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Implementing a hands-on astronomy laboratory on sundial at an archeological museum: the role of cultural heritage to increase students' motivation towards science and astronomy.

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Introduction

We will present a Teaching - Learning - Activity (TLA) developed for lower secondary school students as part of the project Next-Land. This project aims to increase students' interest in STEM involving them in out-of school laboratory activities to be implemented in university laboratories or in museum. As researchers in Physics Education, we were involved in Next-Land project to design a TLA based on research results. As a main topic for the TLA, we chose astronomy and for a suitable context to implement the activity the National Archaeological Museum of Naples (MANN). We focused on astronomical topics because astronomy is fascinating for its own nature and thus can represent a "Gateway Science" (National Research Council, 2012) to engage students in STEM (Slater, 2018). Furthermore, we selected MANN as setting for the TLA because it is strictly related to Astronomy. First for its history: Ferdinand IV in 1791 appointed the east corner of the University Building, nowadays part of the MANN, as the place to set up an astronomical observatory. The project was soon abandoned, creating only the wonderful sundial in the floor of the "great hall". This sundial is the object of investigation of our TLA. Second, it features many historical exhibits related to astronomy, e.g., ancient sundials or frescos representing divinities related to astronomy, thus representing a privileged informal setting for an interdisciplinary laboratory activity focused on astronomy.

Thanks to Next-Land project we were put in contact with MANN' experts, and we collaborated with them in designing details of the TLA. This TLA was piloted implemented with a class of lower secondary school students and qualitative data were collected to assess the efficacy of the TLA in increasing students' interest in science. Results from pilot implementation will be presented.

Theoretical Framework

Context-based learning (CBL) This approach aims to connect learning of scientific concepts embedded in out-of school situations chosen to illustrate the application and relevance of scientific knowledge, and to increase students' interest and learning achievement in related subjects (e. g. Bennett, 2003; Gilbert et al., 2011; Parchmann et al., 2006). CBL engages students in learning that demands activating their thinking and metacognitive skills, motivates students to learn, and encourages them to be scientifically-literate (Bennett & Holman, 2002). Bennett et al. (2007) in their review of the research results on CBL, find that this approach has a positive impact on students' affective outcomes which is the main aim of Next-Land project. Therefore, CBL approach represents a suitable framework for our TLA.

Spatial thinking and misconceptions in Astronomy Even if students experience astronomical phenomenon in their everyday life, they encounter many difficulties in developing a scientifically correct explanation for what they can observe. In our TLA, students are introduced to the MANN's sundial, used to measure in which period of the year we are, and are asked to explain how it works. The sundial functioning is related to the evidence, well known by students, that in summer the maximum height reached by the Sun above the horizon in the course of a day is higher than in winter. The astronomical cause of this phenomenon is the same of the change of seasons: the Earth's rotation axis is inclined with respect to the earth's orbit plan and does not change its direction during Earth's revolution around the Sun. Anyway, students may have many difficulties in explaining this phenomenon. For example, they may think that the Sun moves (Stover and Saunders, 2000), or that the Earth's axis change direction during the year, so that the Sun appear to be in different direction (Trumper, 2006).

From many studies (Testa et al., 2015; Plummer, 2014) it emerged that students' difficulties in developing a scientifically correct explanation of astronomical phenomena is related to low spatial thinking skills, because astronomical explanation often require to link together what an observer can experience from the Earth's surface "*Earth Perspective"* to what he could see from a "*Space Perspective*" observing the Earth's motion from space. To help students to address this issue, in our TLA we plan two different activities (see Phases 2 and 3) specifically designed to help them to experience the same phenomenon from both Earth and Space Perspective.

Aims of the TLA

- increase students' awareness of the cultural heritage of their city and of MANN;
- increase students' motivation towards science and astronomy;
- support students to develop their spatial reasoning skills.

Research Question

During the pilot implementation of the TLA we focused on the following Research Questions:

RQ1) Is the developed TLA effective in increasing the students' motivation towards science?

RQ2) Is the proposed TLA effective in supporting students to understand the astronomical phenomena which allow the sundial's functioning?

Sample

We piloted implemented our TLA with a class of lower secondary school students (11-12 years). Students involved were 19 students (9 female and 10 male). They were from a problematic socio-economic background, because this was the target of Next-Land project. Only 3 students declared to have previously visited MANN even if they live nearby. Their teachers declared to usually adopt traditional teaching methods, almost lecturers. Finally, teachers declared that they did not address astronomical topics before in classroom.

