Environmental Problem-solving and Hands-on Geometry Learning through Storytelling inside a Geodesic Dome: Ice, Honey and Stardust

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Abstract

In this workshop, we introduce a STEAM learning activity based on the construction of geodesic domes. This workshop will engage participants in various preliminary and exploratory constructions, while also applying the geometry of geodesic domes to approximate hemispheres. Various storytelling, role-playing, and environmental connections that can provide needed context for learners of all ages are explored.

Introduction

In this workshop, we introduce a STEAM educational activity for all levels involving geodesic domes. The event employs experiences recorded in two international mathematics learning projects. The *Discover the Art of Mathematics* project [11] examined and described the learning outcomes of multidisciplinary mathematics learning in informal context within an international collection of Science Centres. The *Visuality & Mathematics*, project [5] argued for the need for mathematics instruction in a multidisciplinary setting, based on the assessment of the main characteristics of Serbian mathematics education.

As a brief introduction to our workshop, we will discuss the lessons learned from these research projects. After the introduction, we will actively try some modules of our STEAM learning activity, focusing on geodesic domes. Our purpose in conducting the workshop is to provide a 90 minute overview of what are daylong experiences for children. Student have already engaged in these activities many times. Our goal in presenting them to the Bridges community is to receive feedback and elicit conversation around the use of this sort of informal-formal blend of learning experience.

We are especially interested in dialogue around the storytelling, role playing, and creative connections we have seen among our students. Children naturally take the items they build and let their imaginations create scenarios in which they might live within such a structure, imagine what sort of creature might need this architecture, etc. We have guided them towards thoughts that include space exploration and hut construction. Further thoughts on where else we could direct student thoughts are welcome.

Lessons Learned from Research

A crucial element in multidisciplinary learning processes is the idea of working upon projects [1, 3, 8] wherein students actively participate in planning and selecting the lessons' content, the learning methods and the practices to be applied. Maintaining the students' sense of motivation [2] and engagement remains the key to establishing their understanding of the goals and having a clear perception of the significance of learning about the given topic. These phenomena are closely related to Csíkszentmihályi's term "flow", which describes engagement and concentration in study or work – characterized by complete absorption in an activity.

Art and creativity form an integrative component in the STEAM approach [15]. Art and Mathematics education have each developed along different pedagogical lines [6]. Their contexts, goals, strategies, and processes encompass vast differences in perspectives on concepts like problem-solving, creativity, and understanding of originality and authorship [13]. However, through careful comparison, several joint potentials emerge. These can be re-contextualized and further developed into a mathematics and arts education framework based on the aesthetics of interdisciplinarity that may: (a) provide motivation and engagement for students and their teachers; (b) enrich mathematics and arts learning in a meaningful way; (c) and enhance inter- and transdisciplinary STEAM learning frameworks with a robust cultural embeddedness and social impact. In each of these, art elevates the activity to an integrative and transformative element of the STEAM approach and not merely a vehicle for STEM learning [8].

Ice, Honey and Stardust: Environmental Problem-solving and Hands-on Geometry Learning through Storytelling While Constructing a Geodesic Dome

Connecting environmental problem-solving with hands-on geometrical modeling and storytelling in a STEAM educational framework provides an opportunity to implement several core concepts of phenomenon-based learning. The participants in this activity will be invited to observe, discover, create and reflect upon interconnected stories while inside and around the approximately 2.75m tall geodesic dome to be constructed at the Bridges Family Day. Leaders of this workshop have observed that constructing a dome with enough space for many children to sit under establishes an environment that can generate such imaginative questions as: "What happens when an astronaut meets a beekeeper, both dressed in their white suit?" or "Can a bee and a Martian communicate through their antennas?" [*sic*]. These creative and lateral lines of thought are core to the STEAM ethos of integrative thinking, based on playfulness, imagination and searching for connections between seemingly disparate objects or topics. Children do not make distinctions regarding integrating knowledge. Math, art, physics, and environmental science all come together in the melange of play, and in this workshop we will be modeling an environment in which this can be fostered by the adults in the room.

General Structure of the Workshop to be Conducted at Bridges

Introduction (10 minutes): we will introduce Experience Workshop's educational research projects related to this workshop program. The workshop leaders will establish the goals of the workshop with emphasis upon how this is an abbreviated version of a full-day experience for children, along with how it will be expanded upon at the Bridges Family Day event.

