

The Value of the Planetarium in Education

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Introduction to the planetarium

What is a Planetarium?

A planetarium is a purpose-built theater where the audience is surrounded by a large, domed screen. Accurate depictions of the night sky and other dynamic imagery are displayed across the dome, extending both above and behind the audience to create a shared immersive experience.

A Brief History:

The first modern planetarium opened in 1925, in Germany.² Over four thousand planetariums now operate worldwide^{3, 4} with at least 612 new facilities opening in the decade 2013-2022.⁴ Permanent planetariums are mostly found in schools, higher education institutions, science centers, and museums.⁴ There are also portable planetariums which are taken on visits to schools, public spaces, and isolated communities. Total visitor numbers are estimated at over 142 million annually.⁵

Classic, 'optomechanical' planetariums have specialized projectors in the center of the dome, using moving mechanical parts and lenses to produce a high-quality virtual night sky for any time and location - ideal for teaching observational astronomy. 'Digital' planetariums, which use video projectors to produce a seamless image across the dome, became widely adopted from the late 2000s, and allow a broader range of imagery to be displayed.

In more recent years, 'hybrid' planetariums have been developed that synchronize both types of projection technology. And within the last couple of years, public 'LED' planetariums (with active display surfaces) have opened to visitors.⁶ New production and design technologies continue to be developed, further extending the versatility of these spaces.

Value of Astronomy and Space Science:

"Space science ... makes an important contribution to social, cultural, and intellectual development, which are inseparable from economic development in the long run ... planetariums can make an important contribution to the study and appreciation of the Universe around us." — Office for Outer Space Affairs, United Nations⁷

Astronomy is both part of our cultural heritage and integral to our everyday lives.

People around the world have long used knowledge of the sky to navigate across oceans and continents, construct sophisticated calendars, ponder cosmology, and connect to ancestors through stories. Continuing to advance our knowledge in astronomy and space sciences is vital as we increasingly rely upon satellite technologies, become more vulnerable to space-weather events, and aspire to deflect dangerous asteroids.

Astronomy serves as a popular and accessible platform for linking to other areas of STEM (Science, Technology, Engineering and Math), and has rich potential for multi-disciplinary learning. On a personal level, we all share the same sky; learning more about what we see helps us understand our own place in time and space.

A Unique Learning Environment

An Immersive Experience:

The planetarium portrays our universe in ways that flat screen films cannot.^{8,9} Though similar to the immersion of virtual reality (VR), the planetarium provides a shared experience, allowing visitors to engage with the presenter and each other;¹⁰ these opportunities for collaborative, social interactions are associated with positive educational outcomes.^{11, 12}

The immersive aspect of the planetarium environment may improve learning by supporting data comprehension, memory, and spatial information.¹² For example, recent research suggests that students in a full-dome environment developed a deeper understanding of concepts that require 3D thinking, reference systems, and use of periodic motion.¹³ The planetarium reduces mental effort as learners do not have to translate from 2D to 3D. It also can help visitors directly visualize the 3D nature of astronomical phenomena more accurately than mediums such as flatscreens.¹⁴ As the dome fills the visitor's field of view, the planetarium may support visitors with spatial navigation and visualization tasks because of how the dome provides necessary peripheral information.¹⁵

Spatial Freedom:

Planetariums allow audiences to travel to view the universe from different vantage points. Optomechanical planetariums can speed learners through time and allow observations from different locations on Earth's surface. Digital planetariums can 'take off' from Earth to navigate freely within scientifically accurate 3D simulations. The operator can zoom learners from Earth to the Moon, to other planets, stars, or even distant galaxies. And pre-recorded full-dome films can immerse learners in even more-complex, dynamic environments. The experience of immersion in exotic locations such as the surface of Venus, or within a nebula, creates rich memories providing concrete examples for further, more-abstract learning.

The changes of perspective offered by the planetarium can help audience members better understand astronomical concepts and phenomena. For example, grasping the cause of Moon phases requires the learner to mentally switch back and forth between Earth and space views and relate the two perspectives for better understanding, which most people find challenging.¹² Recent research suggests that a full-dome planetarium has the potential to help learners make the connections between Earth and space views of the Moon.¹⁶

Inspirational Environment:

Every planetarium immerses visitors in a 3D environment that evokes realism. The incredible number and depth of stars in a truly dark sky immediately captures attention and evokes awe. As cities expand, fewer people have opportunities to enjoy a clear sky and be in close contact with nature, leading to negative psychological effects.^{17, 18} Immersion can elicit emotional responses; larger screens and domes can arouse greater emotions than smaller screens.^{19, 20} Thus, a planetarium's night sky can provide a powerful, memorable, and inspiring experience.²¹

Careers in fields linked to STEM subjects are expected to be in high demand in the coming years.²² Many professional scientists credit childhood experiences in science museums and similar places to have been an inspiration for their career.²³

Benefits and Applications of the Planetarium

Meeting Educational Standards:

Astronomy is found in curricula and educational standards worldwide.²⁴ Common curriculum topics include the motion of the Sun, Moon, and stars in the sky, the phases of the Moon, and seasons. These concepts can be challenging for both

learners²⁵ and teachers,²⁶ partly due to difficulties in imagining multi-body, 3D spatial relationships. Planetariums can display undistorted views of dynamic systems and have been shown to be superior to classroom presentations when complex spatial thinking is required,^{27, 28} with students enjoying longer-term learning gains.^{29, 30} Studies also suggest that students develop more sophisticated explanations for astronomical phenomena when planetarium and classroom teaching are combined in ways that take advantage of the strengths of each learning environment.^{31, 32}

Planetariums can also support teaching of science as a process. They can enable virtual visits to historic and modern observatories. They can tell the stories behind astronomical discoveries, and display data in engaging and innovative ways. They are able to quickly integrate newly released data and images to present science stories as they unfold. Planetariums can stream images from observatories, sharing real-time observations, or stream their own presentations to other facilities.

