Connecting Hands-on and Digital Problem-Solving in Symmetry Education:

4dframe and Geogebra in Experience Workshop's Geodesic Dome Construction Activities

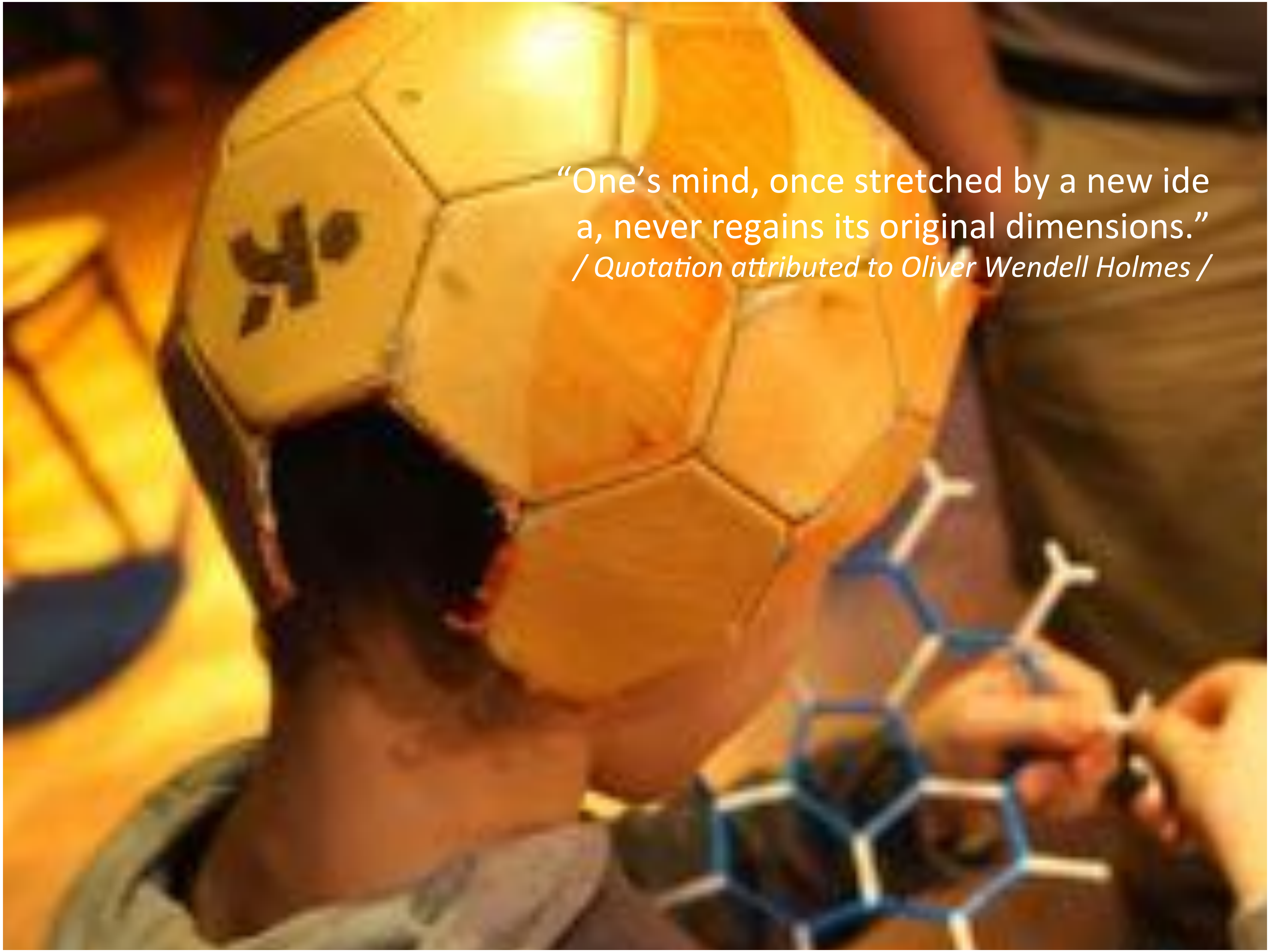
Zsolt Lavicza (Johannes Kepler University)

Kristóf Fenyvesi (University of Jyväskylä)
&
Diego Lieban (Johannes Kepler University)

Prof. Slavik Jablan, 1952–2015

Prof. Reza Sarhangi, 1952–2016

Sir Harold Kroto, 1939–2016


“One’s mind, once stretched by a new ide
a, never regains its original dimensions.”
/ Quotation attributed to Oliver Wendell Holmes /

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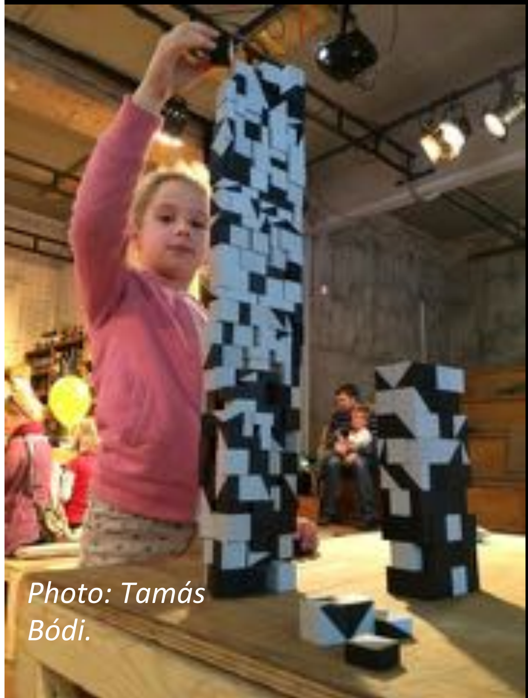
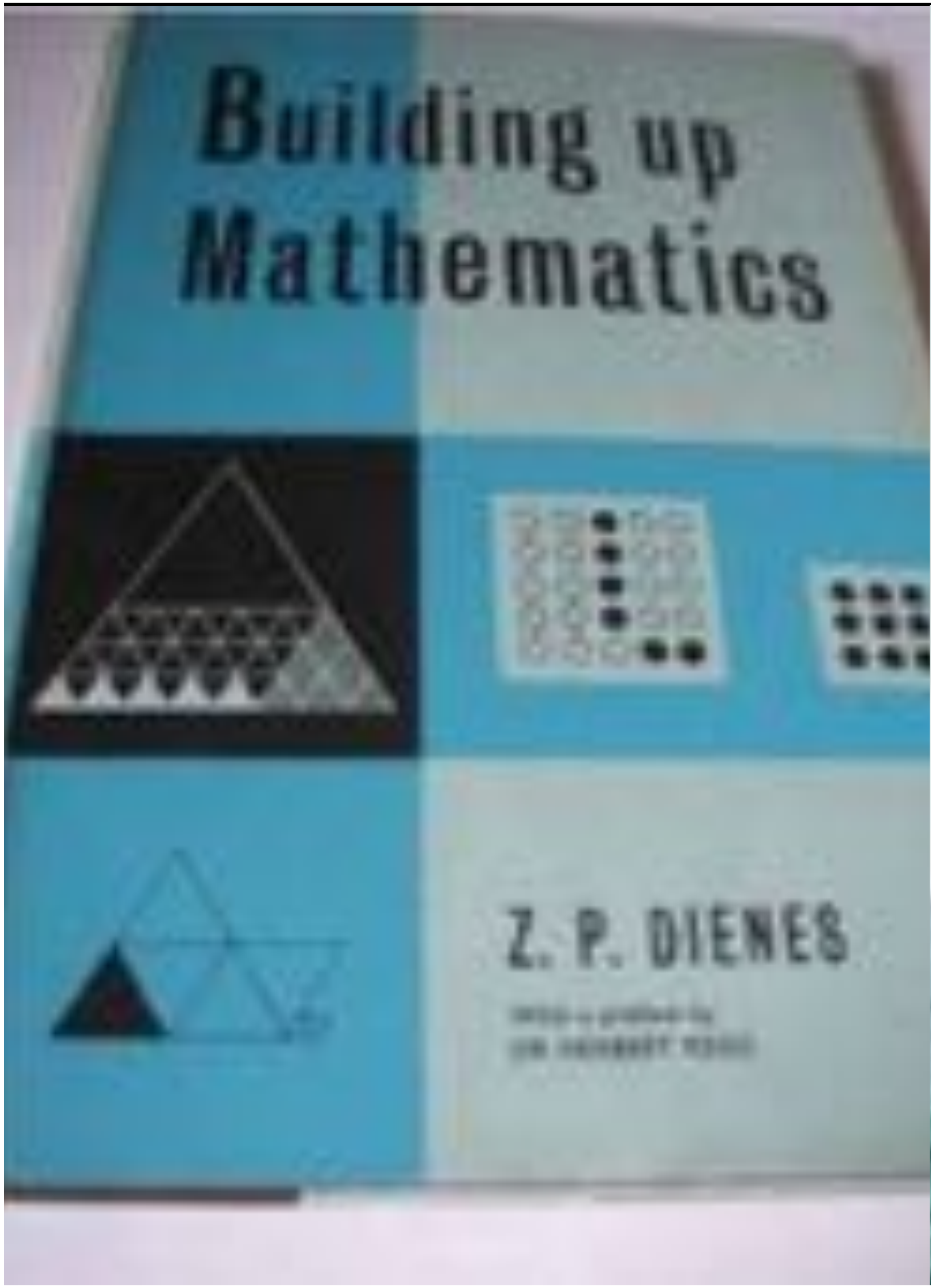


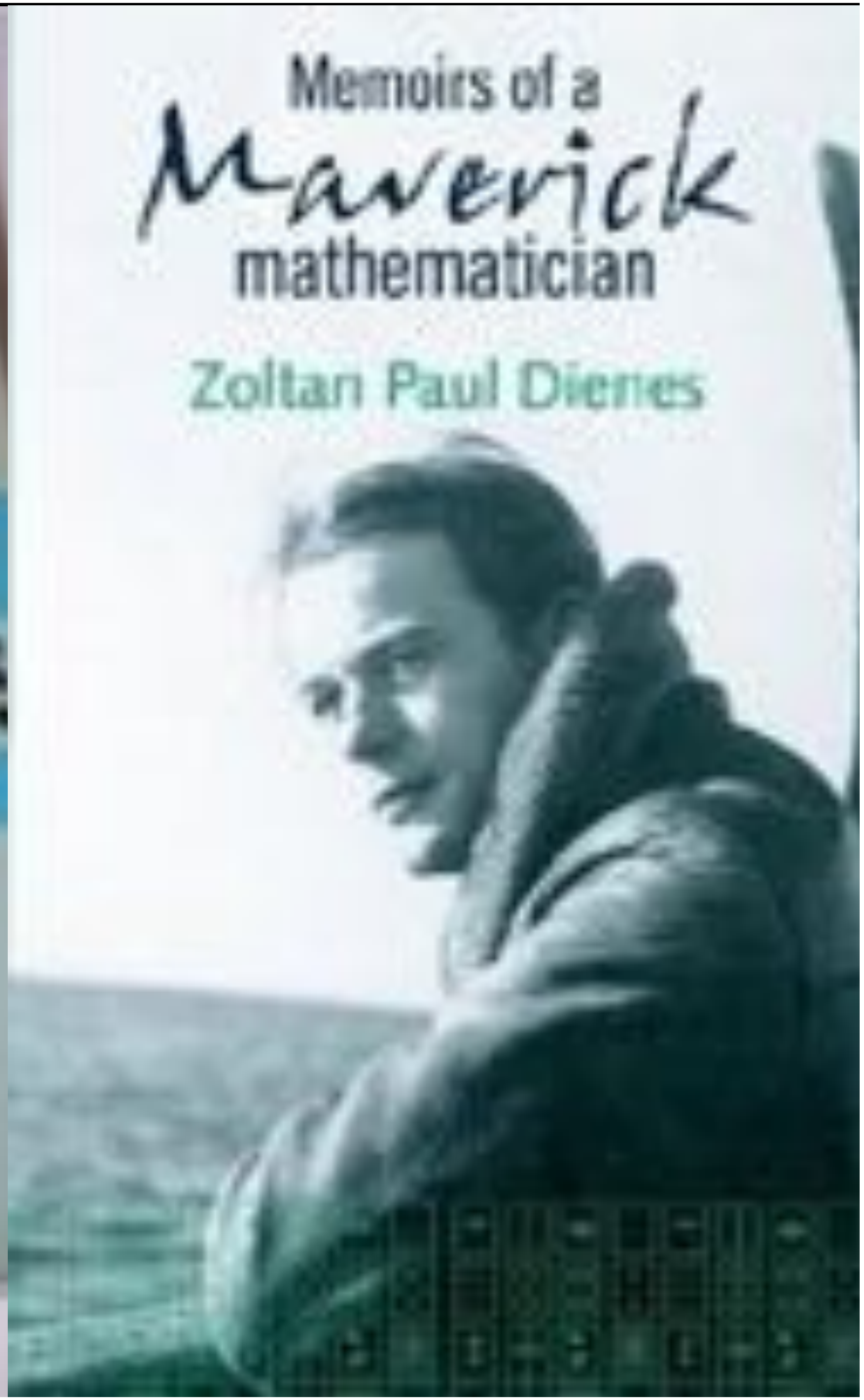
Photo: Tamás Bódi.

