PHYSICS EXPERIMENTS AND PEER-ASSESSMENT: AN HIGH-SCHOOL – UNIVERSITY PROJECT

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Abstract

In agreement with the latest EU recommendations in terms of key competences for lifelong learning, we present an example of close cooperation between students and teachers from secondary school, and professors and researchers from the Department of Physics of Politecnico di Milano.

One of the general aims of school is to enhance the capability of students of making choices impacting their future, in a coherent manner with respect to their own attitudes and competences.

For these purposes, the Italian secondary school system has introduced a dual system of vocational training *Percorsi per le Competenze Trasversali e l'Orientamento*, a mandatory project which helps students to discover their abilities and competences in relation with the professional world or with the academic world. Our activity is an example of this kind of project, involving 50 students of a fourth class and a fifth class (age 17-19) from two different scientific high schools. Each class participated in the project for an amount of 20 hours. The detailed plan of the project included four in-depth meetings on the topic of wave mechanics held by professors of the Politecnico di Milano, an experimental part carried out by students in groups of peers, their presentation of the experiment and a formative evaluation of the proposed work. The steps mentioned above were all closely linked to one another, in order to highlight peculiar features, attitudes and competences of each student. In the part of active involvement, students were asked to work in groups and build a real experiment concerning acoustic interferometry, collect and analyze the experimental data obtained and present them in two forms: a scientific report and a presentation. As a final step, students were involved in a peer evaluation process. Each group assessed the work and the presentation of the other classmates with the same rubric used by all the teachers involved in the project. In this work we present the activity, the results of peer evaluation and the feedback provided by students about the entire project.

Keywords: Peer-assessment, High school-University project, Physics experiments, Vocational training.

1 INTRODUCTION

This paper falls within the *Percorsi per le Competenze Trasversali e l'Orientamento* [Programs for General Skills and Orientation] context (from here on PCTO), written in 2021, a unique year in which pandemic restrictions have made certain previously-tested options complicated, but at the same time have motivated employees to search for alternative solutions.

The *Alternanza Scuola-Lavoro* [a project to approach students into employments], mandatory for all students in their final three years of high-school is one of the most significant innovations of law 107 from 2015 [1] ("La Buona Scuola") [The Good School], in line with the principle of open school. This represents, in fact, a cultural change for the development of an Italian approach to this dual system (school-work), which applies European good practices, combining them with the unique nature of the Italian productive fabric and socio-cultural context. Given the legislative framework, and in particular since 2019 , the *Alternanza Scuola-Lavoro* programs have been renamed *Percorsi per le Competenze Trasversali e per l'Orientamento* [2]and reformulated with a distribution of hours and possible activities during the final three scholastic years. In this context, depending on the focus of study, the educational needs of students, and the characteristics of the socio-economic context of reference, schools' organisational choices may vary.

High schools in particular can structure their PCTO into three modules, with diversified objectives and activities at school and at work in order to respond to students' various needs in terms of curriculum and

guidance: “Io e il lavoro”, “Mi sperimento”, and “Decido”[1], for a total of 90 hours. In the second module, students are exposed to various work environments. The activities here are aimed at developing their ability to use information, make decisions, develop a project throughout its various stages, and handle challenges related to choices they have made. The specific objectives of this phase are intended to teach students to:

- operate in various cultural, corporate, and organisational contexts with a sense of responsibility and spirit of initiative;
- work in a group;
- acquire and develop knowledge and abilities in order to build projects;
- plan action strategies and find solutions in order to complete projects or assigned jobs;
- evaluate their own attitudes, knowledge, and skills in relation to university and job demands;
- strengthen their ability to guide themselves and make autonomous choices.

Interaction with universities [3], institutions, and companies through educational experiences, work projects, and internships, builds a laboratory of knowledge in which to develop thought, creativity, and further organisation. The students participate in an alternative didactic experience, with diversified models and strategies, and apply what they have learned in the classroom.

