbalance occurs. In this case, the perceived outdatedness and inadequacy of the Bulgarian education system threaten to disrupt the symbiotic equilibrium between education and societal needs, potentially jeopardizing the development and prosperity of future generations. Thus, understanding and addressing these deficiencies within the education system is crucial for fostering a harmonious symbiotic relationship between education and societal advancement. Presently, the Bulgarian education system is often perceived as outdated and inadequate in meeting the needs of the current generation.

A 2012 PISA study provides evidence that

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certain innovations need to be implemented [2 - 4]. The Program for International Student Assessment - PISA, conducted by the Organization for Economic Co-operation and Development (OECD), stands as the largest and most representative international formative assessment of students. It evaluates the effectiveness of school education, by measuring the knowledge and skills of 15-16-year-old students in three areas: Reading, Mathematics and Natural Science. The nationwide sample, comprising over 5280 students born in 1996, reveals a concerning trend. A chart succinctly summarizes this alarming situation, indicating that Bulgaria is ranked 42nd place out of 65 countries based on the Percentage of 15-year-old students performing at PISA science literacy proficiency levels 5 and above and below level 2, by education system: 2012 (Fig. 1) [2, 5]. According to the statistics, 37 % of the Bulgarian students indicate a drastically low level of literacy proficiency, while only 3 % demonstrate solid skills and knowledge proven by the test.

According to this study, Bulgarian students mostly fall into the second and the third category, which alerts that those students have significant gaps in Natural Sciences. They can only recognize a clearly described scientific problem in uncomplicated situations, but they lack the ability to determine and explain differences between two graphs (level 4), find connections within their knowledge (level 5) and demonstrate scientific approach in completing tasks of a great variety (level 6) [6].

The latest conducted PISA assessment in 2022 indicates a further decline of 25 points in the results of Bulgarian students in Natural Sciences. The average score that guarantees the presence of basic acquired knowledge is 491 points. When comparing the results of PISA 2012 and PISA 2022 (Fig. 2), it becomes evident that there is a registered rapid decline for a historically short period of 10 years. The average student score has significantly decreased by 25 points. Despite the recorded steep drop, students continue to reach the Second Level, which is determined as "Second Level" (from 409 to 484 points).

The second level is the critical borderline of students' knowledge and skills. Students with results below the second level have significant gaps in their preparation in natural sciences and lack the necessary knowledge and skills that PISA defines as a prerequisite for successful realization. The tasks at the second level are formulated in a simple and familiar context. To solve them successfully, students need to make inferences based on simple experiments and studies; to identify the relationship between a simple model and the phenomenon it represents, as well as to interpret literally the results from a scientific study or technological solution [7, 8].

"Note: White dots indicate mean-performance estimates that are not statistically significantly above/below PISA 2022 estimates. Black lines indicate the best-fitting trend."

An interactive version of this figure is available at https://oecdch.art/a40de1dbaf/C875.

Source: OECD, PISA 2022 Database, Tables I.B1.5.4, I.B1.5.5 and I.B1.5.6.

- Average results for the year 2022 (Fig. 3) showed a decline in comparison to 2018 in both mathematics and reading, while remaining approximately consistent with the 2018 outcomes in science.
- PISA 2022 results are among the lowest ever recorded in all three subjects. An analysis encompassing all PISA assessments conducted since 2006 reveals a discernible pattern across all three subjects: an initial increase in performance, followed by a decrease that started around 2015. This decline culminated in mean performance levels in 2022 that closely approximate those observed in 2006. Notably, the difference between 2012 and 2022 mean scores in all subjects surpasses the typical academic progress made by students around the age of 15 over an entire school year.

