Building Bridges between Researchers and Pupils: Finding Future Chemists through the "Science for Future Researchers: Experiments and Knowledge" Project

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Abstract

Currently, pupils have access to a variety of sources and resources from which they can obtain the necessary information for completing homework, carrying out school projects, or enhancing their knowledge. However, conducting demonstrative or individual experiments, especially in subjects where they are indispensable - such as chemistry – is essential in order to arouse their curiosity, help them better understand processes that take place at the molecular level, and to encourage them to pursue a career in research in the future. To achieve this, chemistry classes must be held in laboratories, accompanied by practical examples. Unfortunately, the laboratories in Romanian middle and high educational institutions have often been converted into classrooms, or the

necessary infrastructure is deficient or completely absent. On the other hand, research in Romania is deficient in attracting young talents, with an acute shortage of funding and modern equipment, even though research is a key pillar of a country. The project *Science for Future Researchers: Experiments and Knowledge*, which received funding from the Romanian Ministry of Education through UEFISCDI, aims to create a bridge between scientists (researchers in the field of chemistry) and students from educational units in the Bucharest-Ilfov area by offering them the opportunity to visit the specialized research laboratories of the project consortium and to participate in workshops, demonstrative experiments, debates or lectures organized right in their classrooms. Although the project is still ongoing, the feedback received so far from pupils and their teachers is positive, highlighting the importance of the practical application of theoretical knowledge acquired in class.

Keywords: chemistry, researcher, pupil, scientific experiments, research laboratory visits

1. Introduction

Education represents an essential pillar in the formation of scientifically literate persons, capable of critical thinking, problem-solving, and active participation in a knowledge-based society. Education serves as the ultimate catalyst for human development, equipping humans not just with static facts, but also with cognitive frameworks required to navigate and decode the complexities of the modern world.

In the context of education, approaches based on scientific evidence, experimentation and interaction with real researchers are fundamental to encourage deep understanding and long-term engagement, but also to open new horizons and approach careers in research. The role of open access science, which disseminates knowledge and provides equitable access to up-to-date scientific information, thereby reducing educational disparities and supporting inclusive learning environments, is also important. Integrating open access resources into educational practices strengthens the connection between theoretical concepts and research, increasing both the relevance and authenticity of the learning process. In this way, education, supported by open science principles, not only facilitates the acquisition of knowledge but also cultivates curiosity, collaboration, and innovation, preparing learners to contribute meaningfully to scientific and societal advancement. Therefore, the educational system must move beyond rote memorization and embrace contextualized exploration. The implementation of science education in schools through direct interaction with the environment and hands-on experimentation is grounded in active learning. In this approach, students observe natural phenomena, investigate real-world situations, formulate hypotheses, and construct scientific understanding through authentic, experiential engagement with their surroundings. Thus, within this framework of understanding the physical universe, specific scientific disciplines provide specialized perspectives through which pupils can investigate the fundamental elements of reality.

Piaget (1971) and Vygotsky (1978) assumed that knowledge is actively constructed by the learner through interaction with the environment. Dangel et al. (2004) pointed out that the schools' curriculum should encourage children to see connections in learning, encourage them to spend more time doing activities and solving problems, and provide them with a variety of tasks. The paper of Shana & Abulibdeh (2020) mentioned that teaching and learning is a complex process that involves many aspects. One of these aspects is the method of delivery and practices used in the classroom by the teacher. This study also highlighted the importance of combining theoretical and practical work in the educational process, specifically in the case of sciences. In Chand's opinion (Chand, 2023), learning is seen as an evolving process, actively constructed, reflective and collaborative, and based on inquiry. In this process, the teacher is a facilitator of inquiry, who scaffolds experiences, supports reflection, and cultivates intellectual curiosity, while students need to take charge of learning, collaborate meaningfully with peers, and develop the critical, creative, and interpersonal skills that are essential in all domains of life (Mir et al., 2025).