2 METHODOLOGY

This paper presents the results of the activities conducted in the PCTO context in two scientific high schools, one in Milan and one in Brescia, in collaboration with the Physics Department of the Politecnico di Milano. [4]

In keeping with previous considerations, or rather with the opportunities offered, the type of scientific high school student, and, in particular, the current pandemic context, this specific scientific experience was conceived. 50 fourth and fifth year students from two different scientific high schools participated. 2 teachers representing the PCTO for the two participating schools, 3 professors from the Politecnico di Milano (one of whom in charge of data collection and subsequent analysis; from here on reference professor), and 2 tutors from the Politecnico di Milano were involved in the project. The program was structured as follows:

- lessons conducted by professors of the Politecnico
- experimental work conducted by the students, divided into groups
- presentation of the experiments by the students
- assessment of the presentations and the work.

Section 3.1 describes the activities conducted by the professors. Section 3.2 describes the proposals for experimental activities conducted by the students and section 3.3 analyses the presentation and evaluation of their work. Finally, section 3.4 analyses the students’ enjoyment of the project.

3 RESULTS

3.1 Lectures

Due to the restrictions in place because of the pandemic, the lessons were conducted online, with a duration of 3 hours each, and took place between the end of November 2020 and the start of January 2021.

In the first and second lessons the basics of wave mechanics were illustrated, introducing the concepts of interference and diffraction for electromagnetic and sound waves, and touching upon the concept of wave-particle duality. The third lesson focused on the physical modelling of a phenomenon, a key concept in western scientific culture and quite different from its eastern counterpart. Finally, in the fourth lesson, several relevant scientific experiments regarding particle interference, and in particular that of antimatter, were presented.

[1] in English, respectively, “Me and the job ”, “I try to do ”, “My choices”

3.2 The Experiment

In the active participation portion, students were asked to work in groups, designing and completing an experiment [5] involving acoustic interferometry, then gathering and analysing the experimental data they obtained and presenting it in two forms: a scientific report and a presentation. The students were divided into 10 groups of approximately 5 students each, and each group was assigned the name of an important physicist. This was another way to further illicit the involvement of the students, who were invited to research the life and discoveries of the individual they were assigned.

So as to leave room for originality and "imagination", restrictions regarding experimentation methods were deliberately not put in place [6], emphasising the scientific approach and theoretical basis of the work, as well as the insights provided during the lessons.

The students had approximately 4 months to complete and present their work. During this time they were given the opportunity to contact, online, a tutor from whom they could seek advice and suggestions for the development of their project. Also invaluable during this time was the role of the PCTO teachers who continuously urged the students to be punctual in their work and provided support in the event that they required technical material or a space in which to work, like for example the school's physics laboratory.

It is interesting to note that 7 of the 10 groups conducted experiments involving the interference of two sound sources, referring to that which they observed in Young's experiments during the lessons with the professors. From a technical point of view, however, reproducing this experience is extremely complicated and, in fact, only 2 groups obtained meaningful experimental results: the primary issues were the inconsistency of the sound sources and the challenge of measuring sound levels in a closed environment where the reflection of the sound waves is very invasive and makes it difficult to measure what is of interest. From an educational and didactic point of view, these challenges, described in the reports, provided an excellent topic of discussion and analysis regarding the role of the researcher and experimenter. The students got to experience first hand the difference between theory and practice, one of the overarching objectives of the PCTO. The other three groups built experiments relating to the concept of resonance and beats.

All of the groups used special apps to record, measure, or generate sound waves. For several years now, the sensors of the latest generation of devices, especially smartphones and tablets, have been used more intensely to teach physics and, in particular, when it comes to the experimental application of its laws. These devices make it possible to further engage students, allowing them to approach a physical phenomenon by studying it through a simple measurement, which would be very difficult without these tools, or through a slow motion video [7]. Specifically, the following apps were used: Physics Toolbox Suite, SpectrumView, Spectroid, Soundcorset, Sonic Visualizer, Online Tone Generator, Audacity.