Construction (50 minutes): participants will construct small 4DFrame geodomes. During this phase the workshop leaders will provide instruction, and involve the participants in the discovery of the geodesics. Further discussion will focus on how these tools (4DFrame) have been used to teach core ideas in geometry, architecture, and art. Main characters and sceneries are created by the "Inuit", the "Bee-keeper" and the "Martian" teams.

Exploration and Play (20 Minutes): the discussion regarding working with children will morph into the use of the domes as props for storytelling, and role-play. Participants will be encouraged to imagine several scenarios in which the dome structures are or might be used or exist and the consequences of their existence.

Discussion (10 minutes): we will lead a debrief of the activity, seeking feedback from the participants in the form of suggestions for enhancing the pedagogical, role-play and storytelling aspects of the experience with geodesic domes. Participants will be informed of their opportunity to participate in the construction of a large-scale dome (almost 3meters in height) at the Bridges Family Day event.

What follows are brief expansions on the final three phases of the workshop: Construction, Exploration and Play, and Discussion.

The Geometry of Geodesic Domes (Approximating Spheres)

The construction phase concerns the discovery of the geodesic dome, both as a geometrical structure and as an architectural concept. An often visited idea in the math-art context is that of tessellation, which typically concerns a 2-Dimensional periodic tiling of the Euclidean Plane. When such tilings are wrapped or mapped onto the surface of a sphere, straight line segments become pieces of great circles known as geodesics—requiring that setting aside of some Euclidean axioms and new axioms are adopted. In practice, we will attempt to make approximations of spheres and while still keeping the Euclidean assumptions. Participants will first experience, in this workshop, the reality that the icosahedron is the limiting case of a spherical frame formed of regular (equilateral) triangles. Furthermore, since all triangles that have their three sides congruent to each other are congruent and amenable to rigid transformations of space, they make the simplest of shapes to form sound structures.

While a single equilateral triangle can be a representation of part of the surface of the sphere, it is a rather poor one. However, when subdivided, through dilation, into several reduced copies of itself with linkages at the midpoints of each of the original sides, the new structure can be warped into an approximation of a partial spherical surface. It can be “rounded” at the joints without loss of a Euclidean notion of straightness of the segments. Upon iteration of this process of subdividing, each successive iteration becomes a better approximation of the desired sphere. These geometric ideas will be explored using small 4DFrames sets by individual participants by experimenting with the structures represented in Figure 1.

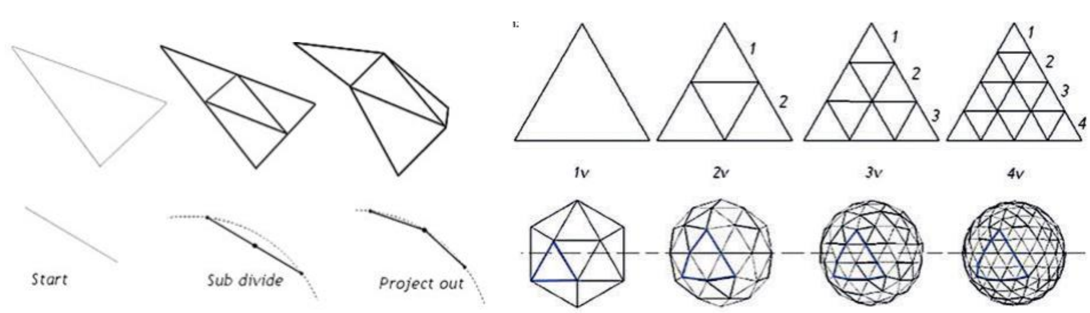
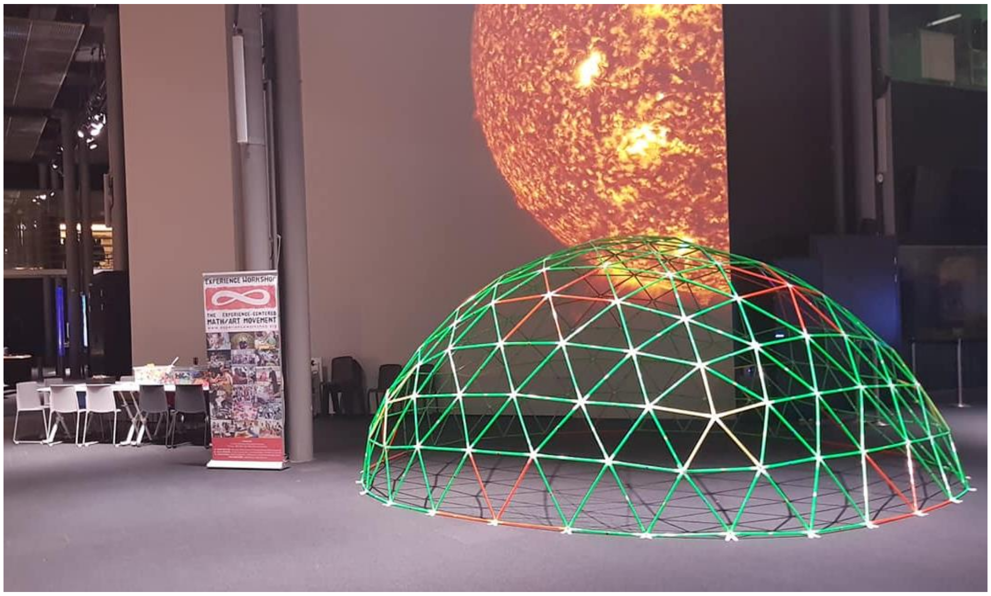