In an educational context, chemistry occupies a central position because it provides a concrete framework through which abstract scientific concepts can be explored, understood, and applied to real-world phenomena. Chemistry represents one of the natural sciences, classified as a physical science, along with physics, astronomy, and earth sciences. It is the science that studies matter, its composition, its properties, and the transformations that undergoes when matter interacts with other substances or energy. Simply, chemistry is the "central science" that explains what everything around us is made of. We find it practically everywhere. In your body, breathing, digestion, heartbeat, and even feelings (such as happiness or stress) are the result of complex chemical reactions. In the kitchen, cooking is pure chemistry. In nature, photosynthesis in plants, the rusting of iron, the formation of rain, or the colors of the sunset all involve chemical processes. Nowadays, chemistry is present in the objects around us, such as phones, clothes, plastic, medicines, cleaning products and so on. However, chemistry is often perceived by pupils as an abstract and difficult subject due to the "triplet relationship" between the macroscopic, sub-microscopic, and symbolic levels (Johnstone, 1991). To bridge these levels, laboratory classes are indispensable. During them, students not only implement what the books contain or what the teacher teaches them, but they also have the opportunity to gain skills in handling laboratory instruments, solving complex problems, asking questions, and being determined to find solutions. According to Hofstein & Lunetta (2004), the laboratory is a unique space where pupils can construct their own understanding of phenomena. In chemistry, observing a color change or the formation of a precipitate provides a "cognitive anchor" that pure text cannot reproduce. Archer et al. (2010) conducted research as a part of *Science Aspirations and Career Choice* (ASPIRES) project, which indicates that "scientific capital" represents a primary predictor of choosing STEM careers. On the other hand, the studies have shown the importance of inquiry-based learning in science education (Hofstein & Lunetta, 2004), proving that when students engage in hands-on experiments, they shift from rote memorization to active model building, allowing them to visualize processes at the molecular level. Other studies (Okebukola, 1987; Cheruiyot, 2020; Musa et al., 2022) have shown that the use of experimental methods for teaching chemistry is an effective method in improving students' performance and increasing their knowledge and understanding. Moreover, using experimental ways to teach chemistry increased pupils' interest and abilities in science subjects as well as their performance in science. This is because chemistry practical classes help students in understanding theories and chemical principles which are difficult or abstract.

Despite the above advantages, the Romanian educational landscape has seen systematic deficiencies. While the national curriculum acknowledges the importance of practical work, the de facto environment is constrained by some important factors such as: (a) conversion of laboratories into standard classrooms due to space shortages, signaling a shift in institutional priorities away from STEM engagement; (b) the absence of instrumentation and reagents, limiting practical work to simple, often dated, demonstrations or their complete exclusion; (c) a disconnect between secondary education and the realities of research laboratories (even these are not very well equipped), so that pupils are often not inspired or attracted to them. Moreover, while the EU focuses on the “Knowledge Triangle” (education, research and innovation), Romania faces difficulties in financing research and development (typically below 0.5% of GDP). All these situations contribute to failing to satisfy the curiosity of digital native pupils and transform chemistry from an experimental science into a text-based discipline, effectively suppressing students’ curiosity and narrowing their career horizons.

Kerekes (2024) emphasized that the lack of chemistry and physics laboratories represents a major obstacle to obtaining a comprehensive science education and that practical skills, together with a deep understanding of scientific principles, are indispensable for attracting young people to such careers. By fostering critical thinking and problem-solving through active learning, schools transform abstract curriculum standards into lived experiences. This holistic approach ensures that pupils do not merely absorb information passively. They also learn to analyze data, question assumptions, and apply theoretical principles to tangible global challenges. Therefore, creating a bridge between students, educational institutions and researchers is a necessity as it reduces the gap between theory and practical reality, preparing students to become citizens with varied skills, who can significantly contribute to technological and societal progress.

2. Project Methodology

The project *Science for Future Researchers: Experiments and Knowledge – ŞTIE* (project no. PN-IV-P10-SS-SC-2024-0045), which received funding from the Romanian Ministry of Education through UEFISCDI, aims to create a bridge between scientists (researchers in the field of chemistry) and students from educational units in the Bucharest-Ilfov area by offering them the opportunity to visit the specialized research laboratories of the project consortium and to participate in workshops, demonstrative experiments, debates or lectures organized right in their classrooms. It operates on the hypothesis that direct exposure to high-level research environments and scientists can mitigate the effects of poor school infrastructure and inspire the next generation of Romanian researchers. Hands-on experiments provide a “scaffolding” that allows students to bridge the gap between microscopic molecular interactions and macroscopic phenomena, which is an emotional engagement that defines a determining factor in career choice. In addition, interaction with researchers allows students to see chemistry not just as a school subject, but as a potential professional identity. The *ŞTIE* project applies a multimodal approach to science communication, designed to inspire the next generation of chemists. This approach starts from a simple but essential premise: interest in science cannot be imposed, but must be cultivated (Doni et al., 2026). Thus, this strategy ensures accessibility for pupils at different educational levels in the Bucharest-Ilfov region, encouraging curiosity, critical thinking, and awareness of the role of chemistry in addressing real-world challenges and in our daily lives.

