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Create your own multimedia learning space (D.O.M.E.)

A DIY planetarium for and by students.

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Abstract. Despite the attraction to astronomy, access to celestial observations and immersive planetarium experiences is often limited by geographical and socioeconomic factors. D.O.M.E. (Design Your Own Multimedia Learning Environment) is a DIY project that emerged with the goal of enabling schools and communities to build their own planetariums, transforming astronomy learning into a practical and engaging experience. In the project, students build a cardboard planetarium with a diameter of 4 meters. The methodology involves a collaborative and interdisciplinary process, having been implemented between 2022 and 2024 in schools in 5 countries, with European funding. Everything begins in the classroom, where students, with the help of the teacher, are the protagonists in creating the triangles that make up the geodesic dome. The projection system consists of a projector coupled to an optical arrangement composed of two camera lenses (50 mm and fisheye) and a flat mirror, on a 3D printed support. As a result, the project involved the active participation of 14 public schools, divided among the participating countries, with 17 teachers directly involved, guiding 191 students in building their own planetariums. During this period, more than 2,000 students visited the cardboard planetariums built by their peers. This initiative proved to be an authentic application of the STEAM approach, stimulating critical thinking, creativity, and problem-solving. D.O.M.E. proved to be a powerful educational tool, not only communicating scientific knowledge of astronomy but also inspiring a deeper and more practical connection with the Universe. By being the builders of their own learning environments, students develop a strong sense of belonging and accomplishment. The project's characteristic of using simple and replicable materials ensures that this experience can be adopted in various contexts, democratizing access to a more engaging and immersive science education.

Resumo. Apesar da atração pela astronomia, o acesso a observações celestes e experiências imersivas em planetários é frequentemente limitado por fatores geográficos e socioeconômicos. D.O.M.E. (da sigla em inglês Design your Own Multimedia learning Environment), é um projeto DIY, surgido com o objetivo de permitir que escolas e comunidades construam seus próprios planetários, transformando a aprendizagem em astronomia em uma experiência prática e engajadora. No projeto, os alunos constróem um planetário de papelão com 4 metros de diâmetro. A metodologia envolve um processo colaborativo e interdisciplinar, tendo sido implementado entre 2022 e 2024 em escolas de 5 países, com financiamento europeu. Tudo se inicia em sala de aula, onde os alunos, com o auxílio do professor, são os protagonistas na criação dos triângulos que compõem a cúpula geodésica. O sistema de projeção é composto por um projetor acoplado a um arranjo óptico composto de duas lentes de câmeras fotográficas (50 mm e olho-de-peixe) e um espelho plano, em um suporte impresso em 3D. Como resultado, o projeto contou com participação ativa de 14 escolas públicas, dividido entre os países participantes, com 17 professores diretamente envolvidos, guiando 191 estudantes na construção de seus próprios planetários. Durante este período, mais de 2000 estudantes visitaram os planetários de papelão construídos por seus colegas. Essa iniciativa demonstrou ser uma aplicação autêntica da abordagem STEAM, estimulando o pensamento crítico, a criatividade e a resolução de problemas. O D.O.M.E. se mostrou uma ferramenta educacional poderosa, não apenas comunicando o conhecimento científico de astronomia, mas também inspirando uma conexão mais profunda e prática com o Universo. Ao serem os construtores de seus próprios ambientes de aprendizado, os alunos desenvolvem um forte senso de pertencimento e realização. A característica do projeto de utilizar materiais simples e replicáveis, garante que essa experiência possa ser adotada em diversos contextos, democratizando o acesso a uma educação científica mais engajadora e imersiva.

Keywords. Teaching of Astronomy – Miscellaneous

1. Introduction

Astronomy makes people feel amazed and curious (Oliveira 2019). However, observational astronomy can be difficult because the weather is always changing and there is a lot of light pollution, especially in cities. The planetarium is a great place to see a dark sky. It's like a dark sky oasis. In a planetarium, the operator controls all the things that can be seen in the sky. This includes clouds, how bright the sky is, where the planetarium is, and even if there are clouds in the sky. It has a certain atmosphere. A planetarium is a place where people can see a realistic view of the sky. However, as Plummer et al. (2011) has noted, people at a planetarium session may be able to see very complex or even impossible sights that cannot be commonly observed. For example, during a planetarium session, you can see the sky from anywhere on Earth, or even in the Solar System. You can see lines linking the stars to form the constellations, zoom in to any planet to see fine details, or even observe the night sky without the atmosphere.