PISA 2022 RESULTS: FACTSHEETS –

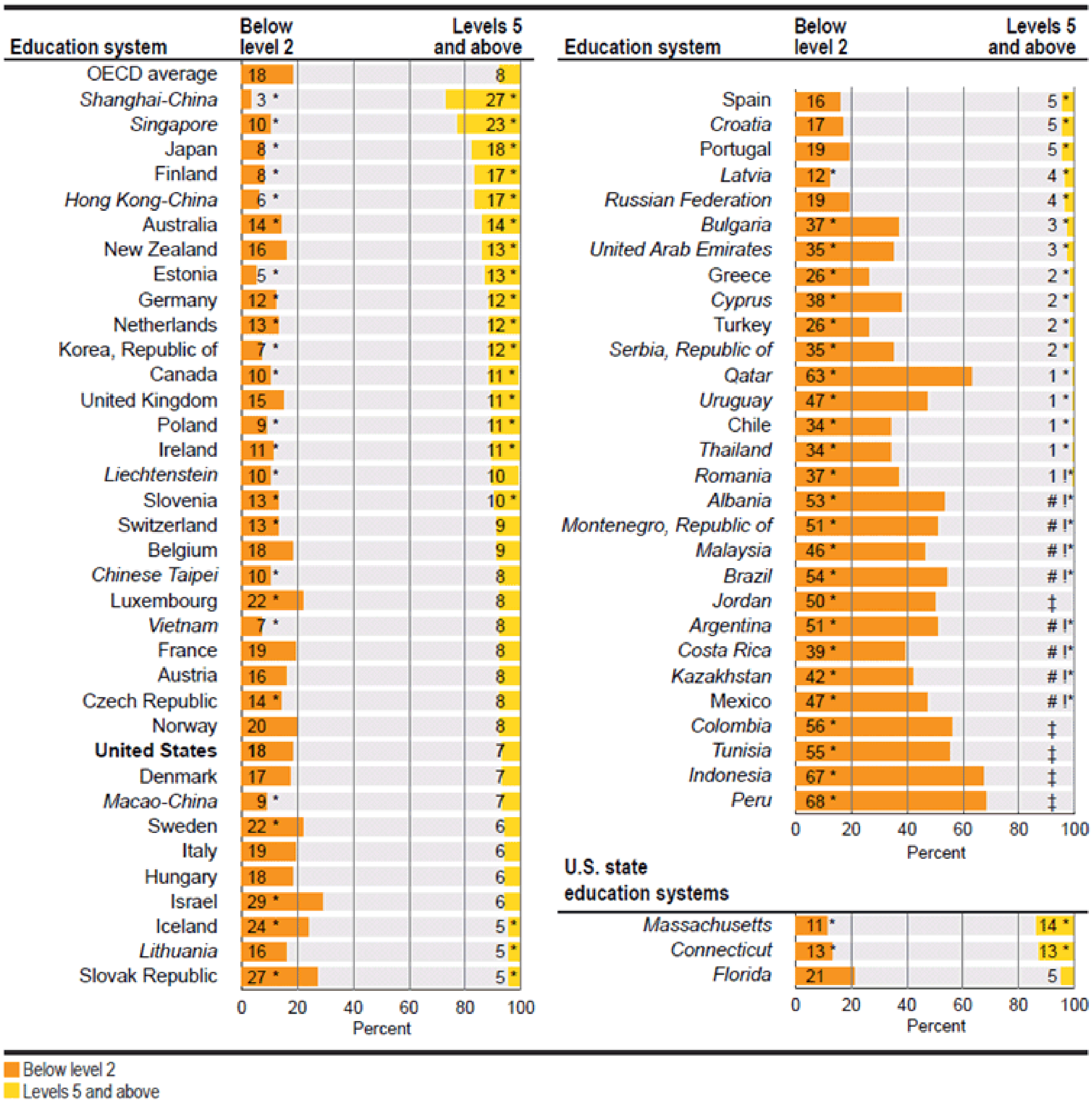

Fig. 1. Percentage of 15-year-old students performing at PISA science literacy proficiency levels 5 and above and below level 2, by education system, 2012.

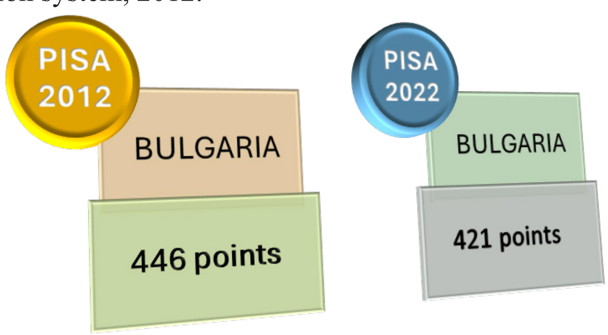

Fig. 2. Average score (in points) in Natural Sciences of students in Bulgaria according to PISA 2012 and PISA 2022.