Within this project, the popularization of chemistry among students is done through a series of interactive activities. For example:

1. **Workshops and demonstration experiments**: Researchers from the project team visit schools equipped with portable, safe, and engaging experimental kits, adapted to the age and knowledge level of the students. Thus, pupils have interactive discussions during the experiments and spend time conducting experiments themselves. These sessions, lasting 1-2 hours, encourage questions and direct participation, making abstract chemistry tangible and fun.
2. **Lab immersion**: To bridge the gap between classroom learning and cutting-edge research, students take part in guided tours of the consortium's research laboratories. Here, they can see both how researchers carry out their daily work and the infrastructure they use. Under the close supervision of researchers, participants observe live experiments and even manipulate equipment, gaining insight into professional workflows and the excitement of discovery.
3. **Debates and interactive lectures**: Dynamic sessions feature discussions led by experts and PhD students on actual global topics, highlighting chemistry's essential role in innovation and sustainability. Topics include high-performance materials for extreme conditions, green fuels (e.g., hydrogen and biofuels), emerging technologies in biomaterials (e.g., hydrogels for drug delivery), and chemistry's contributions to combating climate change (e.g., carbon capture or renewable energy) as well as any other topic that is launched by the participants. Formats include Q&A sessions, debates, and multimedia visual materials, fostering lively exchanges and enabling students to envision their own contributions to these fields.

In this respect, the project emphasizes a collaborative dialogue. Rather than simply witnessing a demonstration, pupils are encouraged to propose hypotheses, predict outcomes, and discuss failures. This shifts the classroom dynamic from a "teacher-led" model to a "community-of-inquiry" model, which has been shown to increase student persistence in STEM fields (National Research Council 2011).

3. Preliminary Results and Observations

At the end of the activities, students are asked to anonymously complete questionnaires expressing their opinion about the session they participated in. These questionnaires are completed either in printed format or online. Up to now, over 800 students have participated in the activities offered by the *ŞTIE* project, but not all of them have expressed their willingness to complete the questionnaires associated with these activities. However, we believe we have enough answers to draw some conclusions regarding pupils' perception of a more applicative and interactive way of learning chemistry.

It is worth mentioning that approximately 100 questionnaires have been analyzed for the present paper. Following this analysis, we observe interesting situations. First, it is interesting to note that the number of high school students who reported that participated in such activities is slightly lower than those who did not participate, while, in the case of middle school students, the situation is the opposite, as can be seen from **Figure 1**.

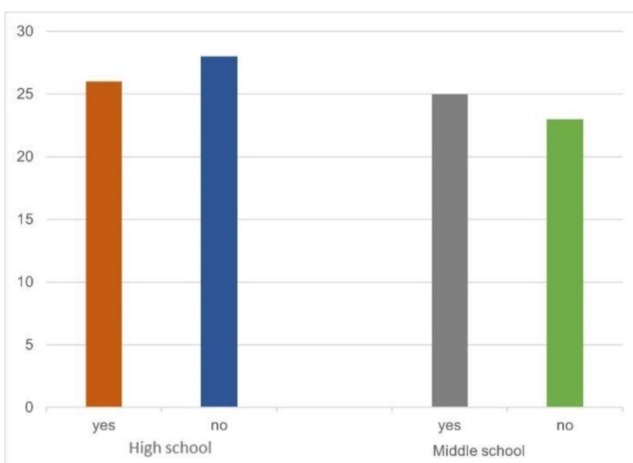

Figure 1. Participation in *ŞTIE* project activities among high school and middle school students

When asked how motivated students are to learn more about science/research/chemistry after following these activities, students considered themselves rather very motivated or motivated to participate in such activities than less motivated. This indicates not only the need for chemistry classes in which theory is combined with the experimental part, but also the fact that students perceive and assimilate the information more easily in this way. This situation is easily seen from **Figure 2**.

At the end of the activities, all pupils reported that the experiments made chemistry more interesting than standard lessons. At the same time, teachers noted that students who participated in the activities were better able to explain some aspects of chemistry processes.

Even though this project is still ongoing, we can consider that this project is well received among young people, taking into account that, regardless of their level of education, all students considered such an activity useful and responded with humanity that they would follow such an activity in the future or would recommend such an activity to another person. This situation is presented in **Figure 3**.

