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Active In-Service Training on Transversal Skills: Two Pilot Cases in STEM Disciplinary Teaching

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Abstract. Promoting gender equality in STEM disciplinary teaching and self-assessment skills in students requires transversal competences and methodologies that are usually not included in teachers' cultural background. Based on previous experiences, we implemented, in an interdisciplinary team, two in-service training courses for teachers. In one, after introducing the topic of gender and related educational issues, teachers were invited to develop a learning path to be implemented in class in the following months and then we analysed together the results and critical issues that emerged. In the other, a laboratory of self-assessment for students is promoted by an in-service course for STEM teachers.

1. Introduction

Transversal competences' learning, while being critical to future professional success, is not an easy or straightforward process [1]. It involves various stakeholders, with a particular focus on students and teachers. It should be explained and participatory, including formal learning, but also non-formal and informal learning, in an integral logic of acquiring and developing competences.

Two pilot experiences were conducted to address issues that have emerged in recent years in our territories, specifically southern Tuscany. In both pilot cases, a problem with significant social implications was addressed through active professional development for secondary school teachers. In order to address the considered issue, the development of soft skills was essential. These issues include a decrease in the number of girls interested in physics studies, reported in the next section, and a decline in science skills among students entering science degree programs, addressed in the following section.

2. Active In-Service Training for promoting gender parity in STEM

Despite being one of the Sustainable Development Goals, achieving gender equality and empowering all women and girls by 2030 is not on track [2]. The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is a well-documented issue in developed countries.

2.1 Gender imbalance in pursuing degrees in science

The inclusion and recognition of women in science have been a long, arduous and still unfinished process (Fig. 1).

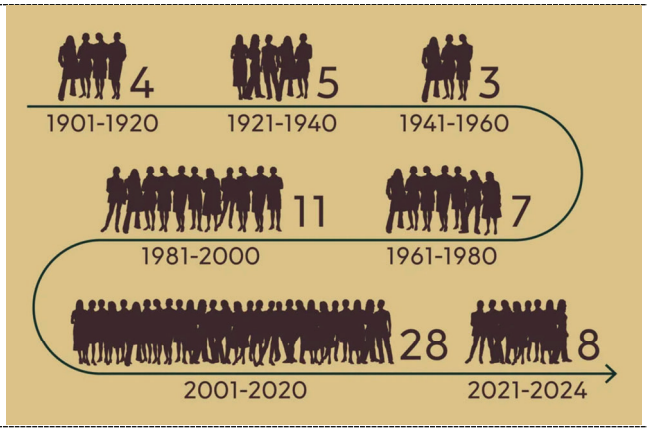

Figure 1. The number of women awarded the Nobel Prize from 1901 to 2024 was 66 out of 976 prizes, divided into 5 in physics, 8 in chemistry, 13 in physiology or medicine, 18 in literature, 19 for peace, and 3 in economics [3]. In the last 23 years, the number has more than doubled compared to the previous 100 years.

The number of female graduates in Italy is higher than male graduates (Fig. 2). In science degrees, gender inequality is very important, while academic positions reflect a society still predominantly held by men.

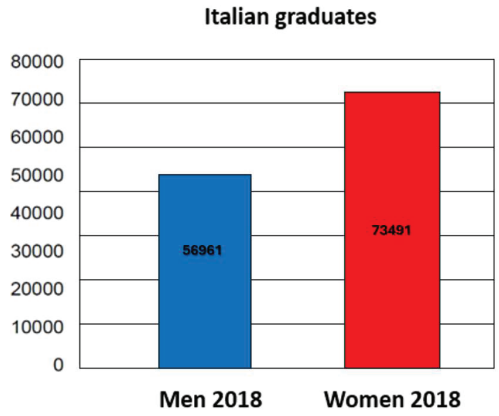

Figure 2. Comparison between the number of male and female graduates in all subjects in Italy in 2018.

As expected, physics and mathematics are mainly boys' choices while girls prevail in life sciences and chemistry (Fig. 3). However, current actions to overcome gender disparities in STEM are far from satisfactory. Courses in biology or mathematics often have a predominantly female gender distribution, which presents the opposite issue. This phenomenon is influenced by pre-existing biases and reinforced by experiences in high school.

Improving transversal professional skills is crucial for science teachers to identify their own and their students' biases, the mechanisms that reinforce them, and the positive actions in disciplinary teaching practice that can weaken them through positive experiences in the scientific field.

