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Construction of didactic devices that materialize the states of illumination of the ground and of the planet

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Abstract. The original design of the IAUS367 included the development of a Workshop, thought to be a face-to-face instance, in order to interact with teachers and researchers, and to discuss the design, the theoretical foundations and the use of some didactic devices to observe and record the state of illumination and shadows casting variations on different objects, natural or artificial, through time, and its interpretation from a local, topocentric perspective, together with a global, planetary perspective. The pandemic forced us to convert this activity in a virtual one, which was very interesting anyway, with the participation of colleagues from different countries and with great theoretical wealth in the discussions. The Workshop lasted 2 hours, in Spanish language. We present here the initial proposal and a summary of what was discussed. (The complete video register can be accessed in the YouTube channel of IAUS367).

Keywords. Construction of didactic devices. State of illumination. Shadows. Local/Global vision. Didactics of Astronomy.

1. Key elements for the construction of didactic devices in Astronomy

The design, construction and systematic utilization of didactical devices to observe and register the diurnal and annual variations of the state of illumination of the ground, of natural and artificial objects of our environment, and of the shadows they cast, even local and of the planet as a whole, have some key elements, which are of great relevance for our proposal for the Didactics of Astronomy (Camino 2012, 2021; Lanciano 2019). **To experience and become aware of regularities** in the everyday environment (space and time), specially related with solar illumination (light and shadow). **To observe and register phenomena in a systematic way** in contact with the sky, and to learn how to construct questions, a task shared with others over time. **To ask ourselves critically** about what the purpose of recording regularities is (practical, cultural, etc.). **To learn how to materialize those regularities**, especially through markers in space and time, and to understand the existing ones, whatever material or social, generated by other cultures. **To understand that life in society**, even today, **is immersed and requires knowledge of the observable universe**, in particular the phenomena of the sky and their interaction with the place where we live.

2. Some examples of devices and the activities we have developed

Natural or artificial photometers. All objects can be used to compare the illumination states of their different parts. Each object could act, for this reason, as a

"comparison photometer", which then allows us to utilize them as indicators of the position of the Sun in the local sky, and as devices to measure time. From mountains to buildings, their state of illumination brings us information of the real sky in real time. **Vertical gnomon**. A straight, vertical rod with a hole at its end, 1 m long (for the sake of simplicity in many mathematical calculations) is a simple but powerful device for the Didactics of Astronomy. Furthermore, we utilize threads of colour to materialize the rays of light that pass through the hole and to materialize the shadows of the gnomon on the ground. The diurnal and annual regularities in the length and orientation of the shadows of the gnomon make it possible to determine the spatial (meridian) and temporal (solar noon) symmetries at the observation site. The light and shadow structures generated by a gnomon during equinoxes and solstices form sections of three-dimensional cones in 3D space and conics on the ground, all of them beautifully materialized by the color threads. On the ground, the relationship between percentage of it covered by the threads that materialize the shadows is equivalent to the relation of the day-night length during that day (space and time linkage). We've developed many educational and research projects in the last decades utilizing these devices. In Patagonian Primary schools (Camino 1988–1989; Camino *et al.* 1998; Camino *et al.* 2020), many children worked weekly, during a two-years period, on the observation and recording of shadows of a gnomon, until they built a sundial. Other projects were developed in a collaborative way with students and colleagues of South America: during an equinox, the latitude of the observation site can be determined (Camino *et alii* 2009), as well as during equinoxes and solstices it is possible to determine the obliquity of the Ecliptic (Camino *et al.* 2014) and the determination of the Analemma (Camino *et al.* 2016) as well. These works highlight the awareness of what is common to all the observers on the Earth and what identifies each one depending on the place of observation and of the culture itself. **Smooth Sphere**. A sphere without any markings, being illuminating by the Sun, is a very important educational tool. Observing and marking on the sphere the position of the terminators (instantaneously maximum circle separating light and obscurity), day by day, as well as utilizing small gnomons casting little shadows, allow us to materialize on the surface of the sphere the observed regularities. During equinoxes and solstices, it is possible to construct the concepts: poles, meridians, parallels, polar circles, tropics, equator, and to estimate seasons, day/night relation, times of sunrise/sunset/noon, for each place in the world, in real time. Those markings on the planet gave rise to many social conventions, some still present nowadays, like the International Time Zone system. The Smooth Sphere brings the foundations of the most powerful tool for the Didactics of Astronomy, the Parallel Earth Globe (PEG). (Camino *et al.* 2020) **Parallel Earth Globe**. The use of a PEG makes it possible to build a dual vision (local and planetary) of the astronomical environment in which we live (Lanciano 2012). Decades of didactical work utilizing the PEG show it is a powerful device not just for the Didactics of Astronomy, but for a multicultural democratic worldview as well (access the official web site of "Globo Local: International movement for the liberation of the globe from its fixed support" project (Lanciano 2020). **The complete set of didactical devices for Didactics of Astronomy by naked eye**. The set of devices that we propose is made up of a gnomon, a smooth sphere and a PEG, located fixed and permanent in the place of observation, see Fig. 1, they should be used continuously through long periods of time, been scholar periods or extracurricular ones. To improve the teaching/learning process about the sky and of the linkage of humans and societies with the sky, it is of great relevance to recognize and to represent, previously, the local horizon by means of drawings, photographs and concrete models. Whenever it should be possible, the construction of sundials, in public spaces and in schools, is an educational and cultural element of great social relevance, and it could be considered as the materialization and conceptual synthesis of the didactical