There are different types of planetariums, from simple pinhole-based star projectors to modern digital projectors. Planetariums used to be limited to buildings, but now they can be moved. Some even have smartphone apps that let you use planetarium software wherever you go. With these, the user can change the view, the date and time, the constellation cultures, or the location on Earth and in the Solar System. These tools show that planetariums can be great places for students to learn without going to school. In a planetarium, students can interact with the object they're studying.

According to Gomes et al. (2017), when non-formal learning opportunities are added to formal practices, they can improve scientific knowledge in general and specific ways.Gohn (2014) said that non-formal education is an important tool for shaping citizens. The author said that this tool doesn't depend on how much education a person has.Allaste et al. (2022) said that non-formal education is especially important for young people because it is less It is more flexible than traditional schooling, which helps keep young people interested and engaged. The results are similar. They were noticed by Menezes et al. (2018), who looked at data from science events about teaching and communication.

In addition, Langhi & Nardi (2009) posit that while astronomy learning can occur in a variety of settings, planetariums offer a more effective and scientifically compelling environment for this purpose. As Oliveira (2019) emphasizes, the planetarium is a venue of significant importance, a place where the audience can be in contact with the exploration and study of the scientific discipline of astronomy, as well as the broader field of science. Planetariums offer a distinctive educational experience that merits further consideration. The audience is immersed in a dark room, where they remain for a limited time, observing a prerecorded narrative or a live presentation. This information was relayed by a professional tour guide.

For a considerable number of educational institutions and astronomy clubs around the globe, the financial burden associated with the construction of a conventional planetarium or the procurement of a portable planetarium can be substantial. In certain instances, the cost of this equipment can exceed the annual budget allocated by a school. Do-It-Yourself (DIY) projects have been shown to engage the public in a manner that is both enjoyable and educational. As Hirshon (2020) demonstrate, there is an infinity of DIY projects that practitioners can reproduce in a variety of settings, including their homes, classrooms, offices, or outreach programs. These projects facilitate comprehension of the workings of specific scientific subjects. In the context of a team-based DIY project, such as the one presented here, learners cultivate a more profound comprehension of the subject matter through experiential learning and peer instruction. This pedagogical approach integrates elements of citizen science and communication, fostering a synergistic learning environment.

The STEAM methodology for constructing a DIY planetarium is straightforward. For instance, the strategic implementation of a planetarium construction project enables learners to explore interdisciplinary concepts from various fields, including science, mathematics, engineering, arts, technology, and innovation. These competencies are further cultivated in the process of developing scripts for planetarium shows. Moreover, the multidisciplinary character of astronomy enables the integration of concepts from other scientific domains, thereby rendering the planetarium an optimal venue for scientific communication (see Langhi & Nardi (2009); Kukula (2017); Marques et al. (2021)).

The following presentation will summarize the findings from the D.O.M.E. Project, an Erasmus+-funded initiative that took place from 2022 to 2024. The project entailed the construction of eight cardboard DIY planetariums and engaged the active involvement of 14 public schools across four distinct nations: Brazil, Ireland, Greece, and Portugal.

2. Methodology

The D.O.M.E. project was based on a prototype that was presented at the FIC.A festival in 2022 in Portugal (see (Oliveira et al. 2023)). Nonetheless, improvements were made to this project, particularly with regard to the base. The fundamental elements were preserved, with the utilization of cardboard and cost-effective materials.

The dome's design incorporates a geodesic shape and operates at a 3v frequency. The geodesic frequency is associated with the degree of approximation between a geodesic and a sphere; high frequencies indicate minimal difference. As Regester & McGahee (2019) explains, this frequency is proportional to the number of triangles required to construct the geodesic hemispherical dome and the difficulty of mounting the structure. As stated by Müller (2005), an exhaustive mathematical exposition of the geodesic approximation technique for the construction of domes is available. In summary, a geodesic with frequency 1 (1v) utilizes a mere four triangles and resembles a pyramid; frequency 2 (2v) geodesics employ 30 triangles, yielding a satisfactory approximation of a sphere; however, a frequency 3 (3v) geodesic requires 75 triangles, resulting in a structure analogous to the iconic dome of a planetarium. It has been demonstrated that the frequencies 4v and 5v offer superior approximations. However, as the scale of construction increases, the complexity and difficulty of the task also rise, reaching a point where further progression becomes increasingly challenging. After a thorough evaluation of the available options, we determined that 3v was the optimal choice, given its judicious balance between form and mounting difficulty.

Figure 1. Photo of our cardboard DIY planetarium mounted, indicating the dome and base.

For the D.O.M.E. project, a planetarium with a diameter of 4.0 meters was selected, which corresponds to an area of 12.36 M^2 on the floor (see Figure 1). This dimension is sufficient to accommodate 20 children, or 10 adults at maximum, in each session.

