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Galileo's legacy: Astronomy paths to teach Physics

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Summary. — Since the latest reform of instruction, the teaching of Astronomy is no longer inside Italian upper secondary education. However, the students' profile at the end of this cycle requires them to possess the knowledge of the fundamental concepts of Astronomy. The context for teaching these contents could be Physics, whose topics are intertwined with Astronomy. In order to investigate the possibility of introducing concepts of Physics through Astronomy, we have structured ATENA (Asiago TEachers Network on Astrophysics), a training course for in-service high-school Physics teachers. The project has started in the current scholastic year by the means of a learning community, on the model of the previous experience with the COLLABORA project. To introduce ATENA, we organised two laboratory and museum workshops, built according to the Object-Based Learning paradigm, which involved the construction of two astronomical instruments and visits to two museums. In this contribution, we will describe these activities and their results. The goal is to explore how this approach can foster the integrated learning of Astronomy and Physics.

1. – Introduction

The inclusion of Astronomy in school curricula at all levels has been recommended for its comprehensive relevance and value [1]. Research in science education on the teaching and learning of Astronomy highlighted different Astronomy topics of interest and stressed the importance of a longitudinal approach to develop familiarity with the sky and to support the understanding of science contents [2, 3].

Until 2010, Italian high school included the teaching of Astronomy in the so-called "Geografia Astronomica" subject ("Astronomical Geography"), typically addressed in the fifth year, within the Science curriculum, dealing with topics from Earth to stars, from galaxies to the structure of the Universe. The latest reform of upper secondary school (2010) strongly reduced the presence of Astronomy in the Science curriculum. However, the Physics curriculum contains several references to astronomical contents and topics that can be enriched by an astronomical contextualisation or application. This suggested that Astronomy can still be advantageously included in the upper secondary school curriculum, combining its topics with the Physics curriculum, which may also stimulate a reflection on the content structure of Physics and Astronomy.

In this contribution, we describe two workshops called "L'eredità di Galileo" (Galileo's legacy), addressed to secondary school Physics teachers. We present the activities we developed and teachers' response, discussing some implications for the integrated teaching of Physics and Astronomy.

The workshops took place in May 2022, involved 19 teachers, and were intended as a kick-off for ATENA (Asiago TEachers Network on Astrophysics), a one-year long professional development course developed on the model of our previous course COLLABORA [4]. ATENA was then launched in September 2022.

2. – Workshop design

The two workshops were structured over the core physics topic of light, which is also a central element for Astronomy. The information we receive from our Universe is sent by the means of light, and its particular nature offers the possibility of reflecting upon the role and evolution of models in Physics. For this reason, we decided to explore the two interpretative models of light's behaviour: in the first and in the second workshop we focused on the ray model and the wave model, respectively.

The core of each workshop was the use and construction of a scientific instrument. In fact, research in Astronomy education has suggested that instruments are a key element in fostering the teaching and learning of Astronomy [3]. The chosen instruments were Galileo's telescope to deal with the ray model, and a diffraction grating-based spectroscope to highlight the wave nature of light.

We incorporated this focus on instruments into the wider perspective of the Object-Based Learning (OBL) approach [5], a student-centred pedagogy that includes the multisensory study of objects to deepen engagement and create more meaningful learning experiences [6]. Objects can become effective learning tools when involved into the learning process, developing both subject-specific knowledge and transferable skills, enriching the affective and emotional component of learning [7].

In this context, museums offer a natural place for studying and exploring instruments. Their collections have an important educational value [8], being a context for non-formal science education which integrates formal activities, increasing the quality of students' scientific literacy [9-12]. Therefore, in each workshop, we decided to include a visit to a museum, which houses collections of historical instruments used in Astronomy and Physics: the Giovanni Poleni Museum of the History of Physics, and the La Specola Museum of the National Institute of Astrophysics (INAF).

For this study we were guided by the following research question: *In which ways can an object-based approach foster integrated learning of Astronomy and Physics?* To collect data, we asked teachers, through a digital platform, what activity they could employ in the classroom, what learning outcomes or competencies could have these activities contributed to, and what challenges and opportunities they saw.