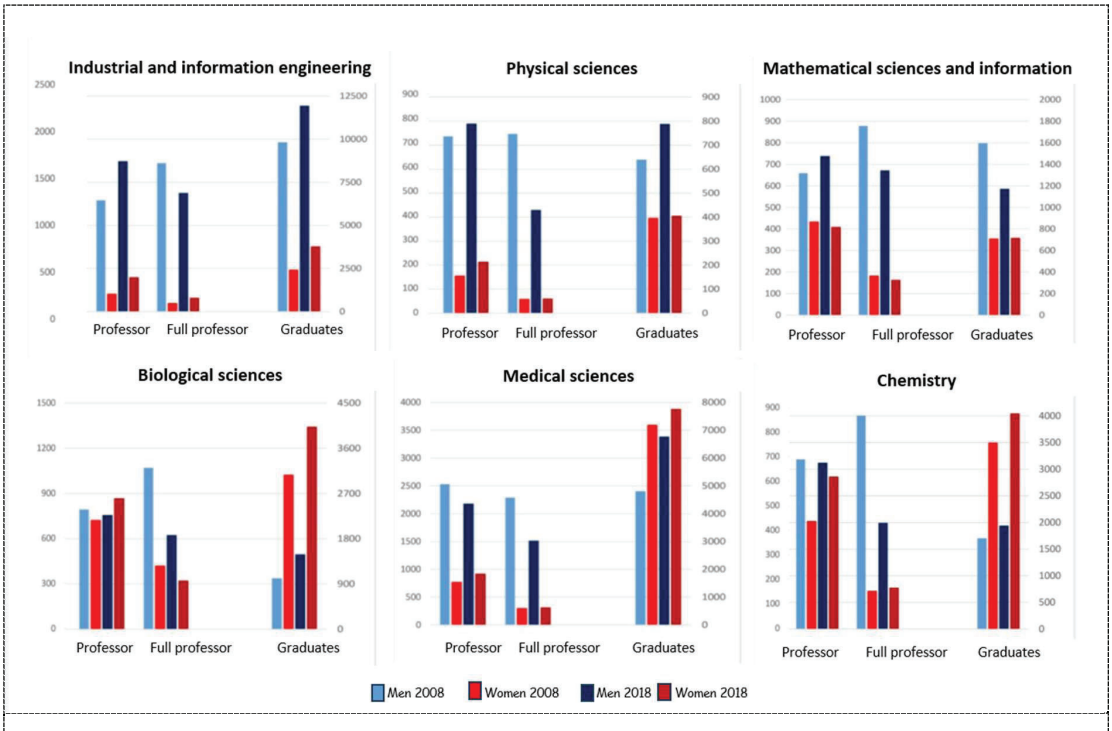

Figure 3. Academic positions1, with respect to graduates, of men and women in 2008 and 2018 in Italy.

2.2 Orientation experiences in high school

For about twenty years we have been providing educational guidance in secondary schools through the National Plan for Scientific Degrees (PLS).

There were few girls, but the number of applications for admission to the local summer school organized every year increased slightly until almost parity was reached.

In recent years, however, applications have fallen sharply, and when interviewing girls involved in other physics outreach activities, the recurring response is “I'd like to, but I don't have the skills” (I don't understand maths, I don't have an aptitude for science, etc.) [4].

Intervention in secondary schools is crucial to tackle the twin issues of low self-esteem and a lack of aspiration to play an active role in science.

2.3 PEACE: an ambitious project

The development of an in-service training course for teachers from every school level, in 2023, was a successful project in this direction. The course entitled PEACE (i.e. Progettare e Animare Comunità Educanti[2] - Designing and Animating Educational Communities) was organized by the Province of Siena, in collaboration with the Provincial School Office and the Zonal Conferences for Education.

The course was divided into two parts, with the first one focusing on addressing issues related to inclusion. It provided active tools [5] for recognizing prejudice and discrimination to all teachers, working for the deconstruction of gender stereotypes, the dissemination and strengthening of the gender perspective through actions aimed at the educational system with reference to schools in the territory of all levels.

[1] Permanent academic positions in Italy are associate professor (referred to as professor in Fig. 3) and full professor.