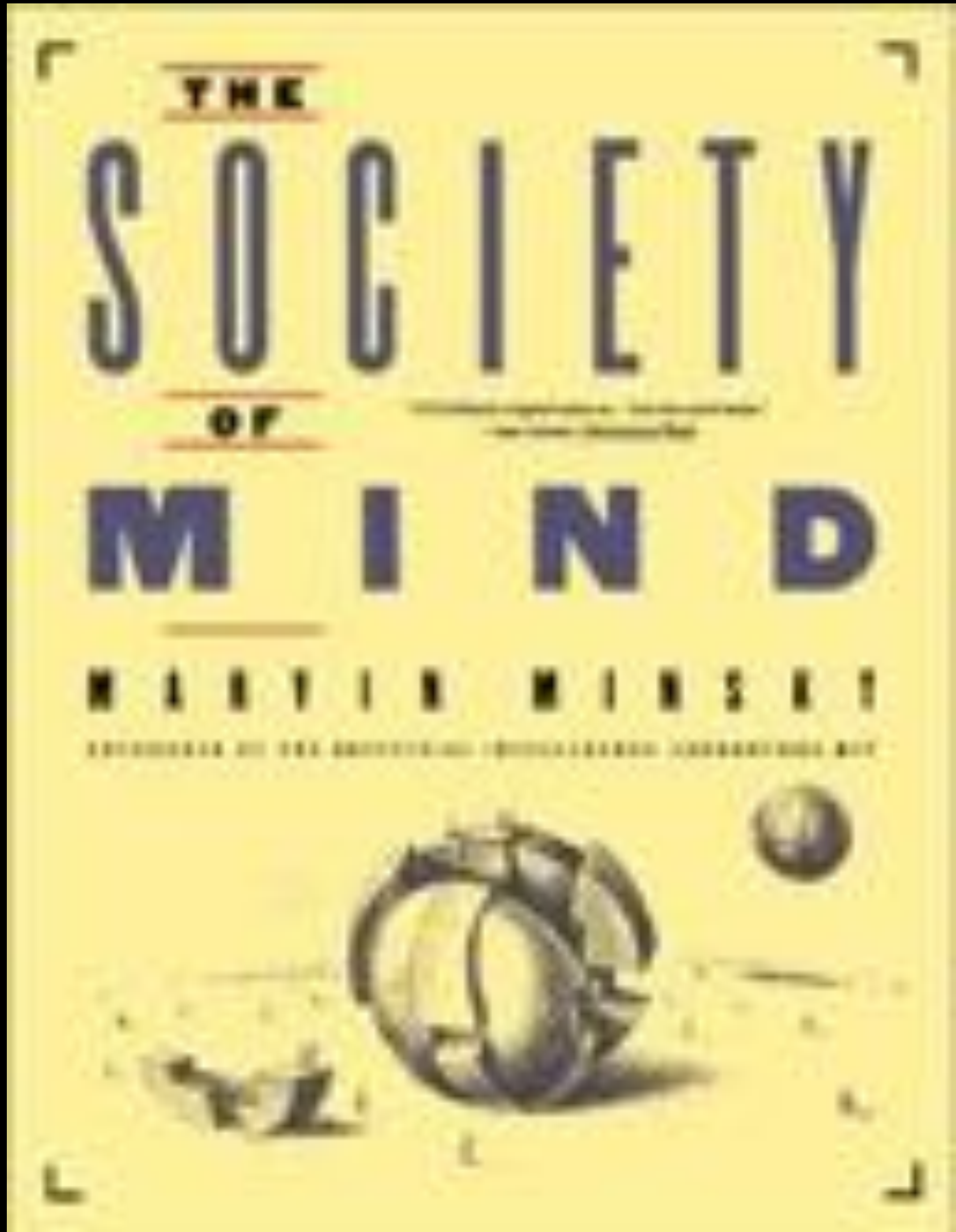
Art as a context for mathematical problem solving can be a fruitful starting point, as art is usually thought to include creative thinking and finding one's own way.

Creative activities may support the students to recognize that *doing "real" mathematics* is creative thinking; and creative thinking in mathematics means, that you do your own mathematics. (Cf. Hähkiöniemi, Fenyvesi et al., 2016)

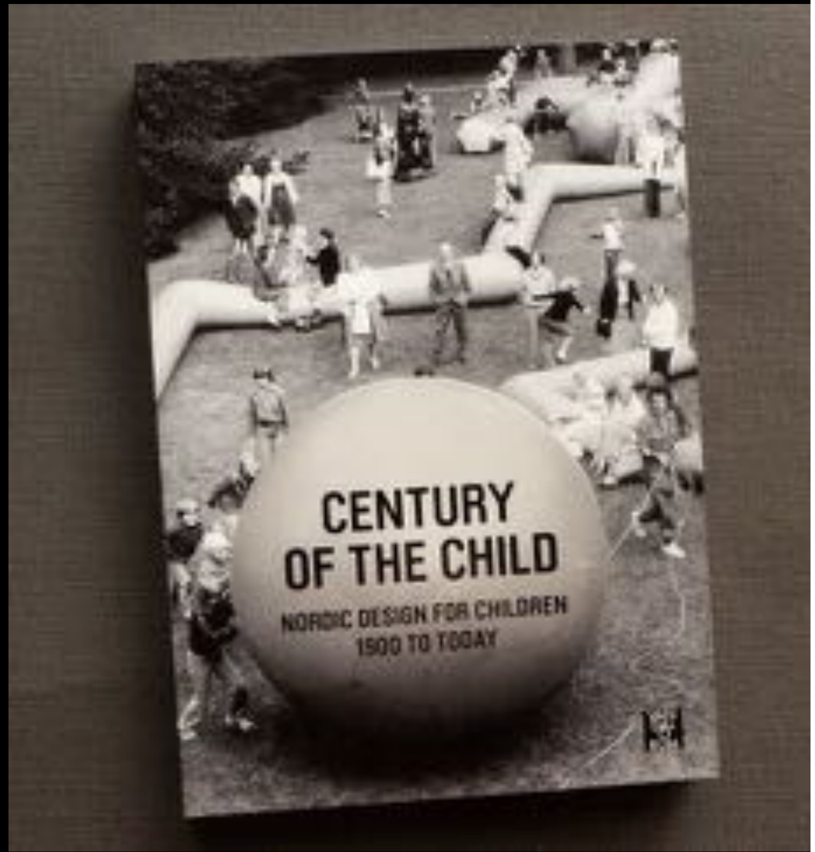
Let the students to BUILD UP THEIR OWN MATHEMATICS through play, art and creative activities!


Building up
Mathematics
Z. P. DIENES


Memoirs of a
Maverick
mathematician
Zoltan Paul Dienes


THE
SOCIETY
OF
MIND
MARTIN MINSKY


CENTURY OF THE CHILD
MoMA


CENTURY
OF THE CHILD
NORDIC DESIGN FOR CHILDREN
1900 TO TODAY

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Photos: G2Photo.

In mathematics education there is a growing need to design activities, which focus on the creative process instead of emphasizing a product, which was created by following a certain plan.

These kinds of activities can underline the **process aspect of mathematics** (Ernest, 1989).

(Cf. Hähkiöniemi, Fenyvesi et al., 2016)

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Photos: G2Photo.

Nowadays problem solving is not thought to be an individual work, but a collaborative effort (Hesse et al., 2015).

Connecting science, technology, engineering, arts and mathematics by solving complex problems through creative processes, can also support students to collaborate.

Different people's strengths in different areas are adding up on the group level.
(Cf. Hähkiöniemi, Fenyvesi et al., 2016)

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Tempus Attitude Survey (TAS) 2013 in Serbia
with the participation of more than 3600 students.

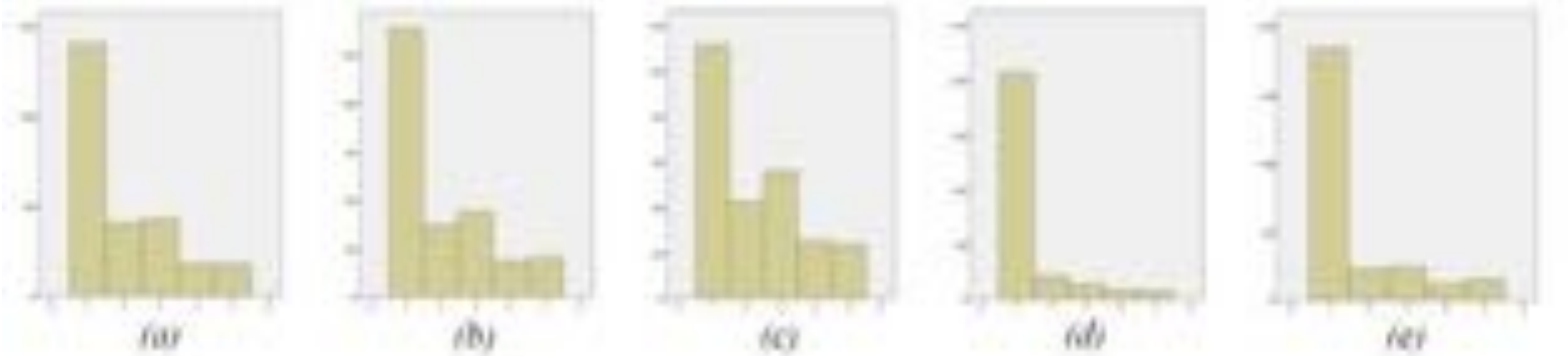

Figure 1: *TAS 2013 results. Students rate how often their mathematics teachers (a) use computers; (b) computer-aided presentations, such as PowerPoint; (c) real physical objects or models for visualization; (d) references to artworks, like paintings or sculpture, etc.; (e) or how often they visited art or science museums to support the understanding of mathematical content. The vertical line shows the number of students; the horizontal line: 1 = never; 2 = a few times; 3 = sometimes; 4 = often; 5 = many times.*

In general, mathematics education content in Serbian schools does not provide an account of the **STEAM integration** of mathematical knowledge and does not connect to the students' **real-life world**.

Photos: Eszterházy College, Eger.

However, there is a rich variety of experience- and STEAM-oriented approaches exist in the Serbian mathematics education.

But these are **not generally spread**, most of these **implemented by only a small number of teachers** for a **very small number of students**.

Photos: Eszterházy College, Eger.

Finding:

There is a correlation between the variety o f implemented teaching methods and the teachers. Teachers, who use certain experiential approaches or tools frequently, they are most likely to implement other experimental contents as well.

Successful implementation of an experimental content, can open the door towards searching for and learning further methods. This is a key for the establishment of methodological and instrumental diversity in mathematics teaching.

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Photos:
Experience Workshop

Photos: Aya Riha
& Sándor Csizmadia

The Digital Challenge...

The growing technologization, digitalization, networkization, and increasing computational complexity of daily practices are reorganizing our society and culture in prolific ways...

We recognize it or not, but the increasing importance of mathematically structured patterns and models has a great impact on our experience of everyday life, and a particular significance for all digitized societies.

