

Enhancing High School Science Education: Integrating Physics, Technology Innovation, and Sustainable Development

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The interest of youth in STEM, particularly physics and engineering studies, is experiencing a decline, despite the pressing need for a new generation of specialists to drive cutting-edge research crucial for innovation, economic progress, and sustainable development. To address this challenge, new approaches are required to inspire more young talents to pursue careers in physics and STEM fields. Contextualizing these disciplines within real-life scenarios, especially those related to sustainable development, proves to be a potent tool for fostering students' interest and appreciation. The pilot project Youth@STEM4SF (Youth at STEM for Sustainable Future), launched in Switzerland in May 2023 with the support of the Swiss Physical Society (SPS), the Swiss Academy of Natural Sciences (SCNAT), and the Swiss national competence center for education about sustainable development, education21, represents an innovative high school program. This initiative presents physics and STEM subjects in the context of real-life situations and sustainable development by integrating applied R&D in physics-based industries and showcasing inspirational role models in these fields during thematic school days. The primary objective is to engage young talents, with a particular focus on encouraging girls to pursue physics and other basic sciences studies. Additionally, the program aims to educate future societal leaders on the value of science in our lives and its contribution to a sustainable future. Measurable impacts, including changes in interest and attitude, have been assessed, and initial results are highly encouraging. The ultimate goal is to achieve a broad impact on a national and international level, facilitated by aligning with new high school educational plans and gaining recognition for the approach from educational authorities.

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1. Introduction / Motivation

The imperative for a new generation of STEM specialists is clear, especially in the context of addressing global challenges outlined by the United Nations Sustainable Development Goals (SDGs), such as climate change, energy, and health [1]. Despite the growing demand for STEM-related jobs, particularly in physics and engineering, there is a concerning decline in the interest of youth, particularly among girls, in pursuing careers in these fields. This trend is alarming given the anticipated creation of 7 million new STEM jobs in Europe by 2025, outpacing the availability of skilled individuals to fill these roles [2]. While physics-based industries significantly contribute to European economies [3, 4], the persistent challenge of recruiting high-quality engineers is exacerbated by a substantial gender gap.

Compounding this issue is the prevalent misperception that basic research, especially in physics, is complex, abstract, uninteresting, exclusive, and lacking appealing career prospects [5]. Much of this perception can be attributed to the limited exposure of high school (HS) students to modern natural sciences in their curricula [6], creating a substantial gap between educational content and cutting-edge scientific knowledge. This disconnection from real-life applications and societal challenges further contributes to the lack of information about the concrete usefulness of these subjects [7]). While there are numerous extracurricular programs offered by the scientific community to bridge this knowledge gap, their impact is often limited as they cater to students who are already inclined towards science. Additionally, the participation in these programs depends on the motivation, awareness, and time constraints of science teachers, who face limitations in introducing new subjects not aligned with existing curricula. Therefore, while providing engaging activities and content is crucial, a top-down approach that officially endorses and integrates such content into the educational system is vital for real and sustainable implementation of new subjects and teaching methodologies. Effectively addressing the counterproductive reality of waning interest in physics and engineering requires a systemic transformation of science education at the HS and even primary school levels.

2. Strategic context

In navigating the challenge of declining interest in physics and STEM fields, it becomes imperative to discover innovative pathways that effectively inspire and cultivate the talents of young individuals while fostering awareness and appreciation for these disciplines in society. While the connection between research and society is a functional approach, it remains an underexplored avenue. While a minority of students may naturally gravitate towards technical subjects [8,9], a substantial majority finds physics more compelling when presented authentically in relation to nature, the universe, human applications, and within the context of societal relevance, such as sustainable development (SD) [10,11,12]. This tangible context serves as a significant source of inspiration, particularly for girls who may be undecided about their career paths [13, 14, 15, 16].

However, the strategic role of basic sciences, fundamental research, and STEM education in driving innovation to address global challenges (SDGs) is not sufficiently emphasized or understood. The applications of these disciplines in everyday life, their socio-economic impact, the potential for vast and intriguing career opportunities both within and beyond academia, and the crucial importance of the scientific method for fact-based decision-making are often overlooked by society and in schools [17,18]. Thus, SD is still generally considered as a topic for specialists on economics, law, social sciences, finance and international relations [19]. Furthermore, SD is typically addressed in schools only during geography and economy lessons, with a lack of teaching resources compatible with STEM curricula, leading students to perceive SD as unrelated to physics and STEM. This creates a gap in awareness about the role of scientists in achieving the SDGs.