[2] EU-funded project: ROP ESF 2014-2020 AXIS B - SOCIAL INCLUSION AND COMBATING POVERTY Activities PAD B.2.2.b. Emergency interventions covid 19: Interventions to support gender equality and work-life balance.

In the second part, teachers followed separate modules in homogeneous groups based on school level and disciplinary macro areas. The module focused on the development and transmission of knowledge free from stereotypes, overcoming the idea of the supposed neutrality of knowledge. This action involved both STEM subjects, in order to promote greater knowledge and interest in them among girls, and humanities and social subjects, which are equally conditioned by stereotypes that still determine an almost exclusively female presence in such paths. As a result of the participants' requests, it was decided to continue with a course for high school teachers (PEACE II).
Specific professional development actions for high school teachers, spread over a 7-month period, were the following:

- cross-curricular, lasting 9 hours dedicated to awareness of the role of gender stereotypes in education, recognition of such stereotypes and reflection on gender-sensitive school curricula.
- specific, lasting 25 hours for each subject area (universities):
    - ❖ math/physics/science
    - ❖ literary/linguistic
    - ❖ history/geography
    - ❖ economics and law

The math/physics/science area module for high school teachers was designed and coordinated by one of the authors (VM). 25 hours were scheduled in 9 meetings, 7 of which were represented by:

- Seminars (4 in-person, 4 on-line, each one of 2-3 hours), comprised of historical elements of reflection, contextualized personal experiences, examples of favorable and deleterious environments to promote gender equality, possible educational actions, methodological reflections.

One meeting (3 hours) was devoted to teaching workshops to develop learning pathways.
The last meeting (3 hours), in-person, consisted in a Lab Sharing of pathways and peer discussion.

The seminar topics were the following:

- Marie Curie and Lise Meitner: two protagonists of nuclear physics between science and society (VM)
- From chemical research to self-discovery: story of a (in)conscious journey (female researcher in chemistry)
- A life with obstacles: science and knowledge against gender inequality and stereotypes (Two young female researchers in the Environmental Sciences)
- Influences of social ecosystems in envisioning one's future in science (A young female researcher in the Nano Science area presented her experience between chemists and physicists)
- Women@diism Together to Overcome Gender Discrimination in STEM (Young female researchers from the Department of Computer Engineering and Mathematical Sciences)
- National Institute of Nuclear Physics (INFN) and gender equality (Two INFN researchers present actions on gender equality for students promoted by the research institution)
- According to the Nature? An evolutionary look at gender roles (A conversation between biologists and anthropologists on gender stereotypes) (DM).

Participation in the first two courses was as follows:

- PEACE I (Math/Phys/Science) 14 enrolled, among which only 5 were active participants (from 4 different schools), 1 learning path designed, no tests in class with students
- PEACE II 15 enrolled, all active from 5 different schools, 1 learning path designed and tested in classroom involving other teachers, a focus group discussed the experiences gained by the end of the school year.

Compared to PEACE I, PEACE II was a more interdisciplinary course, which allowed the exchange of experiences and reflections with other areas. The meetings were concentrated in a short time frame (15 hours in three afternoons) at the beginning of the school year, making it possible to develop a path to promote the overcoming of stereotypes by students over a longer period. In addition, a larger group of teachers was involved in the project, although, unfortunately, none of them had ever participated in PEACE

I. However, actions and material (video and slides) of PEACE I constituted the starting point for improving awareness of stereotypes in teachers, with the aim of integrating the path on gender into normal disciplinary lessons in the classroom.

It was planned that the PEACE III course would start at the end of 2024, but we are still waiting for the collaboration with the province to continue; we expect the course to be ready in 2025.

To continue the PEACE course, the main difficulty to overcome seems to be finding a workspace in the increasingly complicated working life of teachers.

3. Self-evaluation laboratory in STEM: a pilot case

Prior knowledge is essential for success in STEM courses at university and is usually tested in entrance exams. One of the actions of the National Plan for Scientific Degrees is dedicated to improving these initial skills.

In 2019-2020, the PLS-Biology, PLS-Chemistry, and PLS-Natural and Environmental Sciences from Siena, adhering to the self-evaluation action of the National PLS Project, promoted an activity aimed at improving the scientific skills necessary to pass the respective tests. Based on such positive experience, in 2023-24, the interdisciplinary group of the Sienese PLS[3] proposed a self-evaluation laboratory for the high schools of southern Tuscany, this time extended to all the scientific disciplines involved in university entrance tests.