Overall, the planetarium is a powerful tool which can be used in a multitude of ways by a skilled educator to complement other learning activities. The experience can be localized through the use of familiar viewing locations and by incorporating cultural knowledge such as indigenous astronomy and local stories. Planetariums have been described as places to initiate a love of science, where the educator is a mix of scientist, artist, and teacher.³³

An Astronomical Laboratory:

The planetarium can serve as an astronomical laboratory, where time and space are manipulated to allow learners to make their own observations from any desired location. Activities that would normally require access to clear night skies over a period of months can be completed in a single daytime session. Speeding up phenomena also makes them more visible - planets can be tracked against the stars, and the position of sunset is clearly seen to change through a year.

The responsiveness of the planetarium allows learners to make predictions and request specific scenes to test their ideas. Collaborations between planetariums and classroom lessons can successfully engage children in scientific inquiry; with children making observations in the planetarium and bringing those observations back to their classroom for further sensemaking and explanations about astronomical phenomena.^{34, 35}

Multi-Disciplinary Power:

Planetariums across the world have reached beyond astronomy to teach additional subjects in their domes.^{36, 37} Such programs may use space themes directly (e.g., history or literature shows), as a context for adjacent disciplines (e.g., geology on other planets), or use entirely different fulldome visualizations (e.g., inside a living cell).

Most planetarium software now includes multidisciplinary content as standard, including a large number of Earth surface datasets (e.g., temperature, population, land cover). These allow dynamic exploration of geographical concepts, zooming in to examine features at multiple scales. Biological content is also popular, including layered models of the human body which can be manipulated to serve the purposes of the lesson.

Pre-recorded fulldome films allow virtual fieldtrips to natural and cultural sites; learners can visit the Grand Canyon or shrink down to observe tiny fish in a coral reef. They can travel to Australia to learn about Aboriginal dance, or to the Arctic to discover how locals are responding to climate change. Recent innovations in live action fulldome capture³⁸ mean that this type of content is becoming increasingly available.

Planetariums also serve as wonderful venues for performances of music, poetry, and theater.³⁹ They can support and inspire the artistic process, creating unique, collaborative experiences that could not be staged in any other setting.⁴⁰ The domed theatre itself offers a compelling and novel venue for varied events and programs. Planetariums attract new audiences by hosting lectures, competitions, karaoke, video games, music visualizers, movie nights, ceremonies, concerts and more.

Lifelong Learning:

Planetarium visits are a popular recreational activity; people visit planetariums to learn something new, be entertained, and spend time with family.⁴¹ Planetariums, like other informal science venues, may be better than formal spaces at eliciting a positive emotional response to science, better at showing the ways science is relevant to our everyday lives, better at demonstrating the nature of science, and better at connecting young people to science.⁴² Visitors include members of the public, community groups, and professional organizations. Abundant evidence suggests that this kind of informal science learning experience supports lifelong science learning in ways that may generate interest in science, improve academic achievement in students, and develop skills and understanding of the natural world.⁴³

Planetariums also contribute to developing a well-informed citizenry by contributing to visitors' understanding of the serious scientific issues ubiquitous in the modern world.⁴³ Planetariums, along with other informal science venues, have the potential to build on visitors' interests in the natural world and to provide opportunities for continued pursuit of that curiosity.⁴³

An Inclusive Environment:

The International Planetarium Society's Equity, Diversity and Inclusion Committee offers guidance for improving accessibility for audiences including those with autism spectrum disorder, physical and sensory impairments, or intellectual disabilities.⁴⁴

Modern planetarium designs offer a variety of solutions to enable accessibility for visitors with physical and sensory disabilities. Seating can include spaces for wheelchair users and companions. Well-designed lighting can support both comfort and safety. Hearing loops and similar assistive technologies can be installed, while planetarium software increasingly includes closed captioning and subtitle integration. Sign language interpretation can be pre-recorded and projected, or performed live with the interpreter lit by a dim red light. Visually impaired visitors may benefit from use of 3D-printable astronomy resources, and one producer is developing films centered on use of surround sound specifically for this audience.⁴⁵ The planetarium community continues to develop new and innovative methods to improve accessibility.^{46, 47}

Planetariums may offer live presentations or fulldome films in multiple languages to improve access. Most fulldome films are available in multiple languages, and most producers are supportive of efforts to create additional versions.

Providing an inclusive environment also includes thoughtful and respectful representation and promotion of how astronomy is part of a broad range of cultures and traditions. For example, the IPS's Indigenous Astronomy Working Group (including Planetarium Professionals, Indigenous Star Knowledge Keepers, Indigenous Astronomy experts, Cultural Astronomers, and allies of Indigenous STEM communities from Canada, U.S., and other countries), has published a guide describing best practices for dissemination of Indigenous astronomy for the planetarium community.⁴⁸

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