In the current societal and political context, the global societal challenges and SD are, however, the key strategic entry point to create an effective and appreciative dialogue of scientists with

society and even an access point to shape the official school science education. Thus, it is important to play this card by science community given two strategically relevant facts: Firstly, the science community holds a vital card to play in light of two significant facts: the period 2024-2033 has been declared by the UN as the International Decade of Sciences for Sustainable Development, following UNESCO's proclamation of 2022/2023 as the International Year of Basic Sciences for Sustainable Development [20,21]. This official call urges collaboration among the scientific and policy-making communities and other societal stakeholders to promote a scientific approach for informed policymaking, ensuring sustainable governance [22]. Secondly, education for sustainable development is recognized as a goal in itself as a means of attaining the SDGs [23], promoted in various countries, including Switzerland. The new Swiss high school education plan [24, 25], currently in consultation, emphasizes the inclusion of cross-cutting and multidisciplinary themes, such as citizenship education, sustainable development, applied sciences, and career decision capacity. During and after the transition period, when teachers are being trained and new official teaching materials are being developed, extra-curricular activities with external partners, like Youth@STEM4SF, will play a crucial role. Therefore, pedagogical innovation through modular teaching in formats like thematic days, workshops, or school projects is strongly encouraged.

Through knowledge and technology transfer from both basic and applied research, industries play a pivotal role in bridging the gap between science and society, conveying powerful and attitude-changing messages to students and politicians alike. The industrial community can significantly contribute to inspiring youth by showcasing concrete applications, technologies (directly or indirectly aligned with SDGs), and the vast array of career opportunities, with 70% of scientific careers lying in business and industry.

3. Project Youth@STEM4SF

All the elements outlined above find inherent expression in the groundbreaking pilot project Youth@STEM4SF (Youth at STEM for a Sustainable Future). This initiative is designed to kindle the passion of future scientists and society leaders by introducing an additional layer to existing high school STEM education and outreach activities. The project achieves this by contextualizing physics and STEM within the realms of real-life scenarios, societal contexts, and sustainability. It leverages direct demonstrations from the research-industry nexus and draws inspiration from diverse role models of both genders.

The project adopts a holistic approach, deliberately targeting entire classrooms, specifically selecting non-science-oriented classes and students with general interests, diverse backgrounds, and identities. This includes ensuring a gender balance and engaging students with neutral or negative attitudes and unconscious biases around science. The first target group encompasses students who exhibit talent in STEM but harbor hesitations about pursuing science studies due to stereotypes and a lack of relevant information regarding job prospects and the practical aspects of science, with a special focus on encouraging girls to consider physics, engineering, or STEM studies. The second target group comprises future professionals in non-scientific fields, individuals who are often uninformed decision-makers, opinion shapers, participants in various societal fields, and members of the voting public. The project's objective is to enhance their appreciation and understanding of the relevance of basic sciences for society, inspiring them to become scientifically aware and literate citizens, as well as ambassadors for scientific methods and fact-based decision-making in their future professional lives.

Developed over nearly five years, Youth@STEM4SF is the result of collaborative efforts with international multidisciplinary experts and stakeholders from various communities, including scientists, science educators, knowledge transfer and science business experts, teachers, students, industries, educational authorities, and the UN. The extended design phase aimed to create a project feasible for all stakeholders with broad nationwide and long-term impact. The project is anchored in an innovative outreach concept that involves captains of industry serving as ambassadors for the value

of science and education in (particle) physics/STEM - a concept proposed by the author in her former function as the Industry Liaison Officer of Slovakia to CERN, and subsequently recommended by the European Committee for Future Accelerators (ECFA) in 2018 [26]. This approach has been shown successful also by CODE project in UK [27].

3.1. Inaugural Swiss Pilot

With invaluable support from numerous knowledge partners and financial backing from education21 [28], SPS [29] and SCNAT [30], the inaugural proof-of-concept unfolded on May 11, 2023, at Gymnasium Bugnon in Lausanne, Switzerland. This groundbreaking event involved 55 students and three science teachers (specializing in physics, chemistry, and biology), embodying a transdisciplinary approach. The thematic day, both within and outside the school premises, provided students with interactive sessions featuring female physicists with EPFL [31] and CERN backgrounds, as well as engineers & scientists of both genders from two pioneering tech companies, Solstis [32], a well-established EPFL start-up focusing on solar panels, and ABB [33], a leading technology company specializing in electrification and automation for a more sustainable and resource-efficient future.