Figure 1: *Geodesic spheres based on an icosahedron with frequency numbers 1, 2, 3 and 4 and their construction. (Source: http://www.geo-dome.co.uk/article.asp?uname=domefreq)*

However, with the icosahedron being the upper bound of the number of equilateral triangular faces that can be utilized in creating a spherical approximation, some careful edge shortening must occur which will have the effect of altering the number and shape of the triangles that come together surrounding a point on the approximation of a sphere. The participants will demonstrate this as they see their constructions begin to form both hexagonal and pentagonal accumulations. Thus, they will be constructing an irregular geodesic dome to approximate the sphere (Fig. 2a, b).



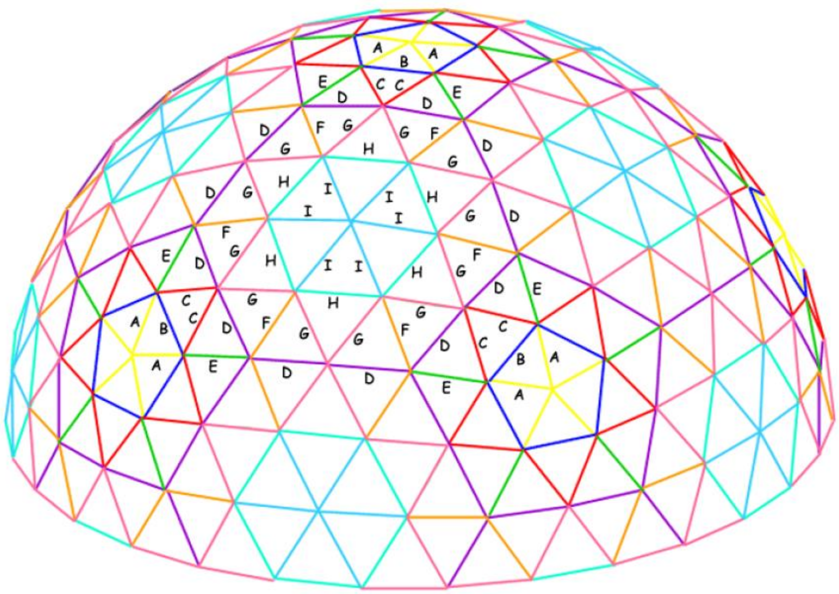


Figure 2 a, b: *Experience Workshop's STEAM Learning Area with the large Super4Dframes Geodesic Dome at Heureka Science Centre's Space Weeks in Helsinki (February, 2019) (top); Structural introduction of geodesic dome (bottom).*

To clarify, the large Geodome (to be constructed at the Bridges Family Day, represented by Fig. 2b) has a "segment" of the Geodome highlighted and annotated. In the center of that segment is a hexagonal collection of triangles formed each with struts of length "I". The segment that encompasses all the lettered struts is a composition of many smaller, triangular regions. Five of these triangular segments will encircle a single point on the surface of the approximated sphere. In Figure 2, we see this in the 72-degree rotational symmetries around the common vertices of the "A" struts.