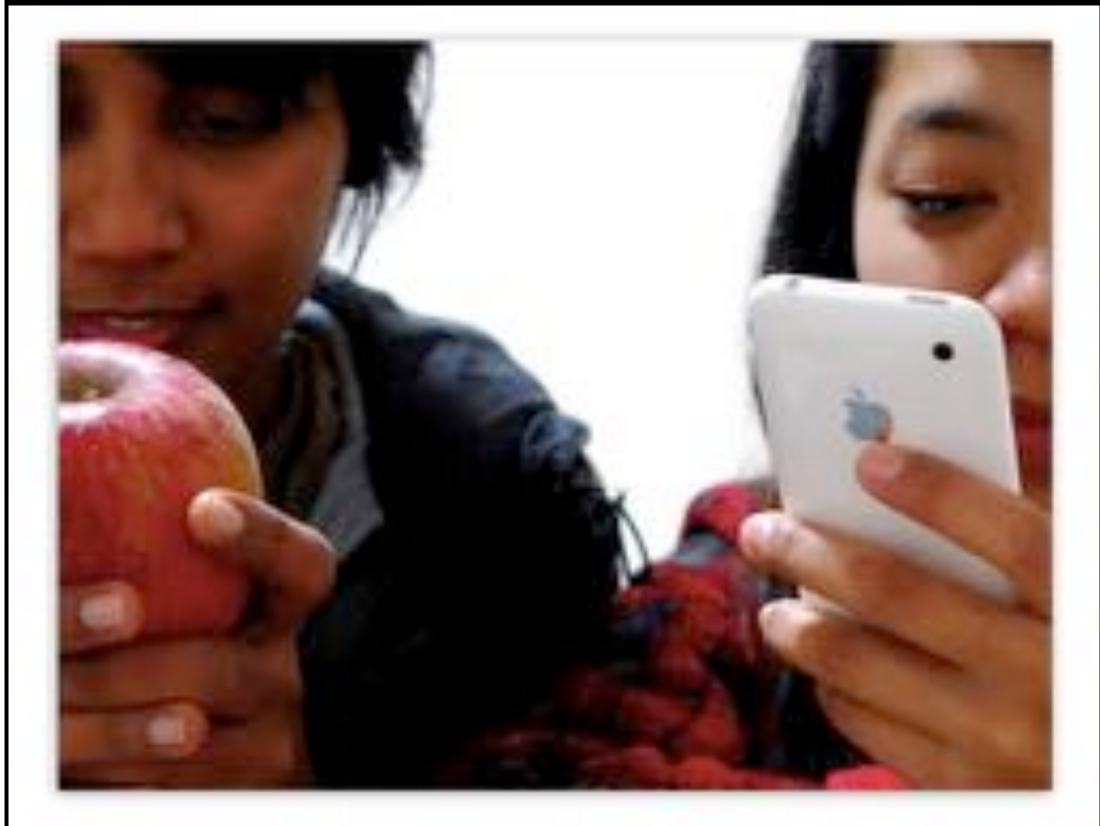

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Photo:
Márton Kállai.

The Attitude Challenge...

Oddly, the abstractness of mathematics as a science makes it a unique discipline often perceived as exterior to the contexts of daily life.

As attitude-researches point out, students tend to sustain an aversion to mathematics (Iben 1991, Ma & Kishor 1997, Ruffell-Mason-Allen 1998, Gomez 2000, Hannula 2002, Uusimaki 2004; and see the term “math-anxiety”: Curtain-Phillips 1999, Ashcraft 2002)...

Students remain largely ignorant of how deeply mathematics is embedded in the world around them (Hannula 2011, 2012, Roesken-Hannula-Pehkonen, 2011)...

It seems to be a paradox that mathematics, although widely implemented in all industrialized societies, is experienced by most school pupils as a difficult and unpleasant subject
(cf. Rogerson, 1986).

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Social and Cultural Challenges:

- ***the Gender-challenge…*** Mathematics often understood as a male domain... This sets restrictions for girls' attitudes toward mathematics...

- Best education for the ”talented” few vs. everybody has a genuine talent.

Photo: G2Photo.

The Motivation Challenge…

Providing sufficient motivation for students is maybe one of the greatest challenges in education today…


Photo: G2Photo.

According to PISA results:

students should find education **enjoyable, develop self-belief and develop stamina to address challenging problems and situations.**

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The Visual Challenge…

Today's children are increasingly exposed to a multitude of visual stimuli (mobile technologies; video games; augmented reality; wearable cinema, Google glasses; 3D cinema already from '60s; "cinema is dreaming of the conquest of the 4-dimensional, or even multidimensional space", Weibel 2014).

…while the traditions and education of the science, especially of mathematics, highlights different tendencies as well…

Photos: EU Info Spot, Budapest.

Table 1: Conceptual changes in the theory of knowledge

Concept / doctrine	**Traditional**	**Networked**
The subject of knowledge	Single individual	Community / network
Knowledge	Justified and truthful information (believes)	Interpreted information
Type of knowledge	Explicit knowledge	Also tacit knowledge and raw data
A fact	Information based on empirical evidence	A transforming node gaining evidence from the network
Thinking	Individual's activity	Collective activity, "we think" and "they think"
Knowledge creation	By researchers, often in a closed environments (labs, institutions), based on existing knowledge	By experts and citizens in the web, based on open communication and sharing tacit knowledge
Knowledge dissemination	Via books (printed material)	Via internet and via collaboration
Perspectives (points of view)	Subjective and eliminable	Inevitable, essential part of knowledge creation
Temporal disposition	One-time units of knowledge	Continuous processes of knowledge creation

Weinberger (2012) as it is summarized by Antti Hautamäki

SUMMIT VIENNA 2015

IS4IS

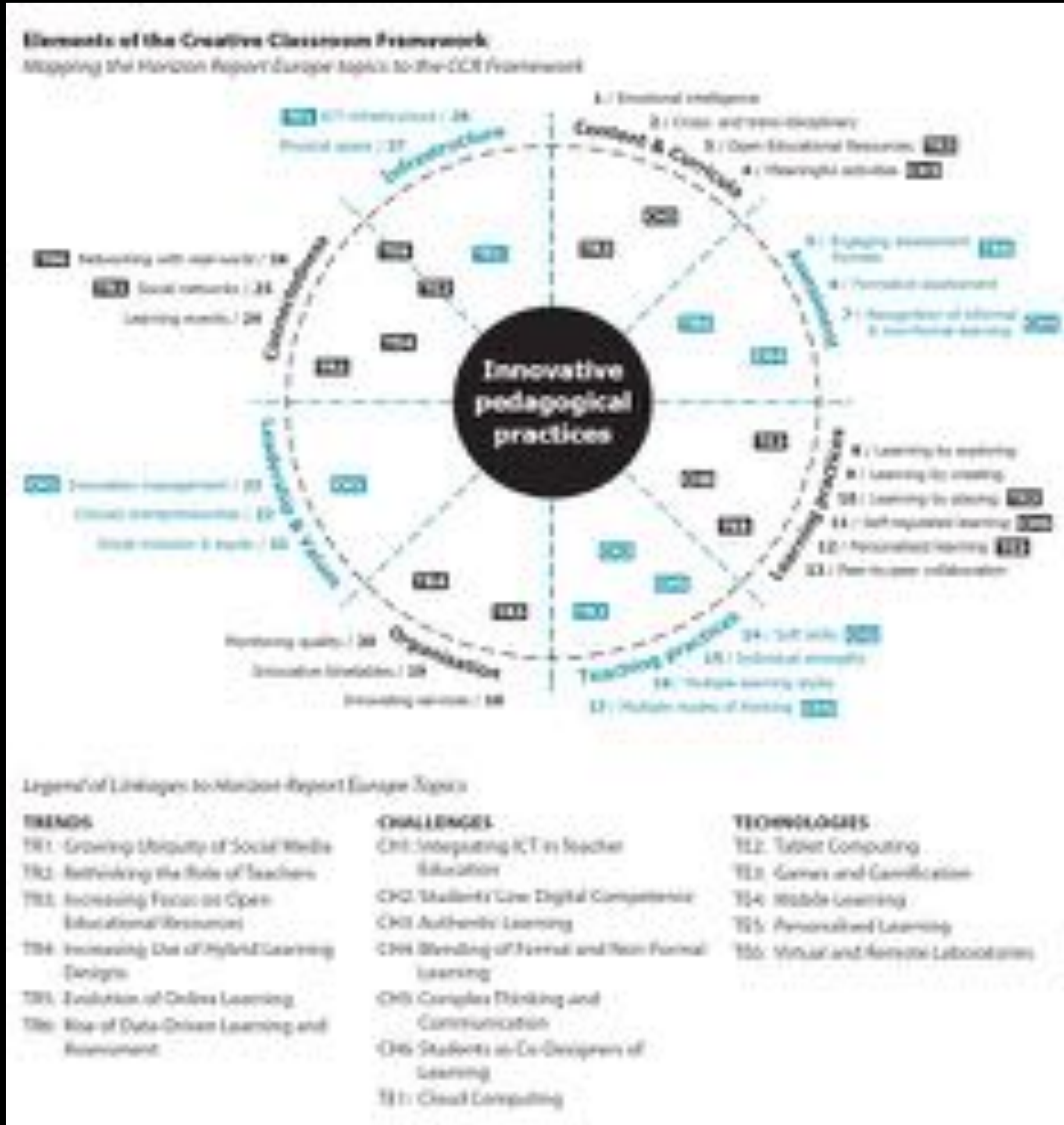
www.summit.is4is.org

THE INFORMATION SOCIETY AT THE CROSSROADS: Response and Responsibility of the Sciences of Information

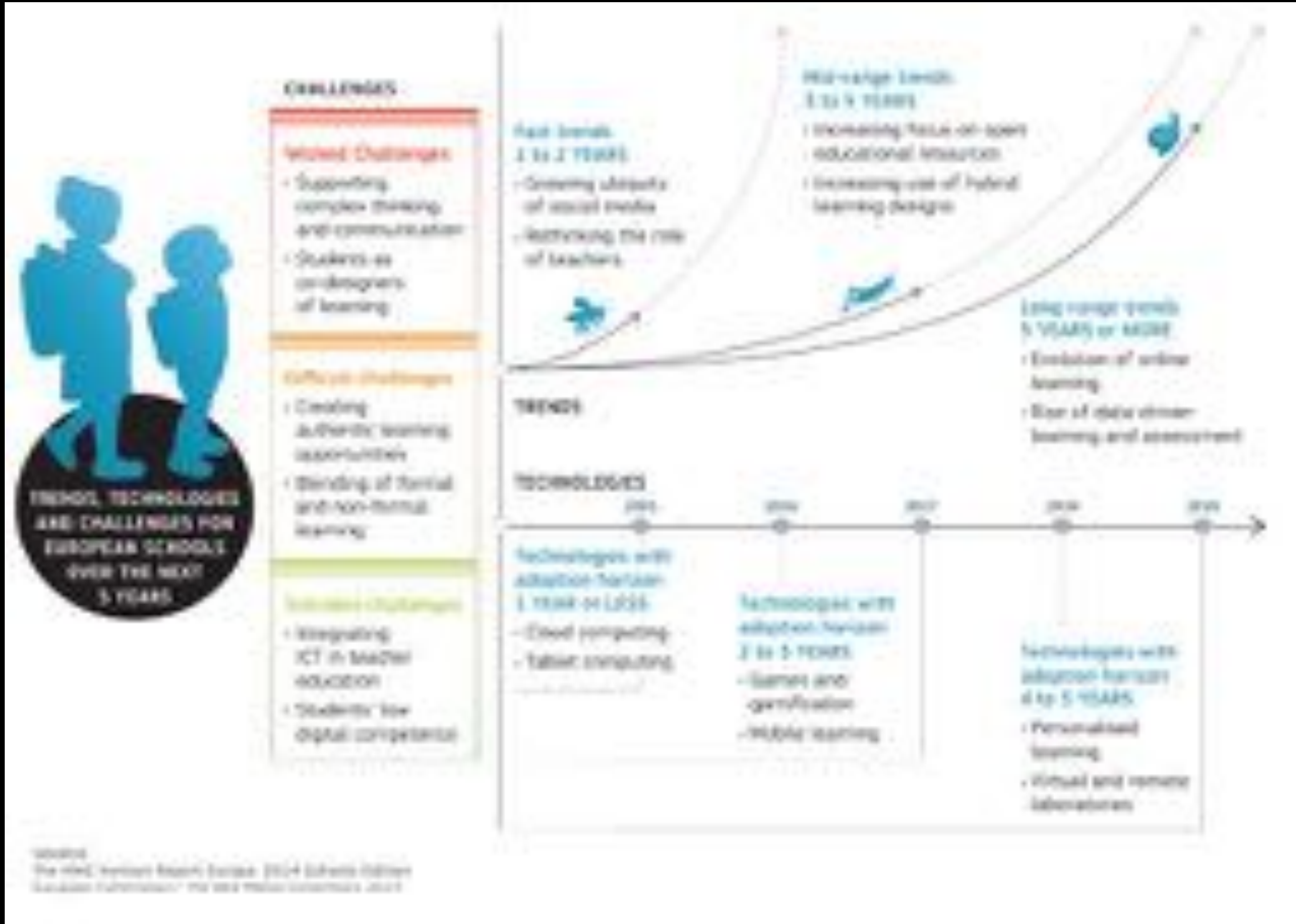
Vienna University of Technology, June 3-7, 2015

ICT IN EDUCATION SYMPOSIUM: As We May Teach? ICT in Education: An Odd Couple

Photos: Kristof Fenyvesi.