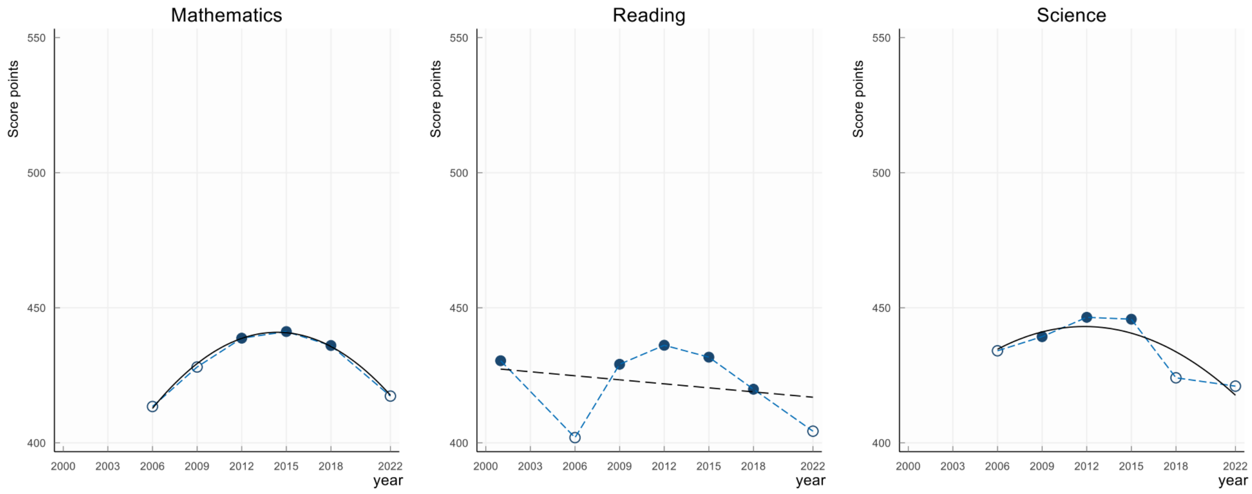

Fig. 3. Trends in performance in mathematics, reading and science.

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Over the most recent period (2018 to 2022), the gap between the highest-scoring students (10 % with the highest scores) and the weakest students (10 % with the lowest scores) did not change significantly in mathematics, reading and science. In mathematics, performance dropped to a similar extent for both high- and low-achievers.

• Compared to 2012 the proportion of students scoring below a baseline level of proficiency (Level 2) increased by nine percentage points in mathematics; by 13 percentage points in reading; and by 11 percentage points in science [9, 10].

As PISA stands as an internationally accredited and recognized study, the statistics it provides demand serious consideration [10]. It is indisputable whether current methods and practices are effective when assessed through one of the most validated global studies along with many analogous ones. While a vast number of studies have been conducted, the topic of today's education garners attention more than ever before. A plethora of studies are conducted, and events, forums and discussions are constantly held, aiming to define challenges in education and arriving at a general solution.

Years ago, people classified the natural sciences into various disciplines to facilitate their study. However, constant new discoveries necessitated this division, leading to a contemporary predicament of reduced comprehension [11, 12]. Furthermore, during The Industrial Revolution, the educational system was tailored to produce skilled professionals, prioritizing the application of knowledge over a profound understanding in science [13 - 16]. Factories operated efficiently, with a minority possessing sufficient comprehension to oversee them. Nonetheless, a global challenge in present and future years lies in the scarcity of leaders who possess a comprehensive understanding of science, rather than merely applying it mechanically. Outdated educational methodologies persist in attempting to shape new generations. The paramount issue confronting humanity is the restoration of interconnections among the sciences to foster genuine comprehension [6, 17].

To achieve a high level of cognitive skills and scientific reasoning, there is a requisite for a completely innovative approach to education

[18]. The traditional classroom-centric system is presently inadequate in addressing students' need to establish connections and apply knowledge within problem-solving context [12, 19].

EXPERIMENTAL

We conducted a survey among students to inquire about the specific challenges they encounter in studying natural sciences. The research involved 184 students currently enrolled in the IXth and Xth grades at Geo Milev English Language School in Rousse. The following conclusions are drawn:

The most repeated response is lack of understanding the connection with everyday life and other sciences. Only 4.9 % of students do not encounter difficulties in studying natural sciences. We conducted a study among teachers, with the aim of summarizing the difficulties teachers face in presenting accessible, understandable, and applicable educational materials. The results, provided by teachers among two High Schools of Rousse, are summarized as follows.

All the mentioned difficulties lead to distancing from the essence of the teaching profession and limit the teacher's ability to be a guide in a quality educational process.

RESULTS AND DISCUSSION

To support students' research aspirations and intellectual pursuits and collectively overcome the limitations of the current educational system, it is imperative for teachers and students to engage in symbiotic interaction, moving beyond the basics and reaching the pinnacle.

If there is insufficient time and opportunity during regular classes to establish connections, draw parallels between subject areas, or explain the practical applications of what is learned, finding alternative ways for this to happen becomes crucial.