Methods

Design the TLA Our research group included two researchers in Physics Education and an expert from MANN. To design the TLA we worked bringing together our different competences in astronomy education and humanities. After two first meetings we decided to organize the TLS into three phases (see details below) including: (i) a guided visit to the museum aimed to increase students' knowledge about MANN's history and heritages; (ii) a visit to the "Sundial Hall" aimed to engage the students with a real problem connected to a scientific problem; (iii) an inquiry-based laboratory activity taking place in the museum itself. We made a guided survey of MANN to select the pat for the guided visit and a series of frescos, related to astronomy, that we want to present to the students. Then, starting from previous studies on laboratory focused on basic astronomical phenomena, in particular on night and day phenomenon (Nobes, Frède, & Panagiotaki, 2022; Rafikh et al. 2020) we design an inquiry-based activity focused on the motion of the Earth in space and on its relationship with the sundial functioning.

Research methods During the pilot implementation a specialized guide conduced the guided visit to MANN (phase 1), while one of us conduced the laboratory activities (phase 2 and 3). As students involved in the study were a small number, we collected only qualitative data taking field note and asking students to answer to a brief structured interview at the end of the TLA.

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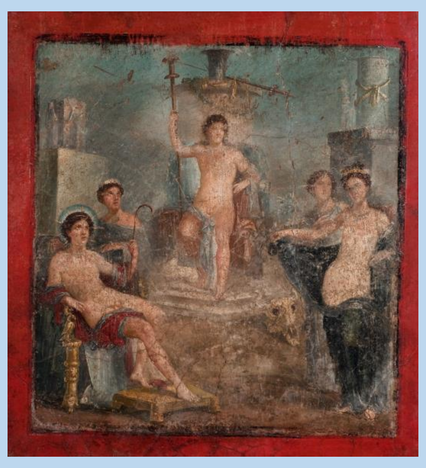
The Teaching - Learning – Activity

Phase 1

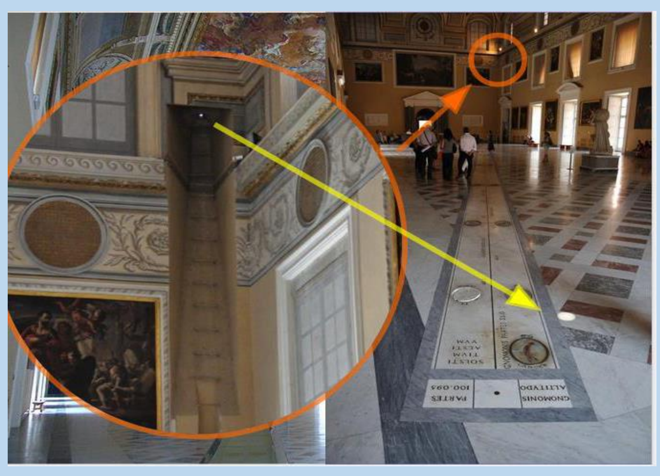


Fresco - Pompei - Espero between Apollo and Venere – MANN inv. 9449

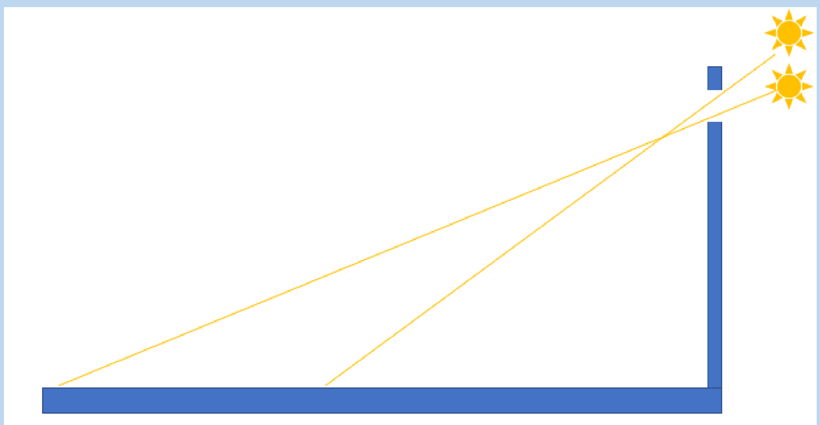
The students are introduced in the MANN and participated in a visit of the museum. A specialized guide give to the students some information about the history of the MANN. Then students are conducted to visit a selection of archeological exhibits related to astronomy as, e.g., frescos from Pompei representing ancient Greece myths' characters related to astronomy (Apollo, Saturno, Venere etc.). Phase 1 is important to engage students and to familiarize them with the MANN which is one of the most important archeological museum in Italy and in the world. Furthermore, the guided visit is fundamental to familiarize students with the MANN that could be perceived as an unusual setting for a teaching activity.