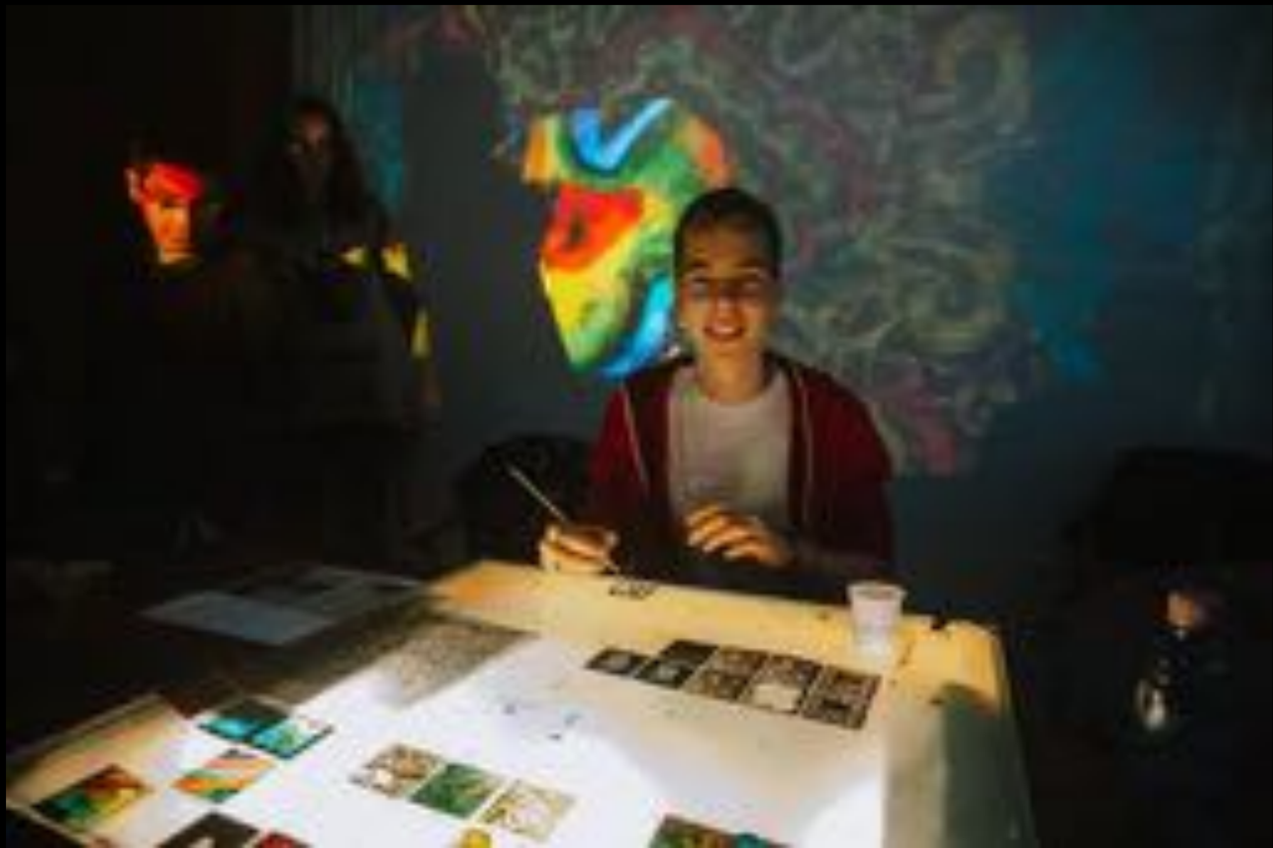


The Horizon Report Europe: 2014 Schools Editions



The Horizon Report Europe: 2014 Schools Editions

Despite the attitude-challenge, and other challenges, students are able to recognize patterns and deal fluently with the abstractions of language, music, arts and design. Numerous research and empirical evidence indicates that people become easily motivated (and even fascinated) when mathematical connections are presented in ways which relate to their experiences by triggering their natural curiosities and aesthetic sensibilities.



There is already significant research made by mathematicians, art historians, educators, and practicing artists and designers in the exploration of mathematical connections between the nature, arts, sciences, music, culture, architecture and design.

Photo: Pécs University.

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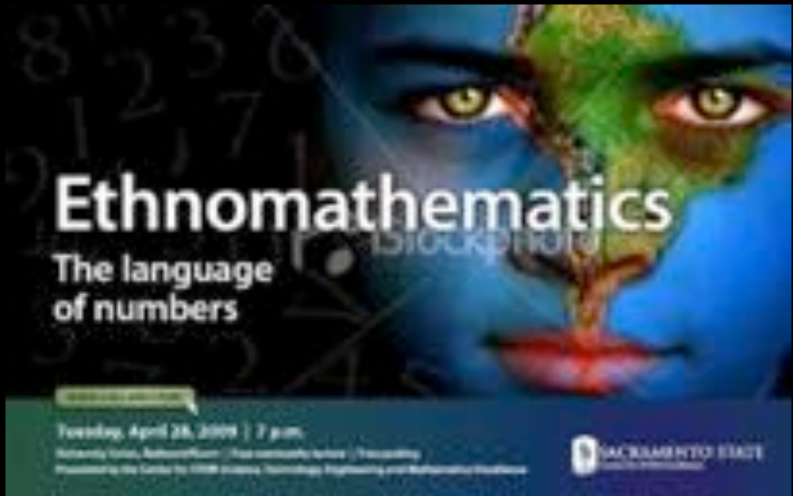
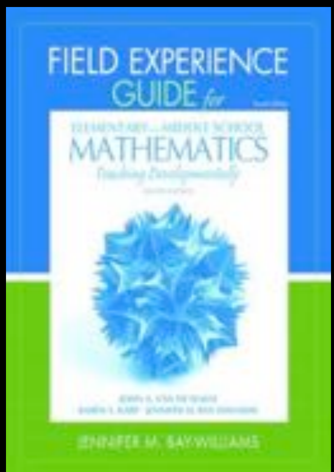
Exponentially expanding interdisciplinary fields of research like ***visual mathematics***, **symmetry studies**, ethno-mathematics, computer aided design, etc. and studies of **experiential education and inquiry-based education** of mathematics have accumulated an enormous body of research results during the recent decades…





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Visual Mathematics – “Mathematics without words and formulas.”

Visual mathematics education *materials are ready for development to make them available in public education!*

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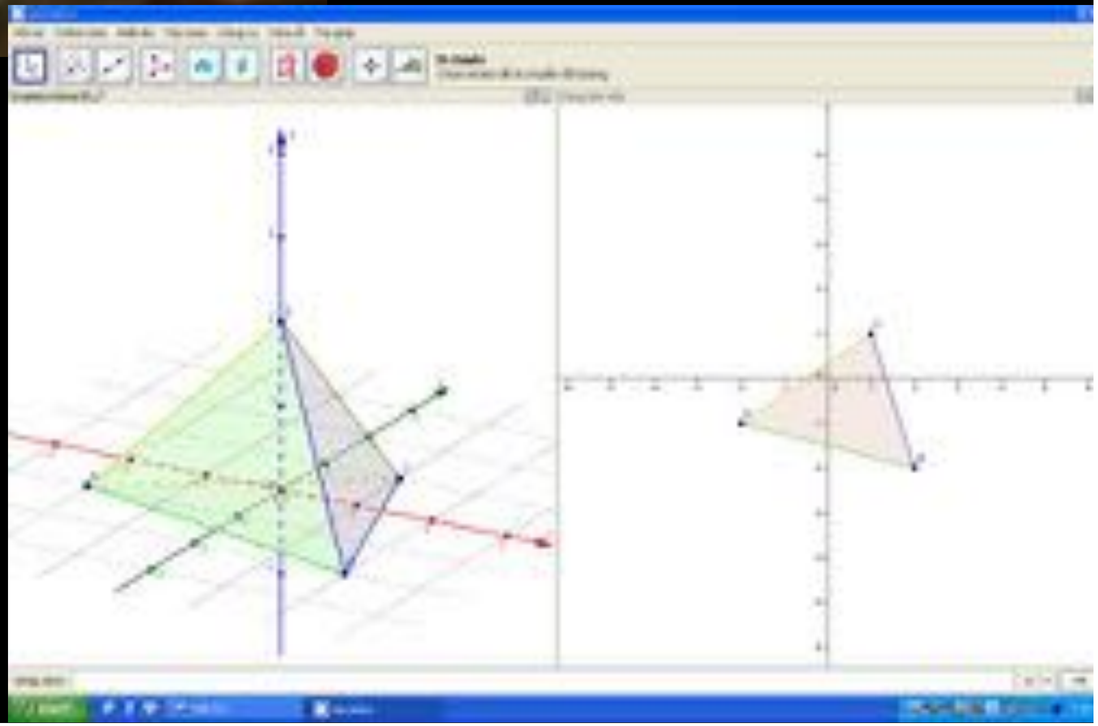
Photos: Experience Workshop.

Connecting Hands-on + Digital Modeling

...studying real-world phenomena with the help of digital applications and vice versa...

Learning through iterative design...



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VISUALITY & MATHEMATICS

EXPERIENTIAL EDUCATION OF MATHEMATICS THROUGH VISUAL ARTS, SCIENCES AND PLAYFUL ACTIVITIES

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Photos: Experience Workshop.

The Experience Workshop Math-Art Movement:

>>> Started in 2008 as a collaborative effort by the worldwide known ***scientists, artists and educators*** *of the* **Ars Geometrica International Conferences and Workshops,** *the* **Bridges Organization** *and* **International Symmetry Association.**

>>> We organize ***math-art festivals, creative schooldays, artistic and scientific workshops, exhibits and presentations for children, parents and trainings for teachers.*** *We present our results in* ***conference-talks, scientific and popularizing articles and books.***

>>> Recently more than ***20,000 students from primary, secondary, high-schools and universities, almost 1000 teachers and approximately the same number of parents*** *participated in our programs.*

>>> Education within and BEYOND the School: OSMOSIS, DISSEMINATION, SUSTAINABILITY,RESPONSIBILITY, PARTICIPATION AND REPRESENTATION.

Our official partner is the ***Zometool Inc. (USA) and 4DFrame (Korea).***

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Traveling Collection of Mathematical Art in Hungary and in Finland

>>> It was founded in 2010 from the donations of the participants of Bridges 2010 World Conference. There are almost 80 MathArt pieces in our growing collection at the moment. The collection has a keyrole in our projects. It represents the cultural, artistic, architectural and interdisciplinary connections of mathematical thinking.

>>> Artists in our Collection: ABY SZABÓ Csaba, Javier BARALLO, Jacques BECK, Anne BURNS, Christopher CARLSON, Doug DUNHAM, F. FARKAS Tamás, Robert FATHAUER, Mike FIELD, Paul GAILIUNAS, Mehrdad GAROUSI, Gary GREENFIELD, John HIIGLI, Slavik JABLAN, KABAI Sándor, Craig S. KAPLAN, LÁNG Eszter, Margaret KEPNER, Teja KRASEK, Merill LESSLEY & Paul BEALE, Kaz MASLANKA, Jonathan McCABE, MUZSAI István, Richard NEWMAN, Rochelle NEWMAN, OROSZ István, Frank & Natalie PRIEBE, Peter RAEDSCHELDERS, Ian SAMMIS, Reza SARHANGI, SAXON SZÁSZ János, Carlo H. SEQUIN, Laura M. SHEA, SZUHAY Márton, Anna URSYN, Joel VARLAND, VIRÁGVÖLGYI Anna, Mohammad YAVARI RAD

>>> Exhibits: Kaposvár University (2010), ANK Education Centre, Pécs (2010), Eger College (2011), World Congress of International Society for Education through Art (2011), Hungarian Science Festival (2010, 2011) and many schools and universities all over Hungary and in the neighboring countries.

>>> SPREAD OUR WORDS: INVITE US! / SPREAD YOUR WORKS: DONATE IT TO US!


Photos: Eszterházy College, Eger.