In response, we propose a comprehensive interdisciplinary project-based learning approach that fosters the exploration of connections between Chemistry, Biology and Physics and the application of knowledge throughout the

Students
• Find lessons long and complex;
• Have difficulties with terminology, formulas, and laws with complicated explanations;
• Believe the time allocated for exercises is insufficient;
• Feel inclined to skip certain topics;
• Have difficulties in concentration.

Fig. 4. Result from the study involving 184 students from Geo Milev English Language School in Rousse, currently studying in IXth and Xth grade.

Teachers
• Experience administrative workload;
• Face a lack of video materials available in Bulgarian that illustrate processes;
• Find time for summarization and exercises insufficient;
• Feel forced to compensate for lack of a set of selected resources approved by the Ministry of Education and Science.

Fig. 5. Results from the study covering the teachers from Geo Milev English Language School in Rousse.

entire academic year [11, 20, 21, 22, 23]. We have developed six themes (Fig. 6) for both ninth and tenth graders, which can be provided for development and exploration by classes.

We anticipate that classes will be divided into working groups and will report on their project work monthly using a specially designed online planner [24 - 26]. The project task themes cover knowledge studied in the respective academic year across main natural sciences disciplines

Sample Themes for Project-Based Approach in Natural Sciences	
IX Grade	
No	Topic
1.	Matter Exchange – Law of Energy Conservation; Types of Energy; Diffusion; Heat Exchange (Heat Balance and Temperature in Living Organisms); Biochemical Reactions (Krebs Cycle and Calvin Cycle)
2.	Biocurrents – Electrical Phenomena; Types of Energy; Law of Energy Conservation; Nervous Signaling (Calcium, Magnesium Ions, and Neurotransmitters)
3.	Voice and Hearing – Auditory and Vocal Organs; Mechanical Vibrations; Application of Ultrasound in Medicine; Electric Current
4.	Origin of Life on Earth – Common and Different Between Living and Non-Living Nature; Biomolecules; Forces of Attraction; Distribution of Chemical Elements in Space, Earth, and the Human Body
5.	Olfaction and Taste – Mechanism of Perception of Chemical Substances; Sensory Memory; Transmission of Nervous Signaling to the Central Nervous System
6.	Sustainable Development and Healthy Lifestyle – Types of Energies; Structure of Matter; Thermal Pollution; Gas Emissions; Nitrogen and Living Organisms; Nitrogen Fertilizers and Nitrates; Harmful Effects of Nitrogen Oxides; Importance of Minerals for Health; Exhaust Gasses from Internal Combustion Engines; Radioactivity; Isotopes
X Grade	
1.	Radioactive Radiations – Health effects on the Human Body; Microwave and Nuclear Radiation; Cosmic Radiation; Radon
2.	Isotopes – Isotopes for Obtaining New Materials; Atomic Structure; Role of Isotopes in Medicine
3.	Electromagnetism – Influence on Humans; Chemical Substances According to Their Electrical and Magnetic Properties; Earth's Electromagnetic Field and Its Importance for Earth's Life
4.	Light – Vision, Lasers, and Laser Therapies in Medicine and Cosmetics; Spectrometers; Visible and Invisible Radiations, or What Remains Hidden from the Eyes; Importance for Chemistry; Einstein and Time Travel
5.	Electronics and Electrical Engineering – Electricity Generation; Artificial Intelligence; Evolution; History and Future of Electrical Power Supply
6.	Ecology – Biological, Physical, and Chemical Pollutants; Types of Energies; Structure of Matter; Thermal Pollution; Gas Emissions; Nitrogen and Living Organisms; Nitrogen Fertilizers and Nitrates; Harmful Effects of Nitrogen Oxides; Importance of Minerals for Health; Exhaust Gasses from Internal Combustion Engines; Radioactivity; Isotopes

Fig. 6. Sample Themes for Project-Based Approach in Natural Sciences for IX and X Grade.

(Physics, Chemistry, and Biology). Students are required to employ a scientific approach, critical thinking, search for connections, deep reflection, and logical deductions [27]. The themes are exemplary and can be reorganized or modified by each teacher according to their needs and expected outcomes.