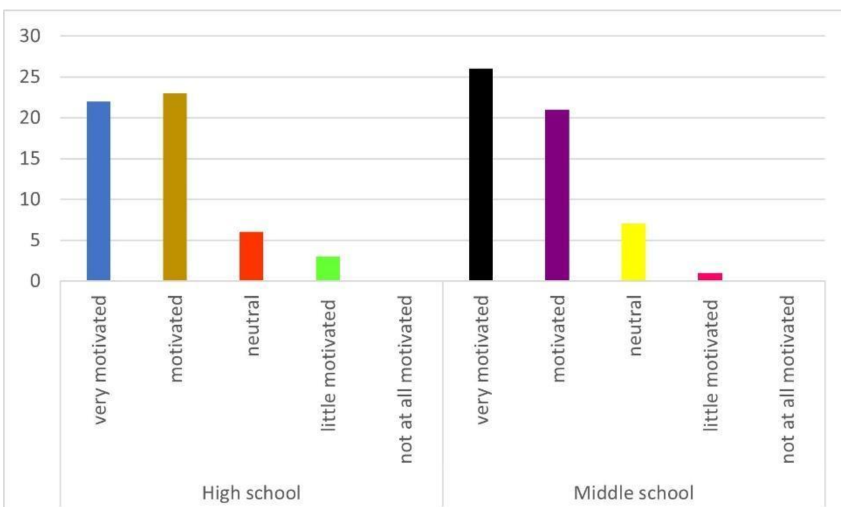

Figure 2. Motivation levels among high school and middle school students

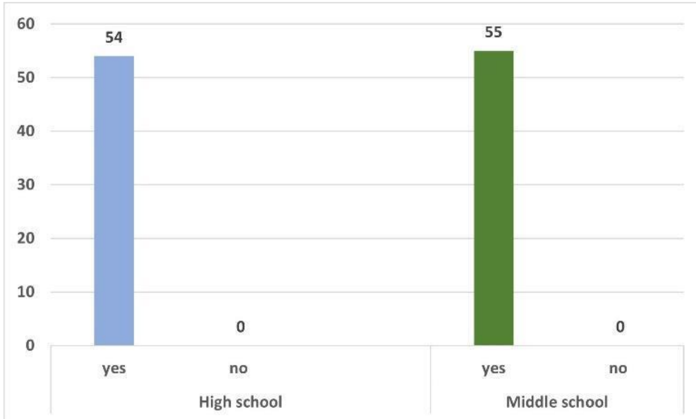

Figure 3. Students' perceptions of the activity's usefulness and their willingness to participate in the future

Following the analysis of the collected data, we can say that the "bridge" created by the *ŞTIE* project has a double scope: it offers students access to equipment that their schools do not have and emphasizes the importance of the researcher, showing that a career in science is accessible and collaborative.

During the activities, the researchers observed that the interest of middle school pupils in such activities and in actively participating in them is higher than among high school students. This may be due primarily to the easy access to technology and information, but also to the fact that high school students begin to have other priorities (e.g., preparing for the baccalaureate exam), chemistry not being among them. It is also possible that this subject, which they have been studying for a few years, is not taught in their understanding and that is why they find it very difficult to learn and uninteresting.

However, in the long term, the impact of such initiatives is profound. They contribute to the formation of a generation that is better informed, more curious and better prepared to understand and address the challenges of the future. At the same time, they create the premises for attracting young people to careers in science and research, in a context where the need for specialists is growing (Doni et al., 2026).

Overall, the practical impact and utility of the *ŞTIE* project are reflected across three distinct educational and societal levels:

- For pupils: it fosters critical thinking through engaging experimental activities, enhances understanding of the role of chemistry in everyday life, and serves as a tool for early career orientation.
- For teachers: It provides tangible support for continuous professional development by offering modern resources and applied teaching strategies that increase classroom engagement.
- For society: It builds bridges of trust and credibility; in an era marked by misinformation, the project provides clear scientific benchmarks validated directly within research laboratories.

4. Conclusions

The transformation of science education requires moving beyond the constraints of the traditional classroom. The *Science for Future Researchers: Experiments and Knowledge* project highlights that students are intrinsically motivated by the "doing" of science. By integrating them into professional research environments, we not only improve the acquisition of their theoretical knowledge but also cultivate the researchers of tomorrow.

The *ŞTIE* project serves as a successful pilot for science outreach in Romania along with the other projects of this kind that have been financed. Preliminary findings confirm that practical application is the most effective tool for arousing curiosity.

As the project continues, data will be collected to see if the trends found so far are maintained or changing. However, the sustainability of such projects remains a challenge. Short-term funding cycles provide “sparks” of interest, but long-term systemic change requires a permanent integration of research-school partnerships into the national curriculum.

Challenges and future implications

To ensure the long-term success of the Romanian scientific research sector, it is crucial that policymakers continue to support such collaborative outreach initiatives, guaranteeing that the "laboratory experience" is a fundamental right of every pupil, not a rare privilege. Therefore, to ensure a constant access to interactive, practical classes as well as laboratory experiments for each student to better understand chemistry but also to capture their attention during the teaching process, and spark their interest so that they can choose careers in research in the future, it is imperative to: (a) restore school laboratories to their primary function; (b) create permanent specialized programs for future researchers; (c) increase fiscal incentives for private-sector involvement in science education.

Unfortunately, the main challenge remains the implementation of such initiatives as those listed above. Although projects such as the *ŞTIE* project are very successful at the moment, this program must continue if other efforts cannot be made to facilitate students' access to quality education.

In the short term, this can be resolved through institutional partnerships so that the universities and institutes' laboratories become an extension of the school classrooms, thus creating a "virtual" infrastructure that benefits both the schools and the research institutions by fostering a pipeline of future talents.

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