Ars Geometrica Eger 2011
Interactions and Border-Crossings
In Art and Science

In 2011, September: we OPENED the Eszterházy College's
Ars GEometrica Art, Science & Education Gallery in Eger city, Hungary

>>> FOUNDERS: Kálmán Liptai, mathematician, Rector of the Eger University / Ibolya Szilágyi, mathematician of the Eger College / Kristóf Fenyvesi researcher, Dept. of Art & Science Studies, Jyväskylä University

>>> Director: Kálmán Liptai, Rector of the Eger University
>>> Scientific Curator: Ibolya Szilágyi, mathematician Eger University
>>> Art Curator: Kristóf Fenyvesi, Jyväskylä University

Homepage: ***www.arsgeo.hu/en***

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www.vismath.ektf.hu/exercisebook

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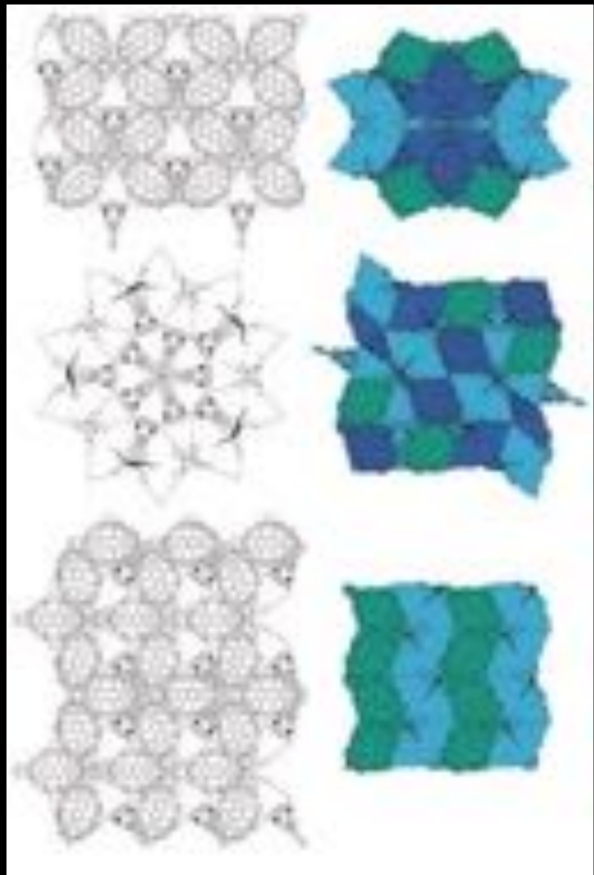
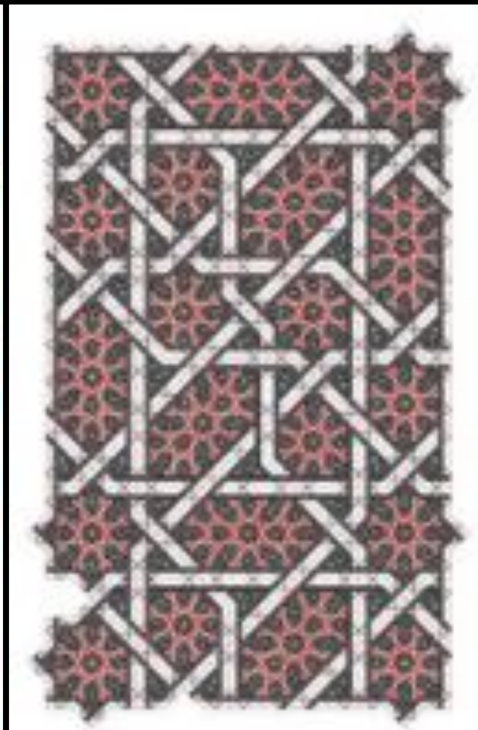
Our New ACTION BOOK for Visual Mathematics Education

Adventures On Paper! Math-Art Activities for Experience-centered Education of Mathematics

Eds. Kristóf Fenyvesi, Ilona Oláhné Téglási & Ibolya Prokajné Szilágyi

Publisher: Eszterházy Károly College, Eger, 2014

Download it from www.vismath.ektf.hu/exercisebook !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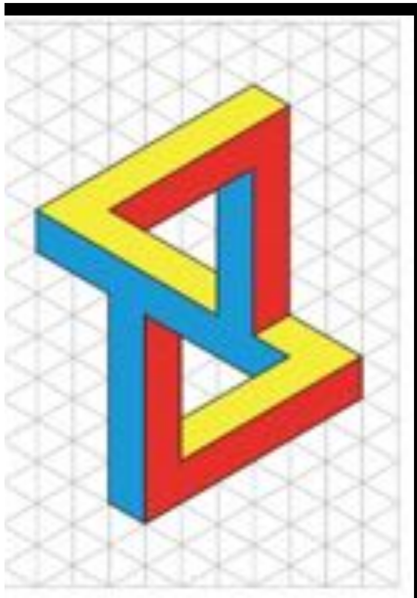

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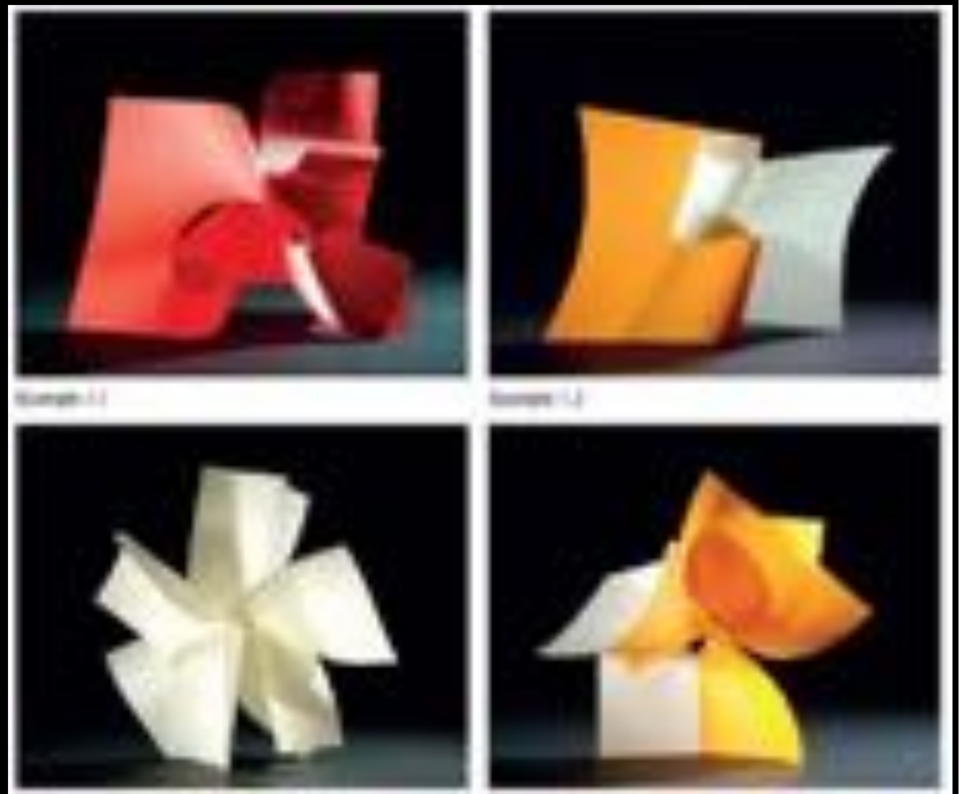

Visuality & Mathematics

Experiential Education of Mathematics through Visual Arts, Sciences and Playful Activities

Gamified Learning – Learning by Doing

POM2SMA Experimental math / math-art relate d problem solving for primary school teachers, grades 1–6.

Photo: Kristóf Fenyvesi

Learning outcomes: After the course a student

- is able to design learning activities in which students investigate mathematics
- is able to utilize mathematical modelling and c onnections to other disciplines in mathematics teaching
- has courage to try new things, think critically a nd utilize own strengths as well as to analyze own teachin g

Contents: Inquiry based mathematics teaching in art relat ed topics. Designing, implementing and analyzing a teachin g unit or a workshop.

Teaching methods: Small group teaching

Bridges Finland 2016
University of Jyväskylä

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Geodesic Dome

Photo: Joep Rutgers

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Photo: Bart van Overbeeke

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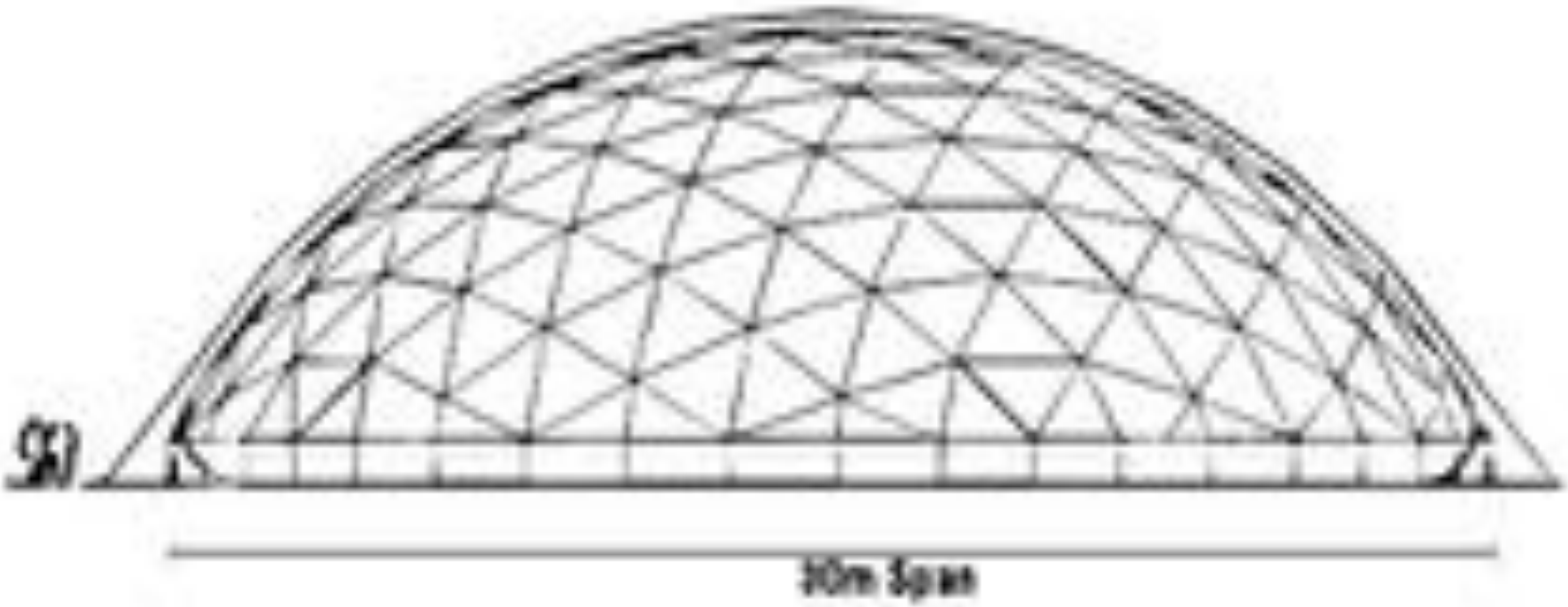
Photo: Bart van Overbeeke


30m Span

Leonardo da Vinci's dome structure,
reconstructed by Rinus Roelofs

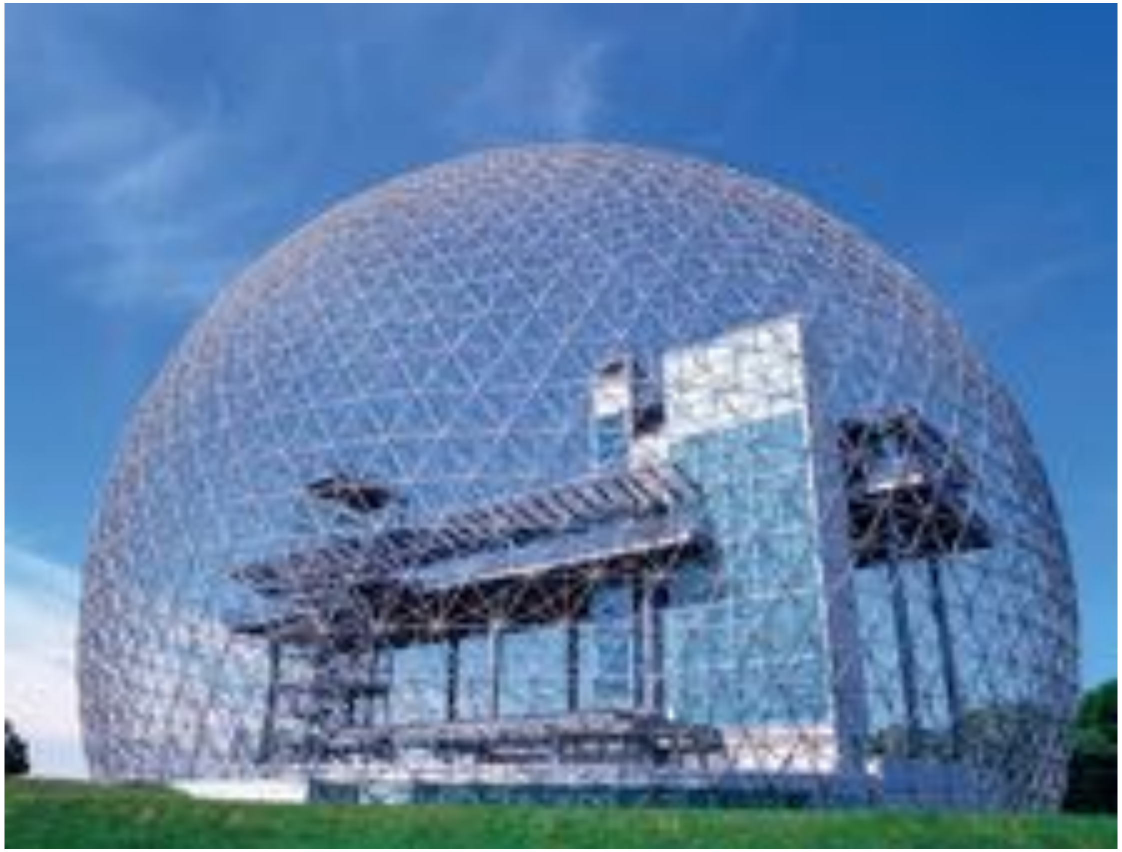
Dr. Walter Bauersfeld's Carl Zeiss Optical Works in Jena in 1922 - at the time called **'The Wonder of Jena'.**

This structure formed the shell of the Zeiss Planetarium. 25 more were built including on e in Chicago in 1930.