In suggesting this approach, we have also developed a list of assessment criteria (Fig. 7), considering both teachers' and students'

CRITERIA FOR ASSESSING PROJECT-BASED LEARNING IN NATURAL SCIENCES		
No	CRITERIA	POINTS
1.	Structuring and Formulating the Project Task, Covering Information from the Curriculum	5
2.	Data Analysis Skills, Describing Graphs, and Conducting Experiments. The student demonstrates the ability to structure and formulate the project task, incorporating information from the curriculum.	10
3.	Scientific Explanation of Real Situations, Argumentation, and Drawing Conclusions. The student shows skills in analyzing data, describing graphs, and conducting experiments.	15
4.	Teamwork – Degree of Participation in Execution, Communicative Skills, and Even Distribution of Tasks	10
5.	Theoretical Foundation – Demonstration of Knowledge, Scientific Language, and Terminology	10
6.	Work with Information Sources – At Least 2 Types, Reliable, Different from the Textbook	5
7.	Presentation Skills – Language Proficiency and Lexical Resources	5
8.	Topic Presentation – Demonstrating Knowledge of the Content, Body Language	5
9.	Comprehensiveness – Complete Presentation, Detail, Without Reading	10
10.	Adherence to Deadlines	5
11.	Time Organization for Presentation	5
12.	Clarity - Clearly Presented and Accurate Product. Clarity is assessed based on the quality of visual materials, such as well-organized tables, appropriately concise text, and suitable illustrations in the presentation	10
13.	Creative Execution – Original Thinking and Presentation of Ideas	5
14.	Self-Assessment of the Student	5
Range of marks 0 – 30 points: *Poor (2)* 31 – 50 points: *Fair (3)* 51 – 70 points: *Good (4)* 71 – 94 points: *Very Good (5)* 95 – 105 points: *Excellent (6)*		

Fig. 7. Criteria for assessing project-based learning in natural science.

perspectives.

It is crucial that a student is frequently placed in a situation where they measure their own effort and convert it into a grade. Therefore, the final score is variable for both the student and the teacher [28]. The criteria are formulated, emphasizing on some of the most important skills that distinguish a well-prepared student and future job applicant from a mediocre one.

This project-based method aims to foster consecutiveness among students over an extended period (one academic year). Thus, young individuals would form strong habits in their studying routine [29]. Furthermore, through the requirement of regularity, students will consistently seek additional information to report their monthly progress in the specially-designed programme and further develop their chosen topic, incorporating real-life examples.

The *Spaces by Wix* (Fig. 8) application was used for visualization, but similar software branches could yield comparable results. In addition, we established a programme focused on tracking the students' progress and work monthly. They would receive notifications on a certain date to record the progress they have made for the period given. This approach allows both the teacher and team members to collectively monitor progress, provide feedback, and engage in trouble-free interactions. As a result, the tutor can maintain a balanced structure within a large group while applying an individual approach based on the entered application data.

Scanning the generated QR code directly sends users to the programme, which guides them towards 18 steps throughout the survey they conduct. Named the *Hansel and Gretel Approach*, the programme aims to help students understand its main objective, which is to keep them consistent while completing steps.

Fig. 8. QR code to online programme tracking the students' progress and regular assignments, called *Hansel and Gretel Approach*.

A potential challenge lies in motivating students. Despite the obligatory nature of the work and the future assessment, there remains a risk that some students may not be swayed by an unsatisfactory final grade, which might be deemed satisfactory by others. Seeking opportunities to foster other types of internal motivation, we are planning a wide-audience event to be scheduled for the end of the school year. Each group will be required to explain their prolonged teamwork and present a dissertation in front of all their classmates, parents and most importantly – the teachers of the three disciplines (Chemistry and Environmental Protection, Biology and Health Education and Physics and Astronomy). The three specialists will assess students separately and independently, considering the specificities of their subjects and the connections made to their subject within the topic. By aiming to impress a broad audience, students would not allow themselves to show incompetence in their own research. Every student who receives the task would be greatly motivated to excel, demonstrating a wide variety of skills and a genuine understanding of Natural Sciences as a unified discipline (Fig. 9).

Fig. 9. Steps to completing project-based learning approach in Natural Sciences.

CONCLUSIONS

The First and The Second Industrial Revolutions might have compelled humanity to develop narrow specializations and deepen its expertise in specific areas. The contemporary digital revolution faces the challenging task of fundamentally changing this approach. In the last century, human knowledge has become incomparably greater, yet the interrelationships humanity explores are significantly fewer. Standing on the threshold of the fourth industrial revolution, humanity, and the educational system in particular, must inevitably focus on the methods used in education. The cultivation of a set of complex skills for integrating and applying knowledge is a key step in developing the collective intellectual power of the upcoming era. In the 21st century, Homo sapiens has all the information just a click away, yet humanity needs to delve into its meaning.

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