2.1. The Dome

The dome was constructed from 3.0 mm-thick cardboard, which was meticulously cut into two types of isosceles triangles, yielding a total of 75 triangle pieces (see Figure 2):

- Triangle X, a base of 81 cm and a lateral edge of 82 cm, a total of 45 triangles
- Triangle Y, a base of 81 cm and a lateral edge of 70 cm, a total of 30 triangles

The connection of the triangles was facilitated through the implementation of tabs along each edge, which are represented by the gray shading in Figure 2. It is imperative that these tabs be folded during the assembly process. The dimensions of each tab are precisely 2 centimeters in height along all three edges of the triangle, which is sufficient to utilize binder clips.

For a more comprehensive overview of the subject, please refer to the project's website[1] and the following bibliography: Oliveira et al. (2023).

[1] https://dome.nuclio.org/

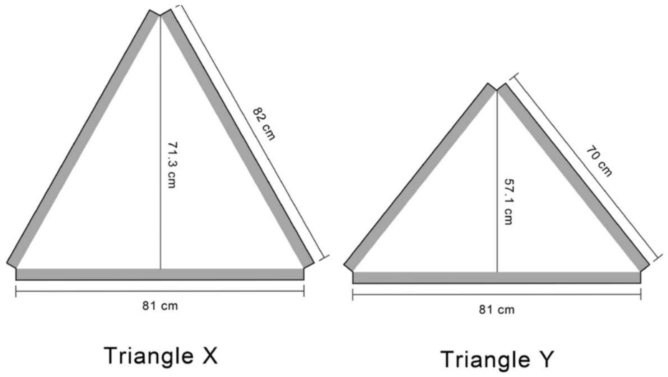

Figure 2. Schematics of the triangles X and Y and their dimensions. The tabs are shown in grey.

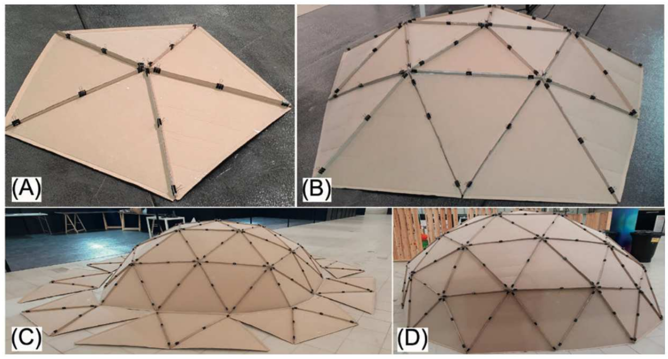

Figure 3. Step-by-step process of the assembly of the triangles: (A) the central pentagon, (B) adding the first layer, (C) positioning the last layer and (D) the dome mounted.

2.2. The Base

In order to establish a better base for the planetarium, it was necessary to make adjustments to the initial prototype. Specifically, the dimensions of the 14 cardboard rectangles were augmented to 100 × 81 cm. This modification was implemented with the objective of enhancing the ease with the audience could be entered and exited on it. The most significant modification was the incorporation of cardboard shipping tubes, which were utilized to create pillars and thereby fortify the entire structure. The utilization of eight “pillars” was employed, with each “pillar” being equally spaced within the confines of the planetarium.

The tabs on the edge of 81 centimeters were linked with the triangles on the end of the dome, once more employing binder clips. The final height of the base is 100 centimeters. A total of 15 pieces are required for a complete base; however, 14 pieces were utilized in this instance because one free space was allocated for the planetarium door.

2.3. Assembling the Planetarium

The sequence of steps is available in video on the project’s website, and it is described in Oliveira et al. (2023). The subsequent layer scheme employed by the dome assembly entailed the connection of triangles to form the central pentagon at the dome’s zenith, followed by the progression to the subsequent layer. As illustrated in Figure 3, a series of photographs have been provided to demonstrate the various stages of the process. This procedure facilitated the assembly process and enhanced the durability of the links, as it allowed for a more thorough connection of the tabs.

2.4. The Complementary Systems

The system under discussion is composed of two components: the projector system and the comfort system. It is imperative to note that both components are dependent on electricity for their operation. Consequently, the implementation of a cardboard DIY planetarium design necessitates the consideration of this essential element. It is imperative to consider this.

The projector system is composed of commercial devices, including a laptop, speakers, a projector, DSLR camera lenses (50 mm and fisheye), and a custom-built support printed using an ordinary 3D printer. The specifications and manuals for this project are available on the project’s website.