The group's report on the experiment was evaluated by the advisors (the reference professor and the two tutors) according to an assessment grid and in keeping with the objectives of the intended learning outcomes (ILOs) [8]. The assessment descriptors were written in the form of questions to which it was possible to answer with one of four options: "not at all" (1), "somewhat" (2), "sufficiently" (3), and "very much so" (4), in which the numbers in parentheses represent the score assigned to the answer.

The questions were:

- Is the report well written?
- Is the introduction satisfactory?
- Is the experiment thoroughly described?
- Are the experimental measurements clear?
- Are the analyses presented well-founded?
- Is the conclusion satisfactory?
- What is the overall assessment?

3.3 Presentation and Assessment

In this third phase the students presented their work and evaluated that of their peers. The maximum time allotted for each online presentation was 15 minutes and, if possible, had to involve all of the members of the group. At the end of each presentation the advisors and students evaluated it.

The assessment grid was previously discussed and shared with teachers and advisors and then proposed to the students. This assessment rubric [9] was in accordance with the ILOs, promoting the concept of formative assessment. [10] This type of assessment does not have certification value, and was only intended to help the students to recognise the strengths and weaknesses of their experience up to that point. In this case as well, the assessment descriptors were written in the form of questions to which it was possible to answer with the same options as before: “not at all” (1), “somewhat” (2), “sufficiently” (3), and “very much so” (4). The following were the questions on the grid:

- Does the presentation have a good layout?
- Is the introduction satisfactory?
- Is the experiment thoroughly described?
- Are the experimental measurements clear?
- Are the analyses presented well-founded?
- Is the conclusion satisfactory?
- Were the presenters clear?
- What is the overall assessment?

With regard to the assessment process, and in particular the peer evaluation [11], a digital platform was used: at the end of each presentation, each advisor and each student, except for those presenting, filled out an online form, assigning a score to each of the above questions. The assessments were anonymous and only the reference professor could know the individual score assigned by each of the students to each group.

3.4 Satisfaction survey

At the end of the presentations, the students were asked to fill out an anonymous questionnaire regarding the lessons, the experimental portion, and the assessment portion, or rather the entire PCTO experience, its success, their expectations, and the results obtained.

The questionnaire posed the following questions, to which it was possible to answer with the same options as before: “not at all” (1), “somewhat” (2), “sufficiently” (3), and “very much so” (4).

The questionnaire was filled out by 28 students and for each question the score percentage relative to the various descriptors was calculated. Here are the questions, subdivided according to the project’s sections, as well as the score percentage obtained for each section.

Regarding each seminar speaker:

1. Did the speaker stimulate interest in the topics that he/she presented?
2. Did the speaker present the topics clearly?

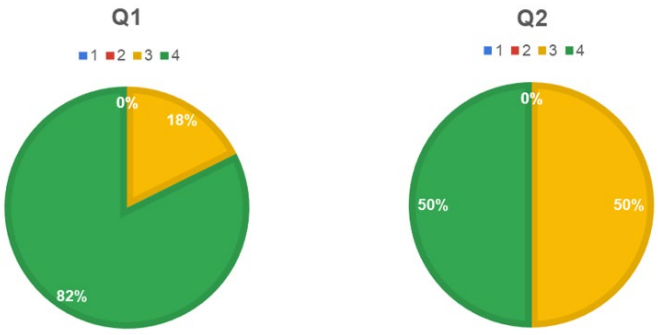

Figure 1. Score percentage referring to Question 1,2

Regarding the experiment and its presentation:

3. Did the experiment stimulate an interest in physics?
4. Did the experiment provide an opportunity to clarify certain experimental concepts?
5. Did creating a presentation stimulate an interest in and a focus on communication?
6. Did creating a presentation provide an opportunity to better clarify certain concepts?

