How Can We Turn the Interest of Young Generations to Study Geoscience Related Disciplines? The ENGIE Project's Review of Best Practices for Teaching STEM and its Feedback on the Project's Strategy

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Abstract

The problems related to the shortage of skilled employees in key scientific professions and the need for modernizing science teaching in schools have become crucial. The recruitment crisis in STEM professions is particularly worrying for the EU, and the challenges are even greater for the recruitment of young girls in engineering and geosciences careers, traditionally considered as masculine professions. The European project "Encouraging Girls to Study Geosciences and Engineering" (ENGIE) was born in 2020 with the aim to turn the interest of 13-18 years old girls to study these specific STEM disciplines. The project is expected to contribute to the improvement of gender balance in these fields. For this purpose, it needs to take inspiration from (and develop) best practices to approach students and teach them STEM-related subjects. Thus, an extensive research on best programmes and practices was carried out with the aim of learning from successful stories and contributing to the customization of the ENGIE Action Plan for the following two years. The research comprised literature studies and historical evaluation of successful programmes and initiatives, gathered from the web and through direct experience. It reviewed past and current actions aimed at raising girls' (and all students') interest for STEM subjects. The purpose was to adapt their scopes and replicating their successes within the field of geosciences and geo-engineering. The review helped identify key lessons for ensuring the success of ENGIE's initiatives and reaching its goals.

Keywords: *Best practices, Geosciences, STEM, Teenagers, Education.*

1. Introduction

The increasing dependence on raw materials from abroad makes the European Union (EU) highly vulnerable to problems linked to market oscillations and to the shortage of expert employees [1]. The need of skilled professionals in scientific fields related to raw materials' exploitation, disposal, recycling and environmental problems is thus more urgent than ever and is strongly linked to the EU's capacity for innovation. For this reason, the recruitment crisis in Science, Technology, Engineering and Mathematics (STEM) professions and the need for modernizing science teaching in schools have become crucial issues [2-3]. The challenges are even greater for the recruitment of young girls in Engineering and Geosciences careers, both closely linked to raw materials' fields, but traditionally considered as masculine and with an evident gender imbalance [4-5]. This latter must be overcome in order to achieve higher levels of creativity and innovation that usually accompany heterogeneous teams [6].

2. ENGIE' strategy to define best practices for teaching STEM

The European project 'ENGIE – Encouraging Girls to Study Geosciences and Engineering', funded by the European Institute for Innovation and Technology in raw materials sector (EIT RawMaterials), aims to turn the interest of young girls to study Geosciences and related Engineering disciplines. The 13-18 target age was selected because career decisions are taken generally in this period [7], and school can act as an inspiring beacon. One of the challenges that the project had to face was the shortage of knowledge on how to effectively encourage and sustain girls' (and, generally, teenage students') interest in STEM. ENGIE has addressed this issue by proposing a dedicated survey to secondary school students and teachers in the first part of 2020. Results indicated the need to promote geo-

education in secondary school, and to focus on women role models [8]. As a further development of the 2020 actions, the project promoted an extensive research on best programmes and practices to increase the interest in STEM disciplines of students in general, and girls in particular, as a contribution to the customization of the ENGIE Action Plan for the implementation of awareness actions in 2021 and 2022. This paper presents the information gathered in that context. Literature studies, surveys, and evaluation of successful initiatives were reviewed with the purpose of adapting their scope and replicating their successes within the field of geosciences and geo-engineering. They were selected after widespread searches on the web and through direct experiences by project partners.

3. Results

Seventy-two projects, actions and studies contributed to the realization of the ENGIE report on International best practice for teaching STEM [9]. The majority of contributions came from Europe, but inspirational examples from outside its borders were also included (Fig. 1). Figure 2a shows the apportionment of these actions into three categories: 1) Theoretical concepts that underlie best practices for STEM teaching; 2) Programs and projects for schools and the public; 3) Actions aimed at girls and women. References to scientific papers and web sources are available in [9]. Projects for schools and actions for girls accounted for more than 80% of the examined material, the rest being studies dealing with theoretical principles. These latter define approaches that can be implemented everywhere, as they attain to emotional and affective domains that are general to many societies. The experience derived from each initiative was translated into indications on good practices to be adopted within the ENGIE project for increasing the interest on geoscience subjects. Fig. 2b shows an example of how each single “entry” was organized in the report, with a concise description and the indication on how to “tailor” it for the project’s purposes [9].