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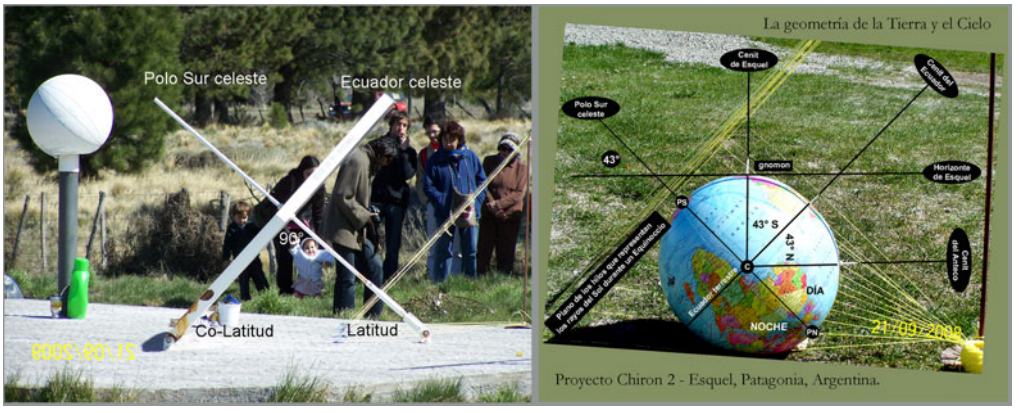

Figure 1. Complete set of didactical devices (Smooth Sphere, equatorial sundial, gnomon, Parallel Earth Globe).

developments presented here (an equatorial sundial should be perfect, and a meridian line in-doors as well).

3. The possibilities offered by our conception of the Didactics of Astronomy

Our proposal for the Didactics of Astronomy bring some possibilities of great importance, not only for the relationship with the sky, cultural and personal, but for the process of knowledge construction in general. In first place, "knowing how to do, while living in contact with the sky", without sophisticated technology being a necessary condition, restrictive and away from real people; in second place, "knowing how to build knowledge", scientific or of any other type of knowledge, strengthening the bond of oneself with the universe and with others, improving the creativeness to formulate questions that lend us to further explorations. I like to think that through this conception of our relationship with the sky, and its educational and social relevance, we could talk and understand each other with the people of the cultures that we study nowadays through Cultural Astronomy. If all of today's technological society disappeared, who would still be able to build knowledge associated with the sky? I consider that nowadays astronomers should be at least as solvent as astronomers were centuries ago, with the ability to build knowledge by naked eye, and then dedicate ourselves to deepen what we've built utilizing very complex technology and modern theoretical constructs. We should have included in our "astronomical genetics" what the astronomers of the past did, and then as sons of our times do all the current scientific Astronomy.

4. Discussion during the Workshop

The participants highlighted their interest in working with the naked eye, in contact with the sky, together with other people, strengthening learning to observe, describe, conceptualize and explain, and critically generate questions. It is very important the link with schools, teachers and student's families to develop long-term projects on Didactics of Astronomy, e.g. in order to continue with the observations throughout the year, including vacations. Strengthen work with teachers, so that as people and as education professionals they know theoretically and experientially what they will later propose to students; the inclusion of Didactic of Astronomy in the initial training of teachers must also be strengthened.

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The importance of the horizon and the local landscape is highlighted, and of the systematic observation and recording of the rising and setting positions of the Moon and the Sun, and of some stars, on that local horizon, as a basis for the work. The devices shown during the Workshop are built as the result of a long-term educational process, and they are built not as a recipe but as a concretion of what has been lived, and what is didactically worked on from what has been lived. Each object, natural or artificial, in its illumination states and in the shadows they cast, carry information about the astronomical environment, you just have to observe them, record them and build knowledge. Every shadow says something, every illuminated surface says something...

How to move from the recognition of the observable in place to the conceptualization offered by a Parallel Earth Globe, which already explicitly presents a conception of a spherical Earth, is a challenge not only to didactics, but also is highly relevant for works on Cultural Astronomy , since the practices of different indigenous peoples throughout history did not necessarily lead to the construction of a spherical model, with a global perspective, of the place where they live. Direct, experiential experience, over long periods of time, is essential to facilitate the passage of spatio-temporal conceptions and to work on the possible epistemological obstacles that could exist in each age group.

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