3. – The two workshops

3˙1. *Workshop 1: Galileo's telescope.* – The first workshop focused on ray optics and began with the visit to La Specola Museum, now part of the National Institute of Astrophysics (INAF). The museum hosts several ancient astronomical instruments, such as globes, quadrants, and telescopes of the 18th and 19th centuries.

Teachers were then involved in the construction of a toy replica of a Galileo's telescope. This instrument is relevant for different reasons: it is a very common configuration

for terrestrial observation and small toy telescopes, but it is also important from a historical point of view, being the first model of telescope to be built, leading Galileo to fundamental discoveries. From the Physics education perspective, it allows triggering a reflection on concepts as image formation and the use of ray diagrams, since drawing and interpreting its ray diagram is not trivial compared, for instance, with the Keplerian configuration.

Teachers started by investigating the properties of lenses on an optical bench through an inquiry-based laboratory. They then replicated a Galileo's telescope on the optical bench using the provided lenses, and finally they assembled a small telescope using a cardboard tube of adjustable length and another set of unmounted lenses. Throughout the activity, teachers were encouraged to reflect on the representation of the light path, objects and images through ray diagrams.

3˙2. *Workshop 2: The spectroscope.* – The second workshop started with a question-posing activity developed according to the OBL approach. Four different tables were equipped with an optical instrument from the Giovanni Poleni Museum, whose description was not given to teachers. Instead they were encouraged to note down all the questions coming to their minds while examining the objects. The questions that emerged were gathered according to six categories (context and history, technical and physical features, function/purpose, value, design and decoration, and creativity) and were discussed to highlight how from these questions one could start constructing knowledge about the object and the Physics it contains.

Teachers were then engaged with a laboratory activity on wave optics, the goal of which was to design and construct a pocket spectroscope with a transmission diffraction grating as a dispersive element. The spectroscope is another fundamental instrument: from the historical perspective, the spectral analysis applied to the study of astronomical objects gave birth to modern Astrophysics. From a Physics education point of view, literature highlights the educational value of this kind of spectroscope that can be used both qualitatively, for simple observation and comparison of spectra, and quantitatively, for instance obtaining a rough measurement of the wavelengths [13-16].

During the activity, teachers sketched the scheme of the instrument and reflected on its components and on their function, in particular on the role of the diffraction grating. They outlined its properties examining the behaviour of a green and red laser as it passed through it. Finally, teachers assembled our version of the spectroscope, made of a black cardboard parallelepiped. One of its bases is replaced by a diffraction grating with a pitch of 500 ll/mm, while a small rectangular slit is cut on the other base. Looking through the spectroscope, teachers were able to see the spectral decomposition of different light sources *e.g.*, sunlight, light from an incandescent lamp, light from monochromatic sources, light from LEDs and light from the fluorescent lamps of the room. Finally, some gas discharge lamps allowed teachers to explore the spectra of hydrogen and helium.

The workshop ended with a visit to the Giovanni Poleni Museum of the History of Physics with a focus on the optical instruments section.

4. – Discussion and conclusions

We conclude by analysing teachers' responses to a short online questionnaire we proposed to gather data on our research question. Teachers appreciated our activities, especially for the different employed methodologies, which helped them identify actions they

could use to differentiate their practice and intercept students' learning styles. They identified several learning outcomes from the activities such as reinforcing some experimental scientific practices, finding the approach stimulating and inspiring. They appreciated the object-based perspective and the question-posing activity, useful for introducing a topic.

The two instruments were found interesting, both for their role in the History of Physics and for their educational value: they commented that the spectroscope activity can be proposed in the classroom, accompanied by pre- and post-lab sessions and encouraging students' cooperation. Also the telescope activity was judged usable, though some teachers suggested using simpler configurations with secondary school students. Other proposed a multidisciplinary path involving Physics, Astronomy, Philosophy, History, and Italian Literature, or to combine geometric optics with the study of axiomatic geometry. The educational relevance of the historical content addressed in our activities was pointed out as a strength: this has been especially considered in the visits to the museums, an opportunity for teachers to be included in their curricular Physics teaching.

Teachers also pointed out some challenges, such as the required time to prepare these activities or their assessment that may rely on observations of students, individual and/or group reflections, and on a final test.

These topics were the starting point for deepening the connection between Physics and Astronomy, and further innovative developments are expected to arise from the school experimentation we are developing together with teachers during the ATENA course.

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