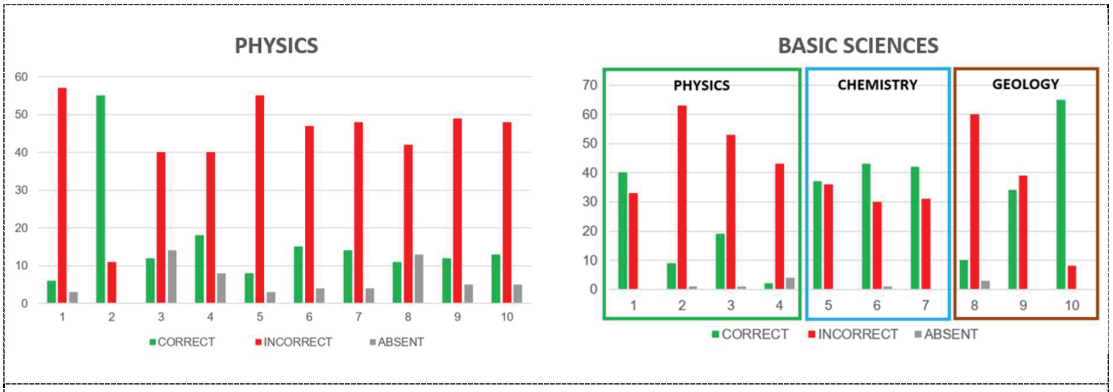

Figure 4. Graphic representation of two examples of answers relatively to questions in Physics (on the left) and Basic Sciences (included in the entrance Test for degrees in Physics, Chemistry, Natural and Environmental Sciences) on the right.

The laboratory is designed for STEM teachers who can enrol one or more classes (preferably in the third or fourth year of the high school course) and consists of an entrance test provided to teachers who will decide which disciplines and topics can be addressed by their students, administered in the same ways and times as those foreseen by the tests administered in Italy almost exclusively through a portal online managed by an inter-university consortium (CISIA). Teachers correct the tests and identify, by the results, critical issues in the teaching of certain disciplinary topics. Through a short course dedicated to professional update, teachers will be able to address and overcome critical issues by designing targeted teaching interventions. The effectiveness of the intervention will be evaluated based on the results obtained by the students in one of the tests on the *OrientAzione* portal [6]. This portal was developed in the PLS to support these actions.

[3] Physics, Mathematics, Biology, Earth Sciences, Chemistry.

Eight schools registered in the laboratory, with 25 classes followed by 36 teachers (18 science teachers and 18 mathematics and physics teachers), but in the end a smaller number completed the first part by administering at least one test for a total of 337 students. The discussion of the critical results with the teachers and the proposal of a strategy to overcome the very poor results took place in May 2024. The approaching end of the school year suggested moving the classroom intervention and the final test on the CISIA portal to the autumn. It was clear from the data that the students did not understand how to take the tests with scores penalized (correct 1, incorrect -0.25, absent 0), as shown in Fig. 4. Students are therefore unable to use the penalty algorithm to optimize their results, demonstrating that they lack problem-solving skills in a real-life situation and failing to achieve one of the objectives of physics and mathematics teaching. The first skill to be developed is therefore transversal i. e. how a simple algorithm, if ignored or well understood, can lead to completely different results with the same level of knowledge.

4. Conclusions

Science teachers need to develop a number of transversal skills, often related to, but not limited to, relevant aspects of the discipline. The impact on society or the opportunities available to students in their future often also depend on these skills. However, the current university and pre-service teacher preparation programs fail to adequately address these professional development needs.

We showed two examples of in-service training courses where, after identifying a problem together with teachers, tools and methods were suggested to overcome it in classroom teaching. The active role of teachers was fostered by asking them to choose and adapt useful teaching tools to their teaching context. A crucial moment was the collective discussion of the results analysing what worked and what can be improved to achieve the transversal skill they want to develop in their students.

Both courses were undertaken on a voluntary basis, with time allocated between various school commitments. It is evident, particularly to the teachers themselves, that this is a professional development that necessitates effort and time.

It is crucial to augment the competencies acquired in the educational environment, going beyond the personal satisfaction of doing well, and to encourage this process by making these professional aspects shared and indispensable.

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