Some decades later **Richard Buckminster "Bucky" Fuller**, an American architect, engineer and visionary thinker popularized the special structure of the geodesic dome throughout the world.

According to his plans, **a geodesic dome was designed to cover the American pavilion for the World Fair in Montreal in 1967.**

The building is still can be seen.



Its diameter is 80 m and it is 65 m high.

"Spaceship Earth," the AT&T Pavilion at
Epcot in Disney World, Florida.

Origami Epcot Ball by students
of Natalija Budinski math teacher

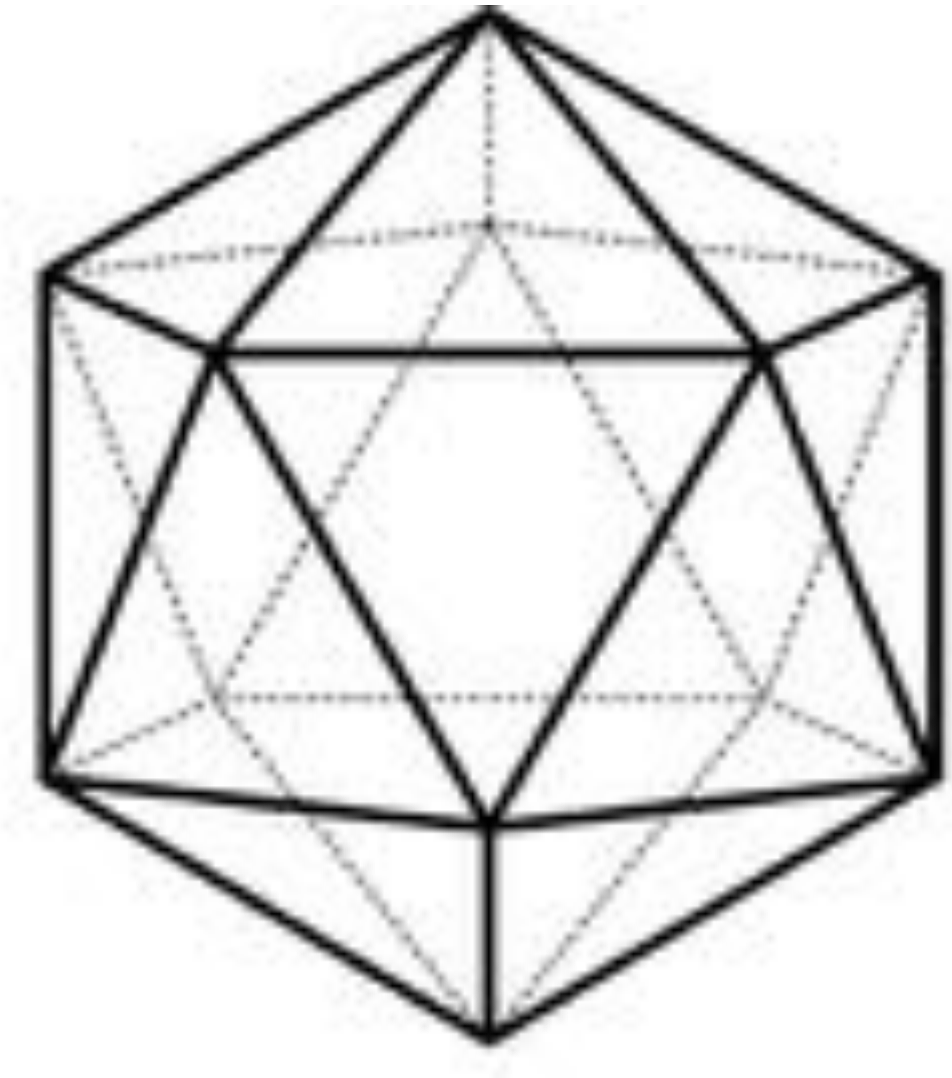
The People’s Meeting Dome by Tejlgaard & Jepsen, D
enmark

Nature House, a gorgeous geodesic dome home located on th
e Sandhornøya island of northern Norway.

A geodesic dome is a spherical or partial-spherical shell structure or lattice shell based on a network of great circles (geodesics) on the surface of a sphere.

The geodesics intersect to form triangular elements that have local triangular rigidity and also distribute the stress across the structure.

(Cf. http://en.wikipedia.org/wiki/Geodesic_dome).

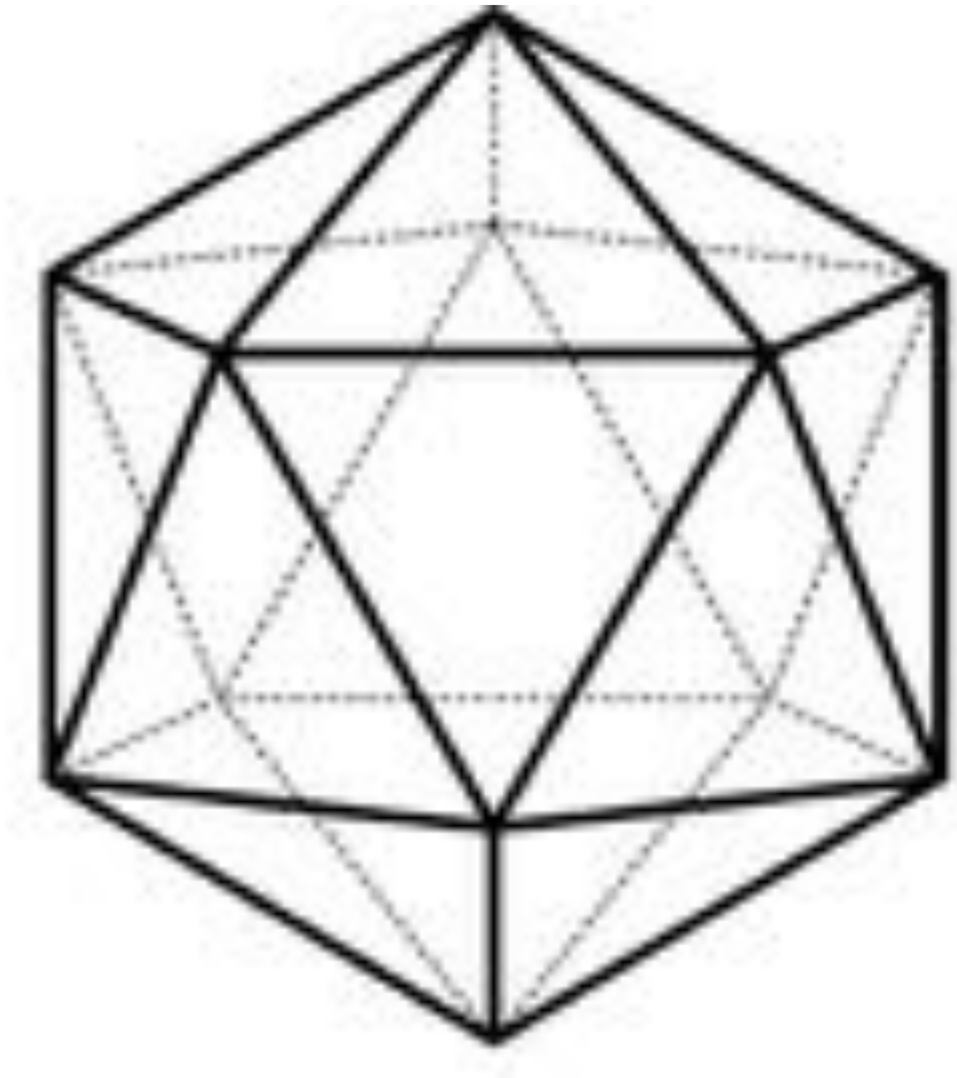


The construction of Fuller's geodesic dome is based on the geometric shape, called **icosahedron.**

If you take a closer look at the figure, you can see that each edge of the icosahedron is of the same length, triangles being components of the structure are equal in size.

The icosahedron is composed of 20 identical equilaterals and a sphere can be circumscribed around the structure.

Features concerning the edges of the geodesic dome are denoted by the frequency number.



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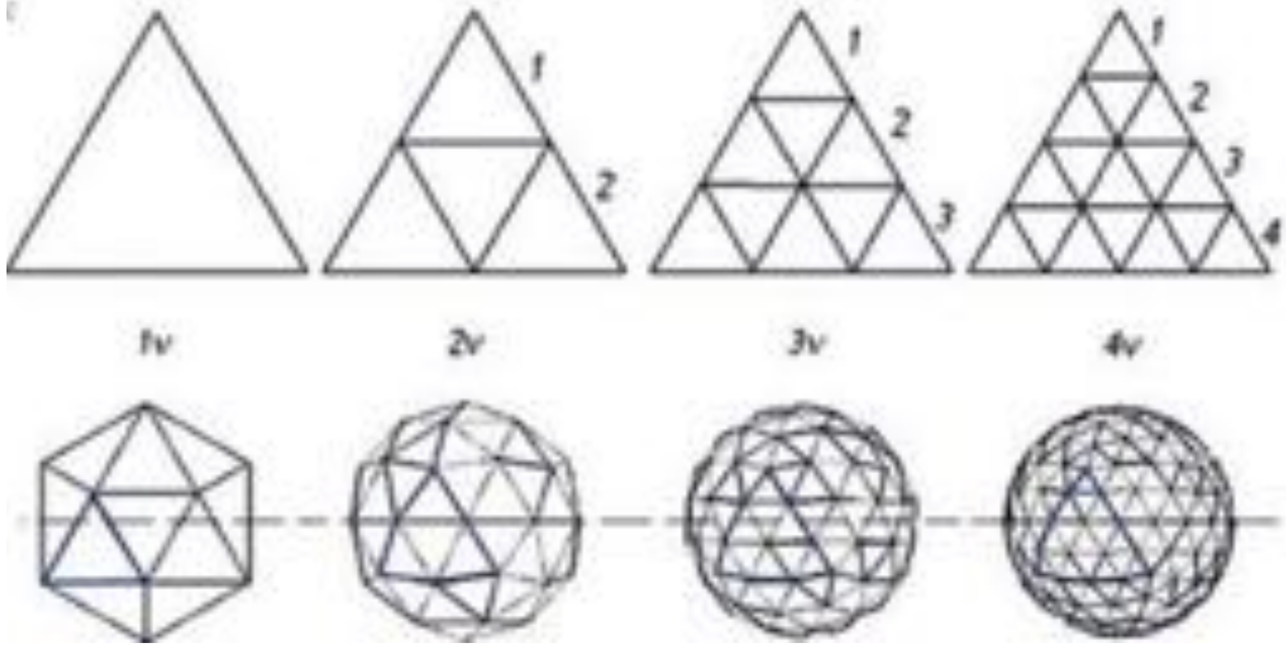
Features concerning the edges of the geodesic dome are denoted by the frequency number.

Because of the equal length of edges the frequency number of a geodesic dome generated from a regular icosahedron is 1.