Fresco - Pompei – Zeus - MANN inv. 9551

Phase 2

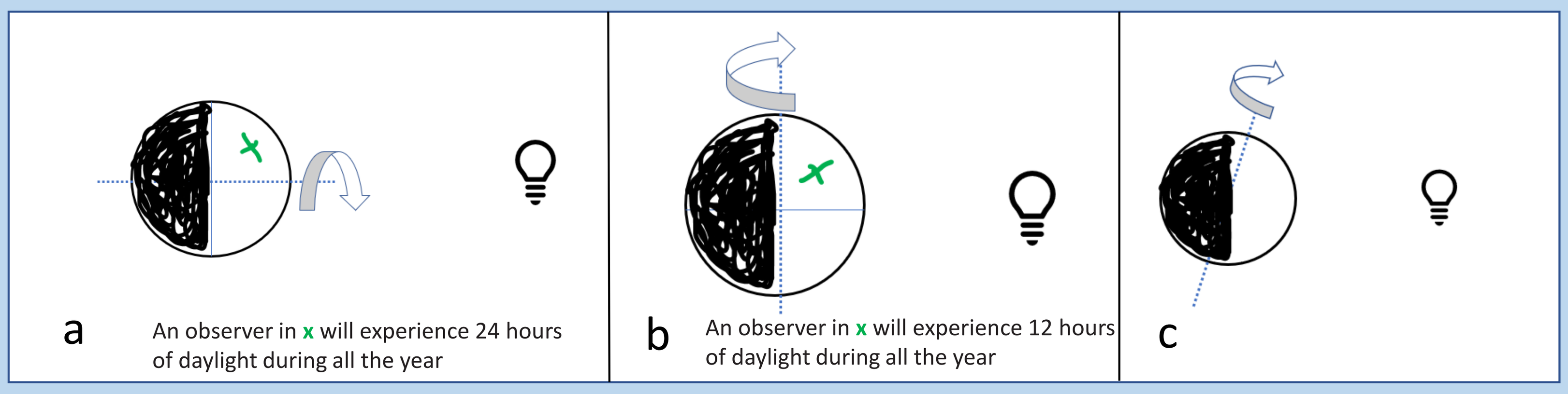


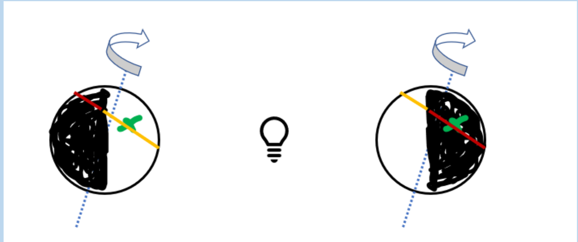
The students are introduced in the "Hall of Sundial" and are invited to observe and describe the sundial itself. This is formed by a brass line, long over than 27 meters, and on both the sides of line there are paintings enclosed in elliptical medallions representing zodiac signs. The students are invited to discuss in small group to explain why zodiac signs are represented in the order they can observe. Starting from this task, they are guided to explore from the *Earth Perspective the* phenomenon caused from the Earth's motion around the Sun and are guided to understand the functioning of the sundial. Anyway, they are still not able to connect the sundial's functioning to its astronomical causes.



Phase 3

The students are engaged in a guided Inquiry-Based hands-on activity aimed to develop and test a model of the Earth and Sun system. They are guided to explain what they observed in the Hall of Sundial but now from a *Space Perspective*. Working in small groups, and using low costs materials (polystyrene balls, torches and toothpicks), students are asked to investigate the situations represented in figures a, b and c in order to understand how the Earth's rotation axis is placed in the space with respect to the Earth's orbit plane.





The students are guided to understand that, to explain what they experience about the duration of night and day, the Earth's rotation axis must be not perpendicular nor parallel to the Earth's orbit plan. Finally, the students are asked to explore what happens to the shadow of a toothpick placed on the ball as it moves around the torch (the Sun). This last activity is useful to reconnect what students previously observed in the "Hall of Sundial" from *Earth Perspective* to what they observe modeling the Earth-Sun motion from a *Space Perspective.* Furthermore, this laboratory activity, making students dealing with different "perspective", support them in developing spatial thinking.

Results

RQ1: At the end of the activity, students reported on average that they find the TLA interesting ("*I would like to take part to similar activities in the future*"; "*I like doing lesson in this way. I like that we were asked to give our opinion and solve a problem by ourselves*"). Furthermore, students declared that they liked the proposed context. They declared that astronomy seems to be interesting even if they did not perceive this matter as fundamental for their everyday life ("*I think astronomy is interesting, but I think that in the past, e.g., when sundial were used, it was more important for men than nowadays*").

RQ2: Students declared that they were not sure to have well understood the proposed topic as they need more time to experiment and test the proposed model of Earth's motion around the Sun ("*I think I have understood but I am not sure I can explain what I experienced to other*", "*We have too less time to discuss and find a solution to the proposed problem, I am not sure I understood everything*").

Limits and future steps

The number of students involved in the pilot implementation was too small to collect also quantitative data. In the future we aim to involve a larger sample of students and we aim to collect data using validated questionnaire. In this way we will be able to assess the efficacy of the developed TLA both in increasing students' engagement in science and also their knowledge about astronomical phenomenon related to the Earth-Sun motion.

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