The scientist offered a holistic view of science in society, presenting concrete examples of how basic sciences contribute to our everyday lives and Sustainable Development Goals (SDGs). This included a rich portfolio from CERN, showcasing applications of particle physics and the broader Swiss science ecosystem in diverse fields such as medical, digital, environmental, cultural, and humanitarian. Emphasis was placed on the importance of multidisciplinary collaboration, dialogue, and the scientific method for fostering innovation and making sustainable decisions based on facts, applicable across various domains. A wide array of concrete examples illustrated possible career paths beyond academia for individuals with physics, engineering, or STEM diplomas, spanning fields such as environment, energy, health, precision/watchmaking, finance, cosmetics, space, entertainment, science diplomacy etc. Stereotypes related to physics / STEM were addressed and debunked.

Following these sessions, students visited Solstis, located within walking distance from the school, immersing themselves in photovoltaic technology and gaining insights into the current energy situation. The visit included a hands-on excursion and discussions on the career paths of role models, including a young female engineer. Engineers from ABB shared their career journeys, offering concrete examples of how their backgrounds, expertise, and competencies contribute to sustainable solutions in electric motors, home automation, robotics, and more. Students gained a deeper understanding of the engineer's pivotal role in creating value for society.

During the interactive two-hour lunch break, students engaged in small group discussions (5-10 members) to reflect on the day's subjects and brainstorm concrete ideas on integrating the theme "science for society and SD" into school curricula and beyond. Such valuable input is intended for use in creating teaching materials during the scale-up phase.

3.2. Impact Assessment

The feedback from students and teachers following the Youth@STEM4SF thematic day was very positive, with participants describing the information received as eye-opening and inspirational. The direct engagement with industry in a real-life teaching context was particularly valued by students, providing them with insights and sparking curiosity about the specific fields of the companies' activities related to Sustainable Development (SD).

The impact of the program was systematically assessed through questionnaires and interviews, focusing on key performance indicators such as awareness, attitude, and interest in STEM studies and the discussed subjects. Questionnaires, administered both before and after the Youth@STEM4SF thematic day, included modules covering general knowledge, perceptions of physics and STEM's societal role, attitudes, interests, career directions, and factors influencing decisions about future studies and careers.

Initial results from the first pilot are highly encouraging. Notably, 30% of students, particularly girls, are now considering new STEM career options that they had not previously envisioned. Girls, in general, express that relatable female role models have made physicists and engineers more accessible in their view. Additionally, half of the students indicate a willingness to serve as ambassadors for science in their future non-scientific careers. These outcomes signify a positive shift in awareness, attitudes, and interests, showcasing the program's effectiveness in influencing perceptions and career aspirations among the participating students.

3.2. Scale-up Strategy

The scale-up of this successful pilot is strategically designed to gather substantial data for robust statistical analysis, encompassing a larger number of Swiss schools with diverse characteristics (private, public/IBO [34], gymnasiums, vocational), age groups (14-18), and geographic coverage (several cantons). This expansion will not only increase the sample size but also widen the scope of science and societal aspects, thanks to the involvement of a variety of participating industries.

In the next phase, the motivated students will have a possibility to work on the subject officially in the framework of the maturity work or take part in the competition to best communicate the value of science for society and SD. The winning future scientists will earn internships in tech or physics-based companies, while future society leaders will have the opportunity to deliver speeches on the subject at the UN Youth Forum in Geneva and alike events.

The unique dialogue established between scientists, industry representatives, teachers, and students during the pilot will continue to be a valuable source of input. This input will be utilized to develop new, professional teaching materials that effectively connect science with SD. Continuous engagement with public and private educational authorities is planned to ensure that the content aligns seamlessly with Swiss education plan(s) while always backed by data showcasing its positive impact. The long-term goal is to secure official recommendations for the project's adoption by schools nationwide. Despite its ambitious nature, Youth@STEM4SF has already been recognized as a pioneering case for implementing the new Swiss high school education plan [25] by the national competence center for sustainable development education, foundation education21 [28, 35].

Having been developed in collaboration with the international community, the project initially focused on 4S+ countries (Switzerland, Slovakia, Sweden, Spain, and others), resulting in the establishment of a "Swiss brand" first. However, with the participation of other countries in the future, an international dimension will be added to the project. This expansion will facilitate the exchange of best practices, enrich the database of teaching materials, and allow for the evaluation of international data. At this stage, there are plans to organize an international workshop on science for society and sustainability at a renowned basic research facility.

4. Conclusion

The project holds significant potential to make a substantial impact in inspiring future physicists, engineers, and STEM specialists, particularly among girls, as well as future society leaders both within Switzerland and on an international scale. Building upon the promising results of the Swiss pilot, its objective is to evolve and influence official high school science education lesson plans. This is achieved by introducing the vital connection with real-life applications and sustainable development, aligning with the ongoing trend in evolving school curricula, as exemplified by the progressive approach in Switzerland.

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