In conducting this workshop with children in the past, the leaders have had the students build and enter the grand dome and continue to study the unique properties of this structure. They discover the configuration of triangles, pentagons, and hexagons that, through repeated, periodic application form this rigid building. Once inside, they are encouraged to reflect upon the Platonic solids and the connection between the icosahedron to the dome structure. They research and collect information on dome structures in the history of architecture, including early examples such as igloos from the North and “honeycomb” houses from Africa and the classic modern examples like Walter Bauersfeld’s and Buckminster Fuller’s domes.

Building small geodesic domes: workshop participants will construct, with guidance by leaders, their own dome with “small” 4DFrame materials. This dome structure (see Fig. 4) will be small enough for individual participants to hold in their hands, and used in the Exploration and Discussion phases of the workshop.

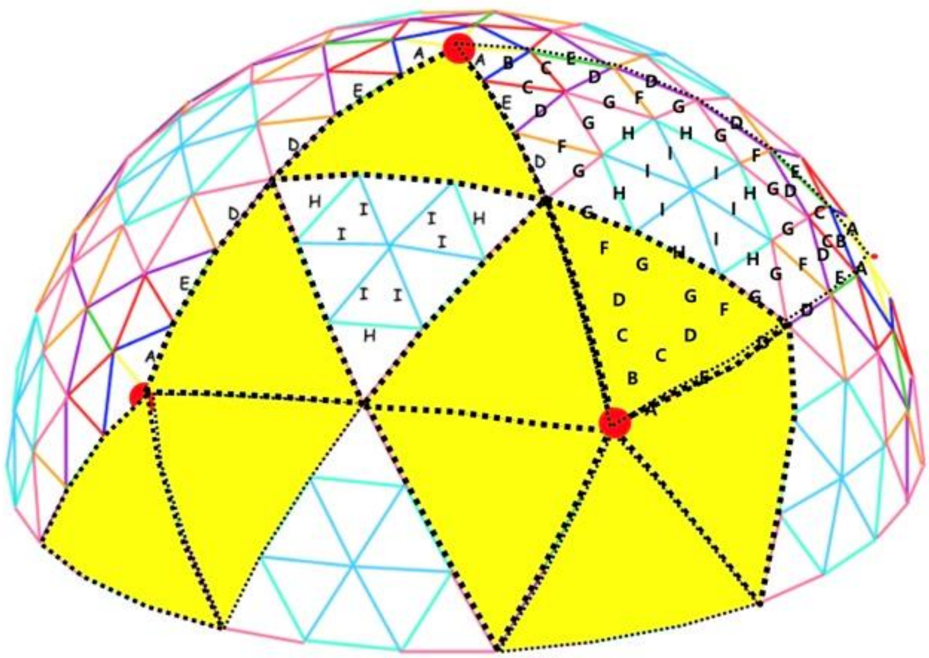


Figure 3: *The 72 degree point symmetry of the newly formed triangles is illustrated in the highlighted pentagon formed from triangles.*

In the exploration stage, participants will be encouraged to imagine that they can transform their dome into a dwelling place such as (a) an igloo, (b) a beehive and (c) a planetary base for a colony on Mars.... Each team member will start acting in a role and build items (Fig. 5a, b, c). We expect discussion that links a wide variety of topics. Through encouragement of self-expression and experimentation with ideas, materials, techniques, forms and colors, the storytelling project creates synergetic interaction between imagination, geometry, architecture and various art forms. The playful connections between ice, honey and stardust have created experimental artistic innovations in the past and these will be shared by the leaders.

Following the construction phase of this workshop at Bridges, we will share examples of how students can be engaged in role-playing, story-telling, and environmental discoveries related to the “Geodome” structure building experiences. What follows are several avenues that workshop leaders have followed in the past to connect the geometry of geodesics and hexagons with stories, role-playing activities, the environment, culture and technology, all in a playful and creative experience. There may not be time within the Bridges Workshop format to investigate these fully, but they are included in the paper as exemplars: (a), (b), (c).