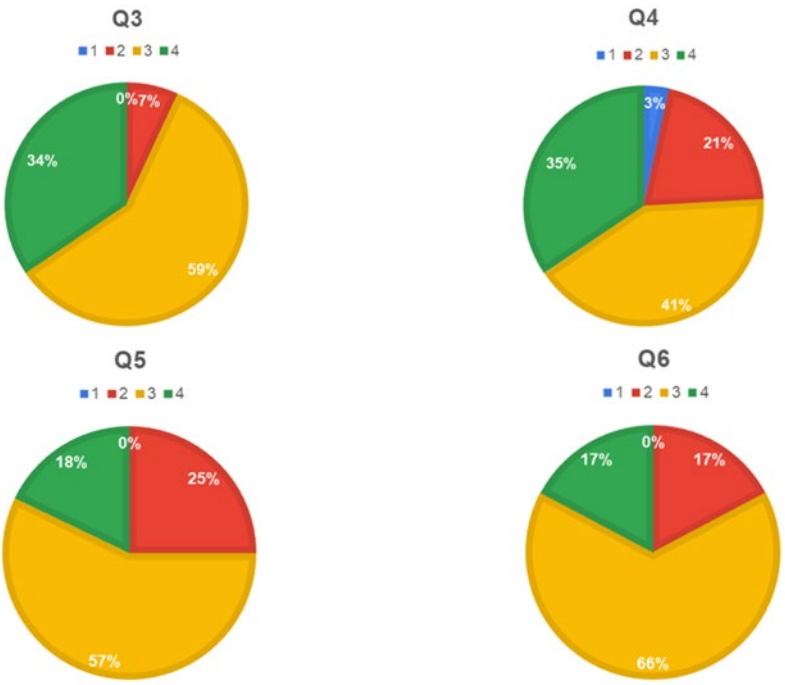

Figure 2. Score percentage referring to Question 3,4,5,6

Regarding the experiment and its presentation:

7. How much did you appreciate that the assessment of the report was conducted by the advisors? (independently of the score obtained)
8. How much did you appreciate that the assessment of the presentation was conducted by the advisors? (independently of the score obtained)
9. How much did you appreciate that the assessment of the presentation was conducted by your peers from the other teams? (independently of the score obtained)
10. How much do you agree with the overall assessment you obtained?

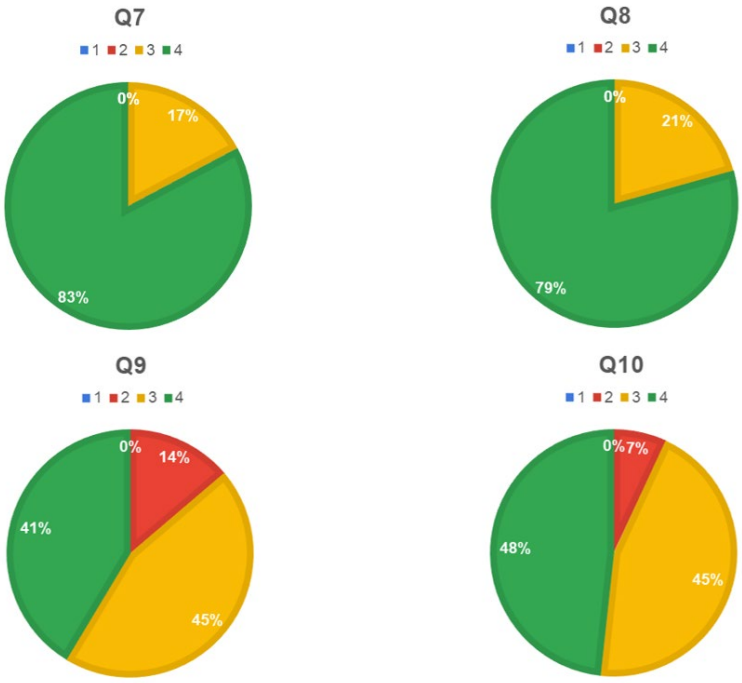

Figure 3. Score percentage referring to Question 7,8,9,10

Regarding the entire PCTO experience:

11. Before this PCTO were you interested in physics?
12. Did this PCTO increase your interest in physics?
13. Did you enjoy the overall didactic method of the PCTO?