1
2
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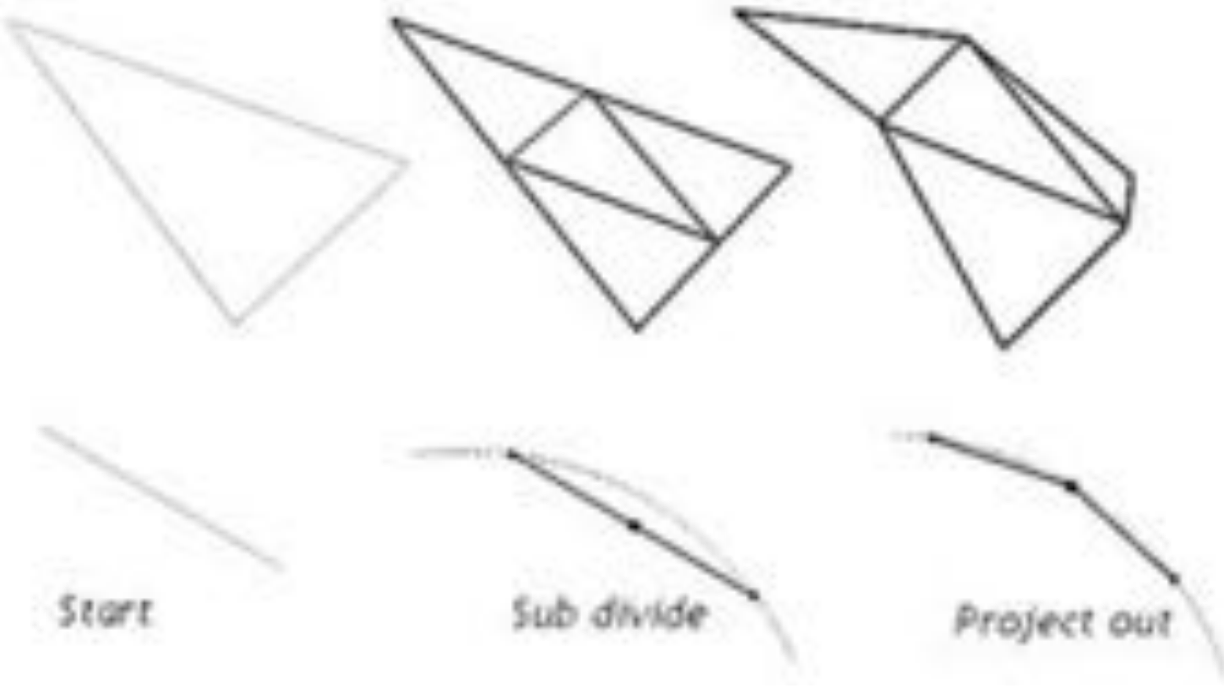
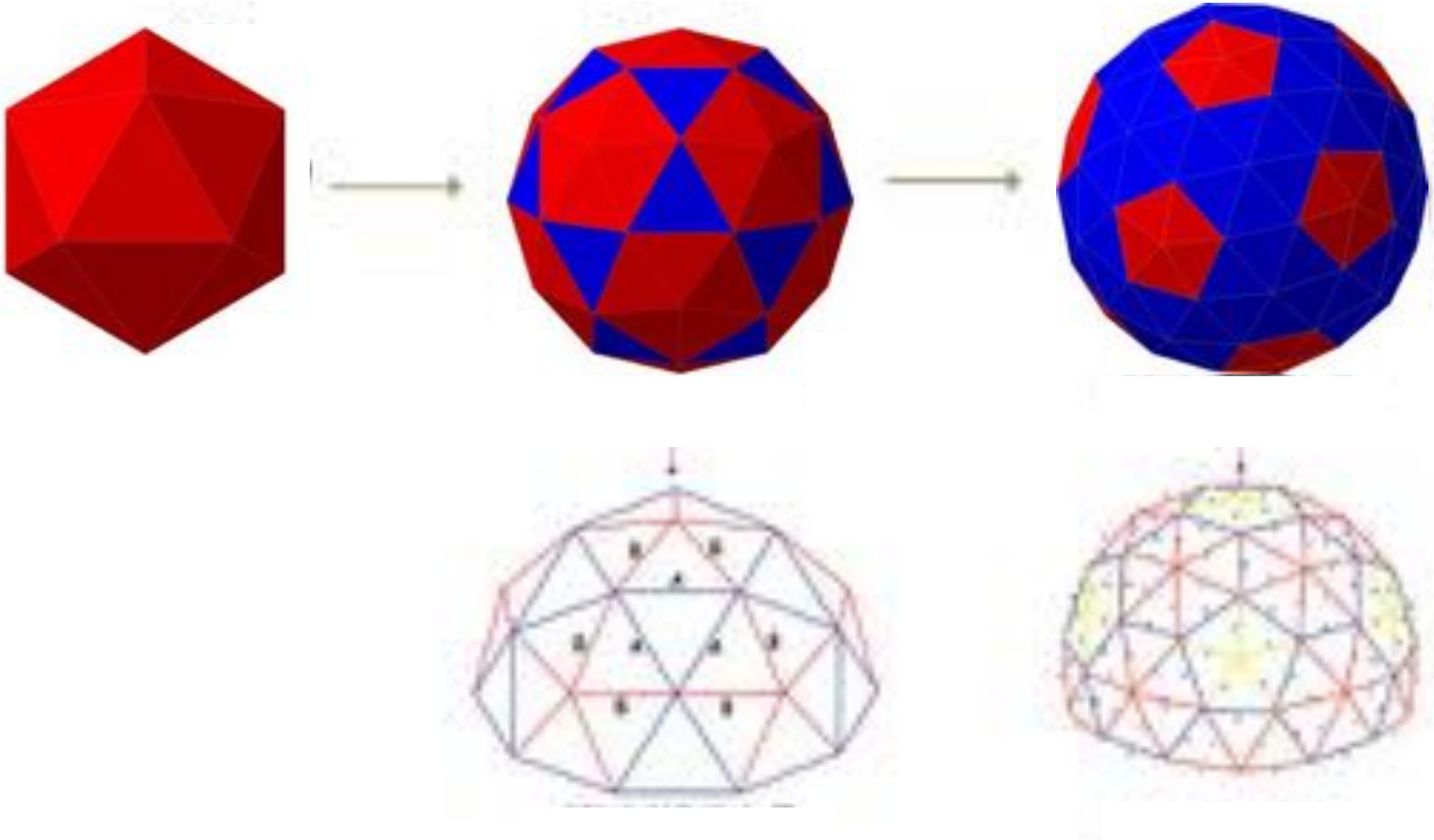
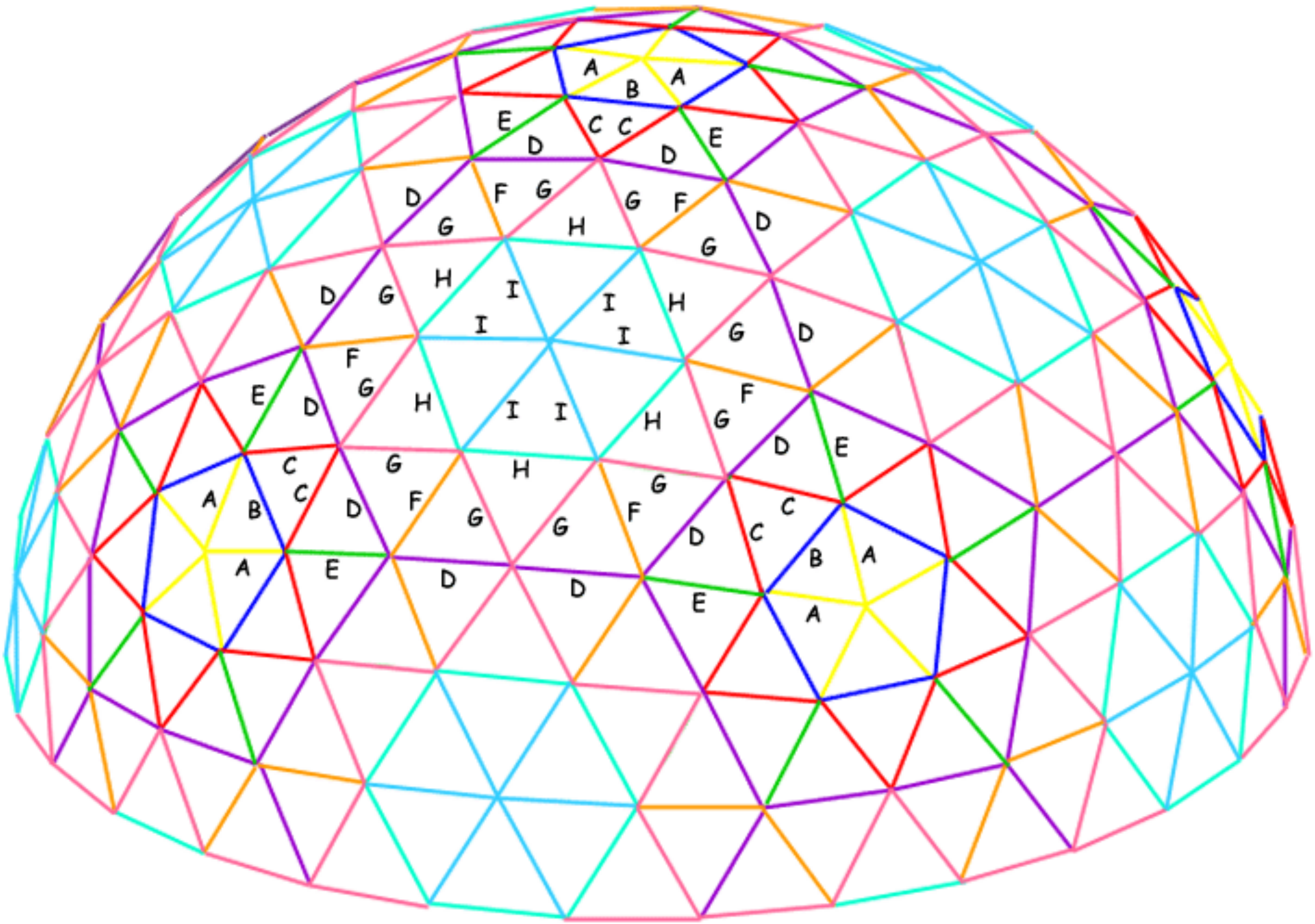
1v
2v
3v
4v


Start
Sub divide
Project out



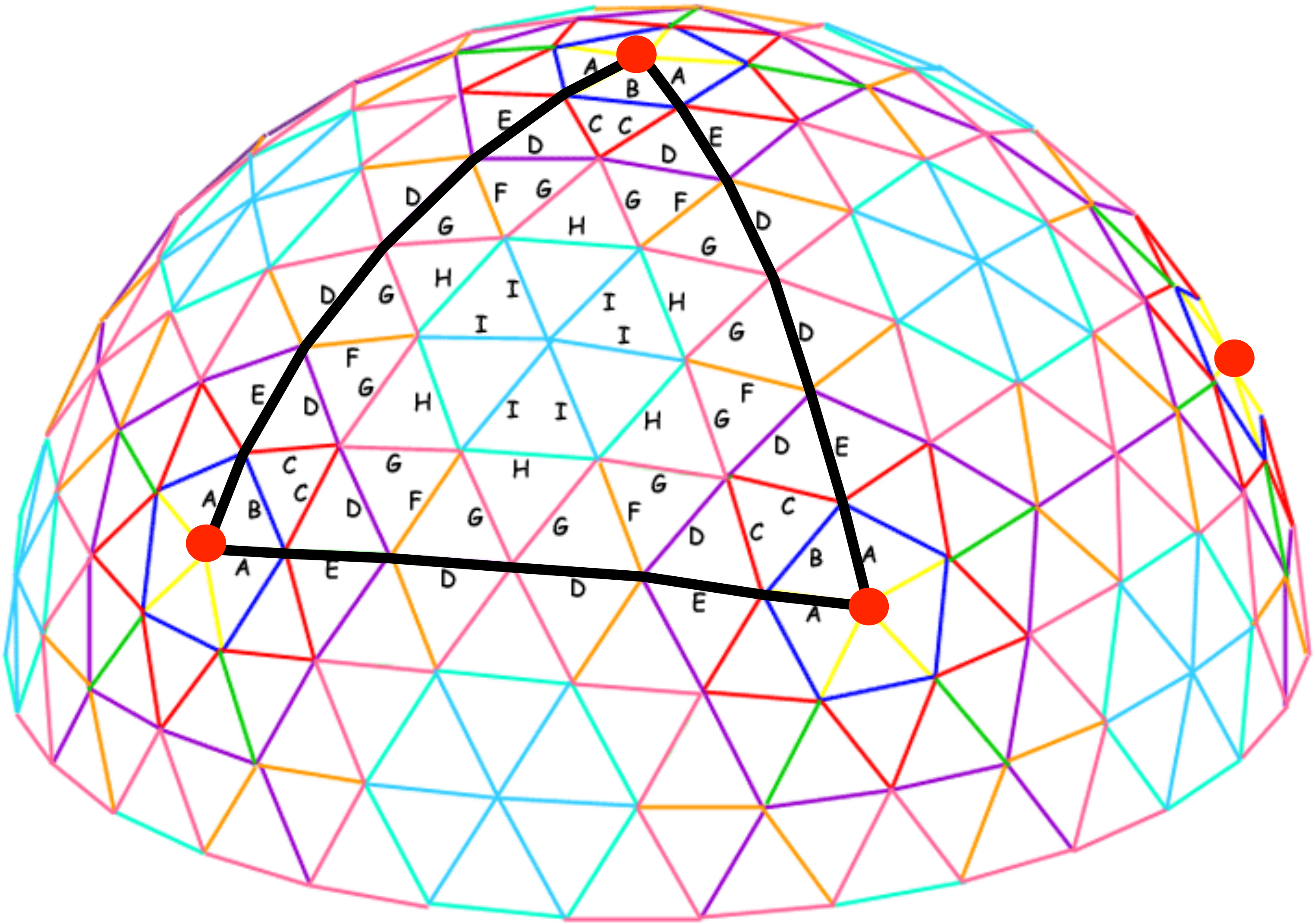
Geodesic Dome

Com pon ents♪	Length of e ach tube♪		Nee ded♪ piec es♪
		after♪	
A♪		42♪	30♪
B♪		49♪	30♪
C♪		47♪	60♪
D♪		52♪	90♪
E♪		48♪	30♪
F♪		51♪	60♪
G♪		53♪	130♪
H♪		55♪	65♪
I♪		56♪	60♪
5-way connectors♪			12♪
6-way connectors♪			380♪