Fig. 1. Number of selected initiatives on a geographical basis.

4. Discussion

The most important lesson learned is that any kind of gender bias has to be avoided. The participation of all students to awareness actions is necessary to promote gender equality and to gain direct experience of the higher levels of creativity and innovation that accompany heterogeneous teams. Open events give this opportunity also to families and the public. Approaches involving strong national networks between researchers, teachers, and other stakeholders are effective in addressing large numbers of students and ensure the long-lasting legacy of educational projects in school systems.

The affective domain at the basis of stable and long-term interest is strongly linked to the examples provided by senior professionals and young women working in traditionally male industries. Similarly

to role models, the mentoring of teenage school girls by their older undergraduate peers, the use of team work, and the interaction between teachers and experts can create positive feedbacks and increase school curricula. Media, social media and other communication forms are suggested for the collection of inspirational stories.

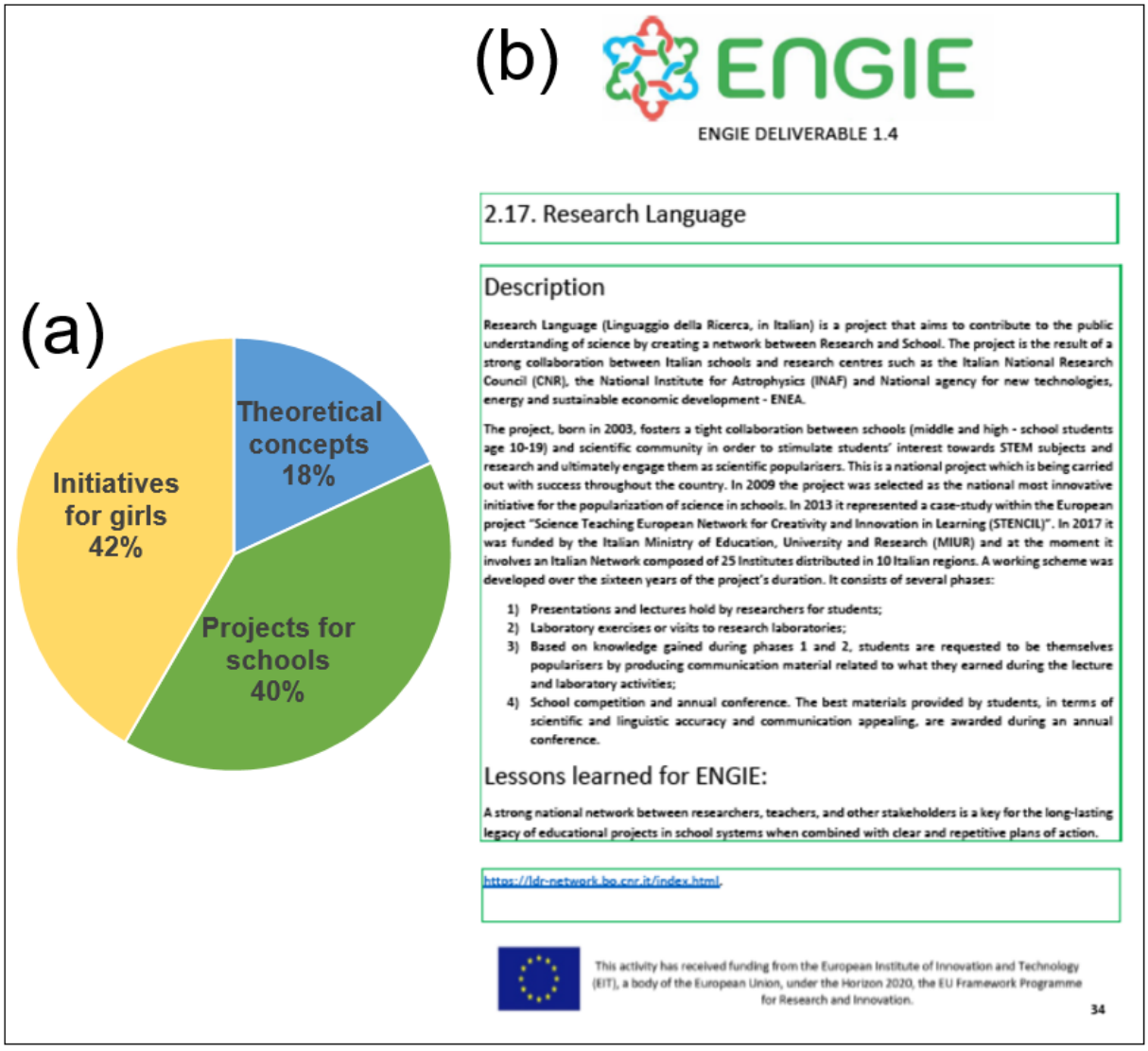

Fig. 2. (a) % distribution of selected initiatives; (b) example of a report's "entry".