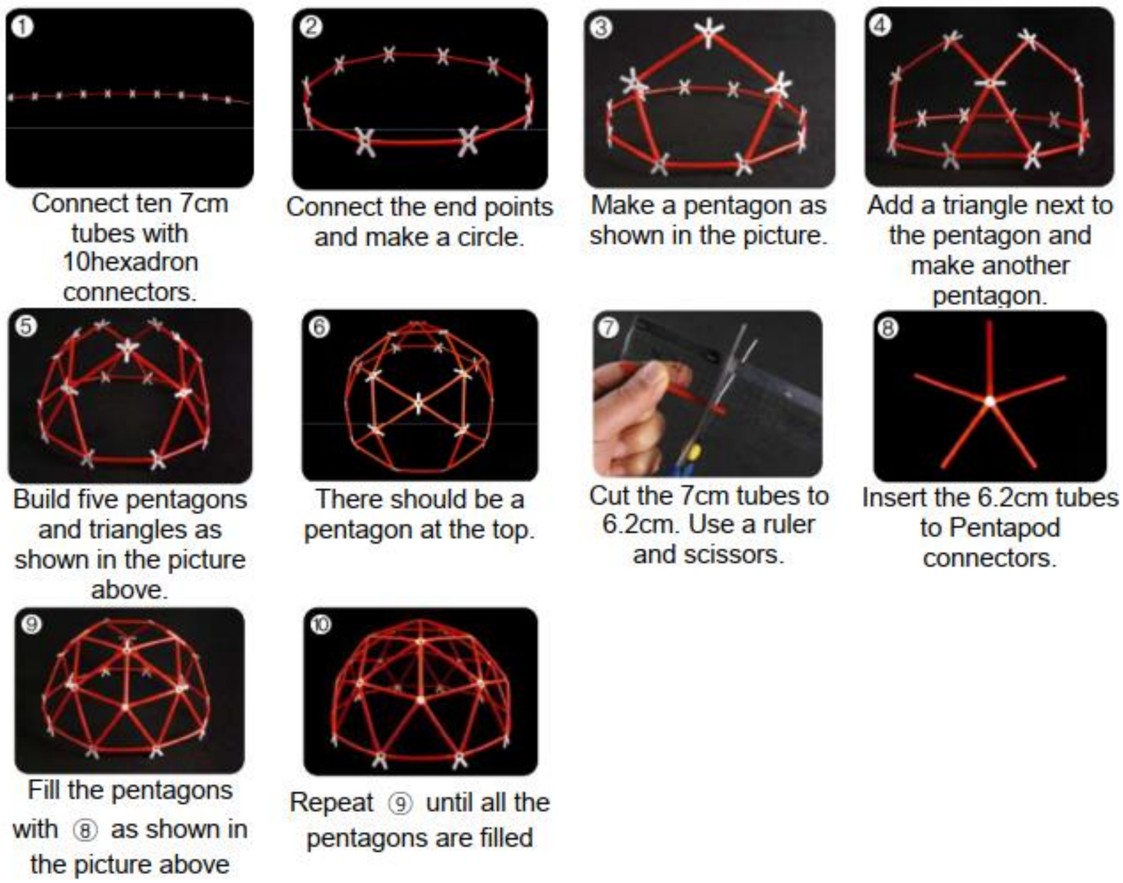


Figure 4: *Making of the small 4DFrame Geodesic Dome. Here there are two distinct sizes of struts. Making this structure what is known as a "regular" dome. During the workshop the differences between regular and semi-regular domes will be discussed and explored.*

(a) Inspirations and activity challenges for the Igloo explorations: Inspirational visual material can be found at https://photos.app.goo.gl/VF7XcHGgm18VQ8Pa9 (Fig. 5a). Place a white sheet that represents snow. Transform the small dome into an igloo. Bring in the ice. Make tea with ice. Create Polaris, the "North star". Create the Ursa Minor constellation. Create the Ursa Major constellation. Make snowflakes with paper. Model snowflakes with 4DFrame, study the geometry of snow and ice crystals. Create snowballs from paper. Create a snowman. Discuss Inuit life, ice-fishing, Inuit kiss.

(b) Inspirations and activity challenges for the beehive explorations: Inspirational visual material can be found at https://photos.app.goo.gl/biQKMpJX5kc4FnMz7 (Fig. 5b). Draw a flowery field and place it around the small dome. Transform the small dome into a beehive. Make tea with honey. Discuss why bees matter. Model honeycomb with 4DFrame, discover the geometry created by bees (hexagon). Find connections between dome geometry and "bee geometry". Incorporate the sound of bees. Study the social structure and various roles inside the beehive: the Queen, the colony of workers work together. Explore the waggle dance. Collect "bee-sayings" (e.g. "busy-bee") and invent new ones. Study various customs related to bees, like "bee bearding". Create a beekeeper costume.