The comfort system is comprised of a small, low-noise fan that functions to maintain optimal air circulation within the dome, thereby ensuring the well-being of all individuals inside.

Figure 4. Mounting the planetarium in the IFMA in Brazil.

3. Using the Cardboard DIY Planetarium

This project aims the own students create the planetarium, so the group working with this project visited some schools in Brazil, Greece, Ireland, Greece and Portugal to incite them to participate of the iniciative. The focus was Portugal, because this six schools mounted their cardboard DIY planetarium, plus one school in Greece, two in Ireland and one in Brazil.

In Brazil, we receive support from Federal Institute of Maranhão (IFMA), at Imperatriz, Brazil, where the planetarium was mounted by students from the university course (Figure 4).

As this project is a great example of STEAM methodology and the Learning by Project, each group of students have the liberty of make some changes of the project to adapt it to the local situation. Some problems, like place to mount and decorative paint was solved differently by each group. The Figure 5 shows the solutions from the students at seventh degree of Basic School of Conde de Oeiras, Portugal. It is possible to note the cardboard shipping tubes close to the door space, inside the planetarium.

The Figure 6 shows a different solution to support the dome, the students of seventh degree of Scholar Group of Castro Verde, Portugal, used barrels of truck oil to support it, it is visible in the figure as the big cylinder cover with aluminum paper. To create this “space vision”, as the students said, they also cover all the dome with aluminum paper.

Figure 7 shows some situations when the cardboard DIY planetarium was used to different public and places. The left photo shows a fifth degree class of St. Anthony’s BNS, Ireland, is

Figure 5. The cardboard DIY planetarium constructed by the students and teachers from Basic School of Conde de Oeiras in Oeiras, Portugal.

Figure 6. The cardboard DIY planetarium constructed by the students and teachers from the Scholar Group of Castro Verde, located in Castro Verde, Portugal

Figure 7. Illustrative examples of the planetarium interior. (A) planetarium session was held at St. Anthony's BNS in Cork, Ireland. (B) planetarium session was held at Secondary School Quinta do Marquês in Oeiras, Portugal. (C) planetarium session was conducted by the author, who is 1.71 meters in height, inside the planetarium during a session.

watching the planetarium presentation, a video about the humans in the Moon. The middle photo is a top view of a seventh degree class of Secondary School Quinta do Marquês, Portugal,watching a presentation in their own planetarium. Finally, the right photo shows the amplitude inside the planetarium, where a man with 1.71 m tall can be stand comfortably together 20 students of second degree class in a science week at School Group Póvoa De Santa Iria, Portugal.

The main result of the D.O.M.E. project was involved directly 14 public schools, divided into Brazil (one school), Greece (one school), Ireland (two schools) and Portugal (10 shools). We have a total of 17 teachers directly involved, guiding 191 students in building their own planetariums. Between 2022 and 2024, more than 2,000 students visited the cardboard planetariums built by their peers and different events in each school.

A secondary yet significant outcome of the initiative was the active involvement of the school community. In situations that arose, the students proactively sought solutions, leveraging their own expertise and drawing upon the resources and support provided by the community. At Castro Verde, Portugal, the cardboard was sourced from a local bicycle store, while the truck oil barrels were obtained from a nearby garage. At Imperatriz, Brazil, the students elected to utilize school desks to fortify the base, as they did not have access to cardboard shipping tubes. These are illustrative examples of the learning by project paradigm within our own project.

4. Conclusion

The construction of a cardboard planetarium by students during school hours or scientific workshops was a significant achievement in the creation of an innovative and engaging learning environment for astronomy and scientific exploration. The successful mounting and operation of eight complete planetariums in a variety of settings, each with unique challenges, demonstrated its potential as a dynamic platform for educational outreach. A diverse group of students, ranging in age from 8 to 17, participated in an immersive planetarium session. This session effectively demonstrated the ability to captivate and educate a diverse audience.

Furthermore, the cardboard planetarium project, in which local schools engaged, exemplified the importance of educational initiatives that allow students to engage with scientific concepts outside of traditional classroom settings. By allocating time within the school day for this project, educators were able to foster students' creativity and encourage them to take ownership of their learning. The integration of creativity, experiential learning, and the dissemination of scientific knowledge is of significant importance. The project's appeal derived from its integration of the allure of a DIY endeavor with the educational value of a cardboard planetarium, offering a tangible and engaging medium for imparting complex concepts to learners of all ages. As this initiative gains momentum and inspires the creation of similar projects, this project stands as a beacon of educational innovation and collaboration in astronomy and STEAM education.

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