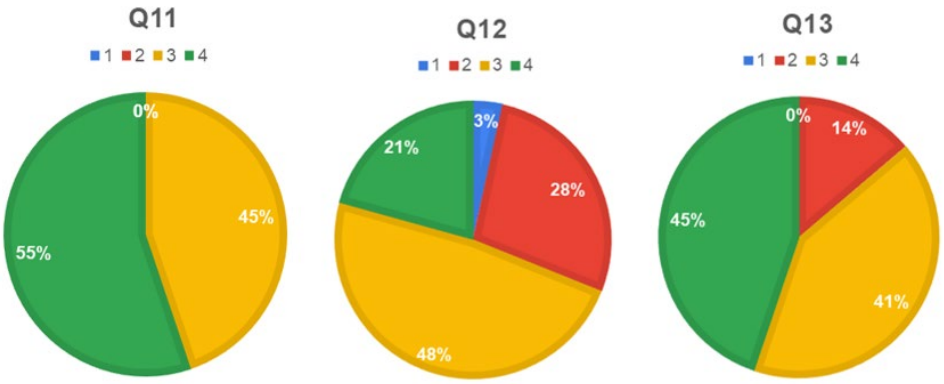

Figure 4. Score percentage referring to Question 11,12,13

In the conclusion of our analysis of this data we provide the score percentages obtained on the totality of questions, for a total of 484 assessments, in which 91% of the scores indicated by the students are in the 3-4 range.

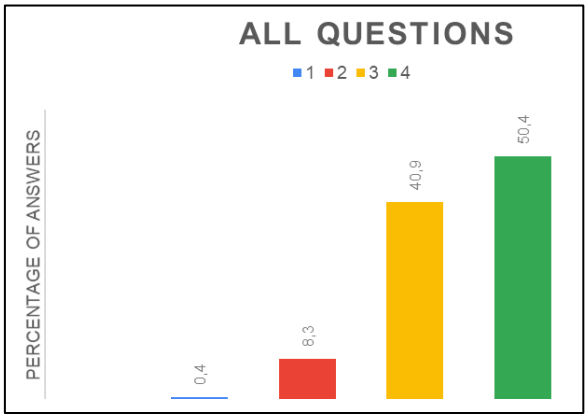

Figure 5. Score percentage referring to the totality of the questions

Meanwhile, the two teachers of the high schools involved were asked to freely express their opinions of the experience. Their opinions of the PCTO were positive. The following is a relevant excerpt regarding the experimental experience and peer assessment: “intelligence of the final presentation because stimulating, but not impossible, guided, but developed autonomously, with possible personalisation, but in collaboration with 4-5 classmates.”

4 CONCLUSIONS

An initial and simple interpretation of the results highlights the efficacy of the PCTO experience conducted from the perspective of the students’ interest and engagement. The decision to have the presentations undergo peer assessment was also highly appreciated: 86% of the students in question 9 and 93% in question 10 gave a score of “3” or “4”. In terms of the experiments, here too the data obtained indicates a high level of enjoyment: in fact, 80% of the students gave a score of “3” or “4” to questions 3 and 4.

It is also interesting to note that the least positive result is in question 12, where the 28% of students assigned rating "2". A first hypothesis that explains this data could be linked to the heterogeneity of the

student group and therefore to their personal interests, in particular referring to their prospective about University. It is certainly expectable that one student that is oriented to enroll in humanistic or social faculties could have confirmed his non-scientific aptitudes and he expressed an opinion compatible with a lack of interest in Physics. Even in this case, however, we would have achieved the goal of accompanying the student in the discovering of his abilities, skills and interests.

Our work will continue by analysing and comparing the assessments given by the students to their peers as compared to those given by the professors. A potential future development will be to validate the peer assessment process that was used.

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