Hands-on activities and the firsthand experience of the professionals' jobs through active learning are among the most effective practices to turn individual interests into stable, long-term professional choices. The use of funny and amusing toolkits in schools and community programmes strengthens family bonds and creates positive memories. In addition, modern technologies and social media are efficient ways for reaching out young generations and capturing their attention.

Whether they include field trips, classroom lessons or After-School programmes, all activities proposed to students need to be carefully organized and tested, in order to ensure the success of the initiatives and the reaching of the goal. A preparatory phase is always necessary to reduce the so-called "novelty space" associated with every new experience, at the end of which an evaluation phase is requested to assess the attained knowledge through tests and/or satisfaction questionnaires.

The use of modern Information Technologies (ITs), developed for learning and entertainment purposes, and alternative teaching approaches are strongly encouraged as they can motivate the audience and capture their attention more effectively than traditional ways. The use of an easy language and of precise tools is mandatory because the interest in the discussed topics increases when a clear connection to the audience's life styles and expectations is made.

The involvement of students in real scientific work is a good way to consolidate their knowledge, and their engagement in science popularizing exercises has been successfully experimented. In addition, students involved in the organizations of events and activities can show their achievements and boost their self-confidence in the fields of science. In this way, students learn to adopt ethical scientific principles for the transfer of correct and sound scientific knowledge to the public. They also acquire reliable instruments for the understanding of the world around them.
Another option to empower students in a funny and engaging way is that of organizing scientific competitions, with awards and bonuses for the winners. The creativity skills that are ignited by these contests can either motivate and encourage further education in STEM fields: participants will likely explore the contest's subject in other ways than those proposed, thus autonomously acquiring more information and knowledge. A further advantage of scientific competitions is that they can be organized online, allowing them to be held also amid lockdown conditions and with enforced social distancing rules.

5. Conclusion

In its aim to turn the interest of girls to study geosciences and geo-engineering, the ENGIE project needs to develop best practices to approach students and teach them geoscience-related subjects. Due to the above-described review, it became evident that students' interest tends to be triggered by an external agent, but will not develop into a more sustained, individual interest unless it is repeated, engaging, and intellectually stimulating. The challenge of the ENGIE project, and more in general to fill in the gender gap in STEM, will be that of providing such stimulating experiences and put into practice the lessons learned.
First, inclusion must be the keyword at the basis of all educational actions that should not exclude male students. Therefore, the focus on girls will be limited to the quantification of their attendance. Secondary school teachers should be supported i.e. in having access to tools for more gender-fair teaching practices (i.e. the ENGIE magazine) for the advancement of gender sensitivity.
The positive effect that role models have on youngsters can be used: the ENGIE project indeed, collects and disseminates interviews of successful women in the field of geosciences and geo-engineering to encourage girls into pursuing similar careers. Regarding these activities, the partnership with industry is encouraged.
Teamwork and mentee-mentor interactions are advisable for educational activities, as ways to reinforce self-esteem and the perception of one's own abilities. In particular, activities and experiences that pertain to students' everyday life, help breaking cultural barriers, and attain vocations' promotion. In addition, the development of prosocial goals is another aspect to be considered, since it is especially suited for students who aims at interacting with others. The use of modern technologies and social media can be useful tools to reach this aim.
Photo contest 'Girls in Geology' will also be organized as in the ENGIE project, perfectly fits the need to engage students in competitions with awards and bonuses, in order to ignite their creativity and motivate the deepening of specific subjects.
Active learning and hands-on activities should be favored for their capacity to attract attention and fix the experience in long-term memory through funny and instructive ways. They have to be carefully planned with preparation, realization, and summary units to maximize the results. The principles at the basis of this procedure can be tailored for different teaching needs. Many of the programmed ENGIE activities (e.g. Researcher's Night, Science Clubs, and Family Science Events) should then be prepared and tested in advance in order to ameliorate their outreach goals.

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