(c) Inspirations and activity challenges for the Martian colonization explorations: Inspirational visual material can be found on https://photos.app.goo.gl/1AfwKZYfEB9Z6AnQ7 (Fig. 5c). Create the Martian planetary base from the dome, using silver color materials. Create stardust. Make tea with stardust in a capsule. Create Martian astronaut costume with antennas on the helmet. Create Solar system. Create a rocket and discuss its purpose and properties.

In the discussion phase, we will solicit the participants' ideas on other or further topics and prompts that they might imagine as profitable to include in future workshops with children. Feedback and conversation around the role of providing creative environments and settings for learning will be the focus.

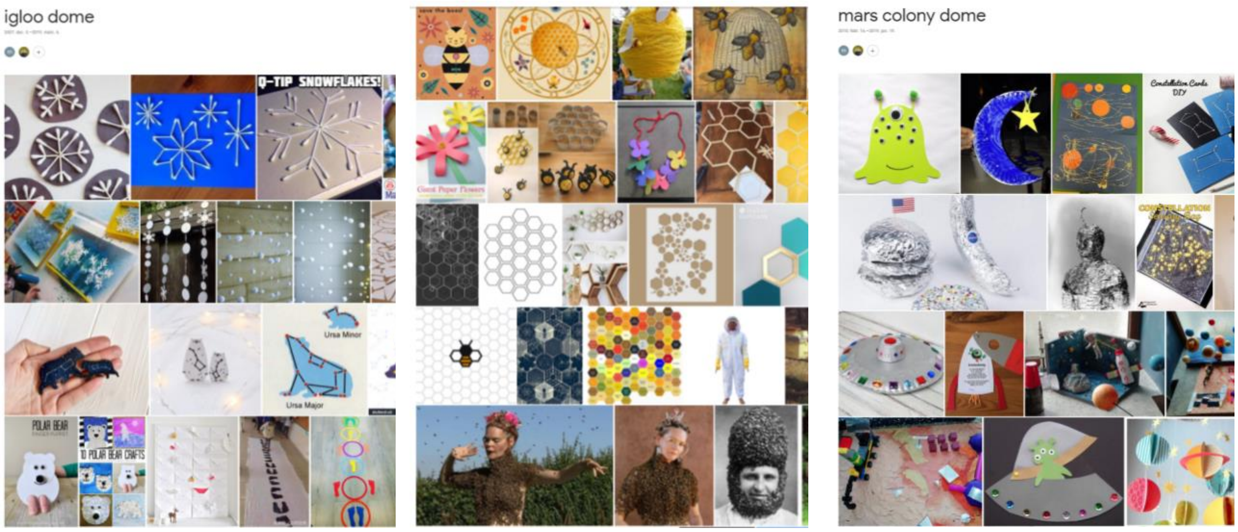


Figure 5 a, b, c: *A detail of the collection of inspirational images for the (a) Inuit team, (b) the beekeepers, (c) the Martians.*

Final Thoughts

Both policy and research recommend that children be provided new ways to approach problems, gain skills, and create and use tools in an innovative fashion [12]. Education that focuses on methods that keep students isolated from real problems and from pursuing their own goals can no longer be the norm [11]. Breaking down 'subject silos' by developing multidisciplinary and phenomenon-based forms of learning, such as the extension of STEM into STEAM wherein the arts are integrated into problem solving, adds a creative and human dimension which can bring learning to life [1]. Furthermore, the so-called, rehumanization of mathematics, through an emphasis in creativity and play, holds great promise for making progress towards more equitable and accessible mathematics for all.

Activities that involve a genuine, human context while additionally turning the world outside of schools into a learning opportunity are an essential component in STEAM's integrative approach, which is quickly spreading around the globe and especially in the European Union's leading educational communities [4]. These echo discussion around "twenty-first-century skills" where the starting points are the five habits of mind: imagination, inquisitiveness, persistence, collaboration, and discipline. These also exemplify Resnick's Four "P"s of Creative Learning: Projects, Peers, Passion, and Play. These further consist of subskills such as developing techniques, playing with possibilities, crafting and improving, reflecting critically, daring to be different, wondering and questioning and, last but not least, tolerating uncertainty [7]. This workshop will provide participants with an experience wherein they can incorporate their creativity, embedded in a mathematical environment, to brainstorm experiences that enhance children's learning.

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