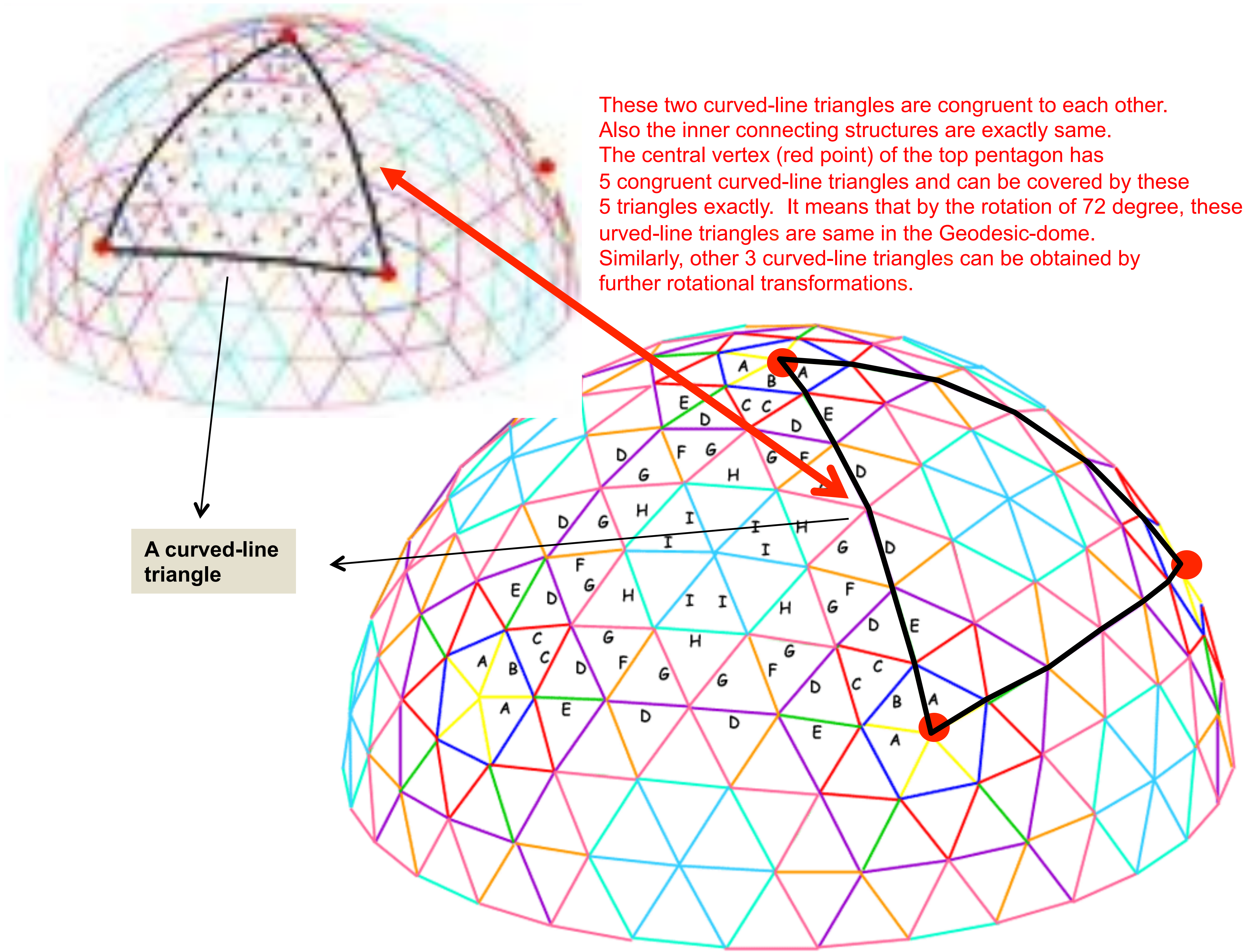


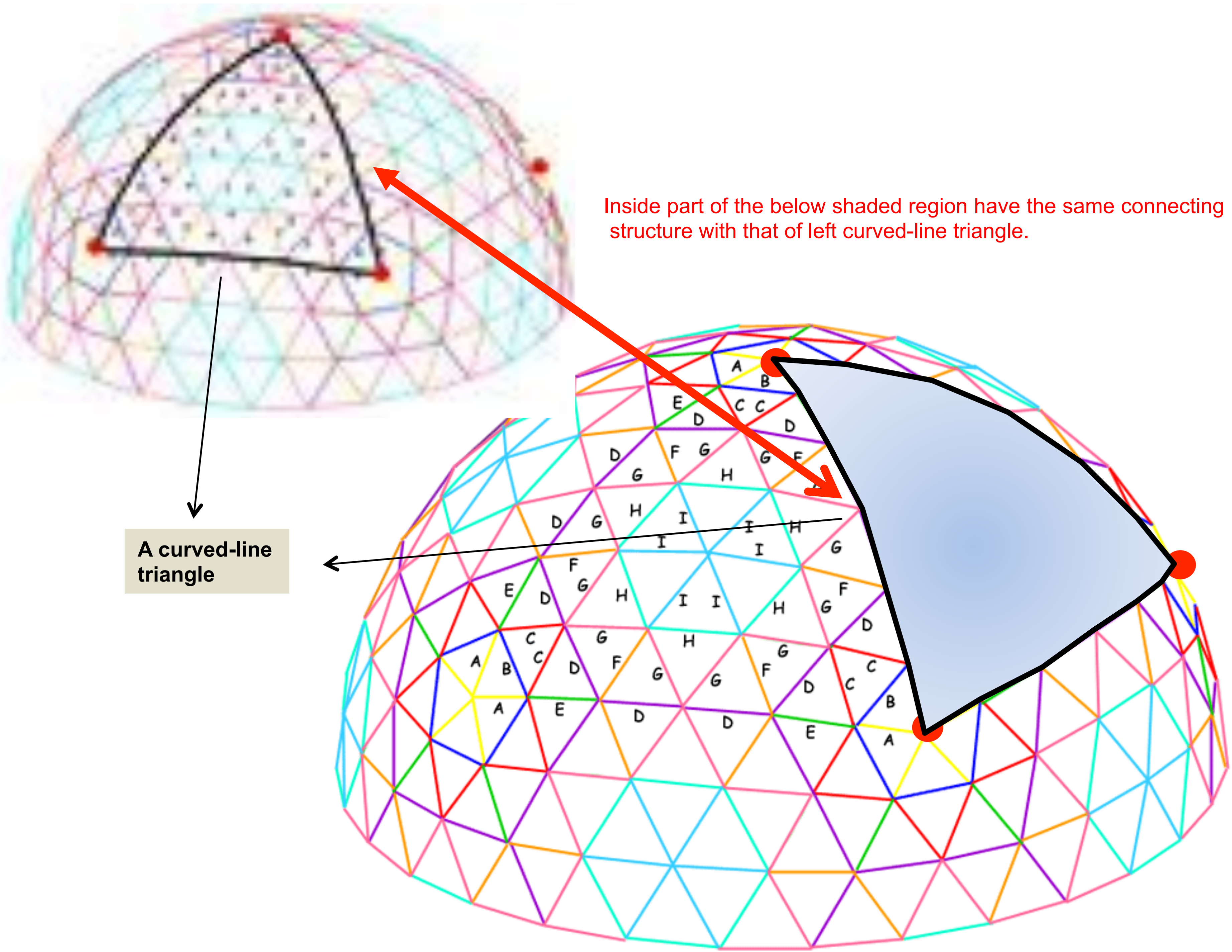
http://desertdomes.com/domecalc.html♪

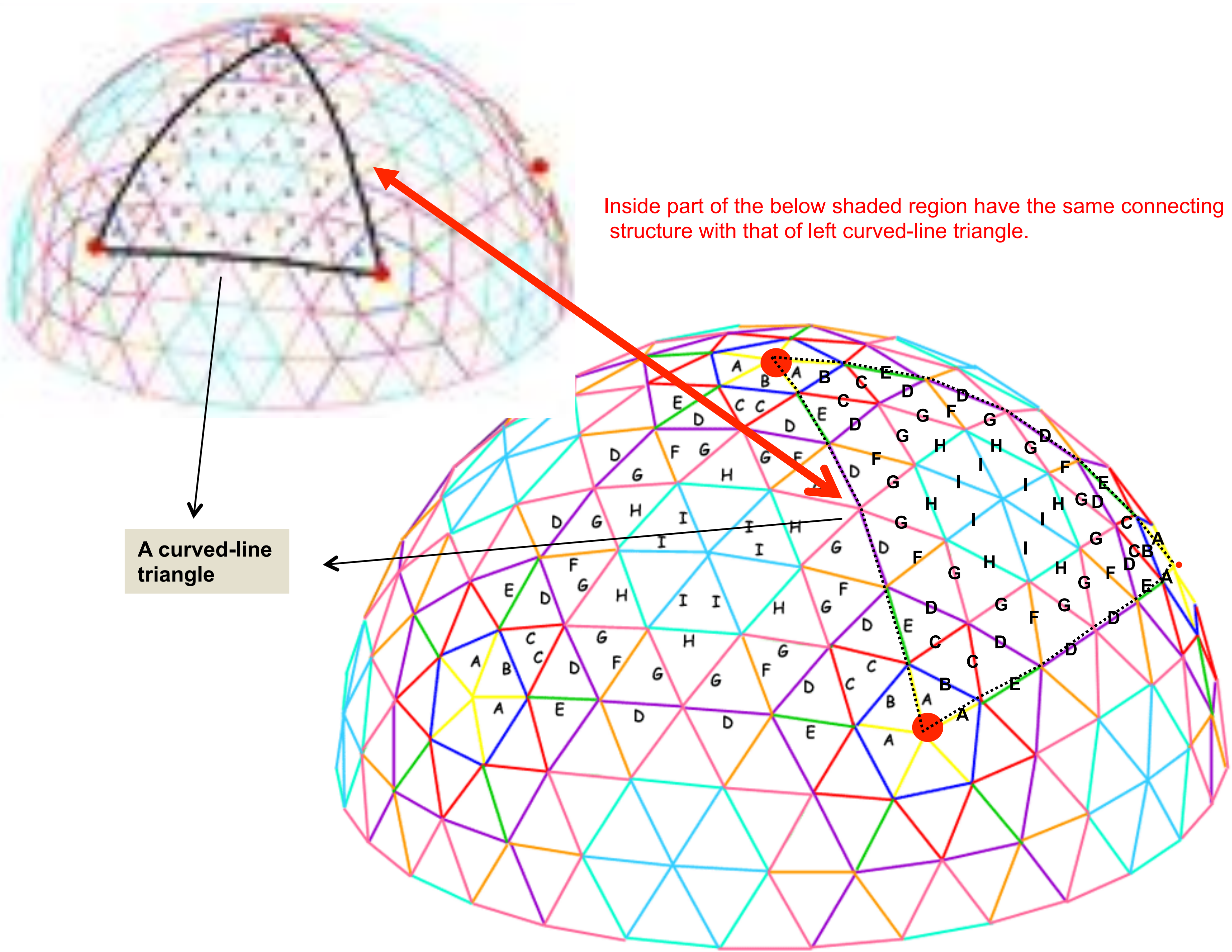
Understanding the symmetric structure of Geodesic Dome

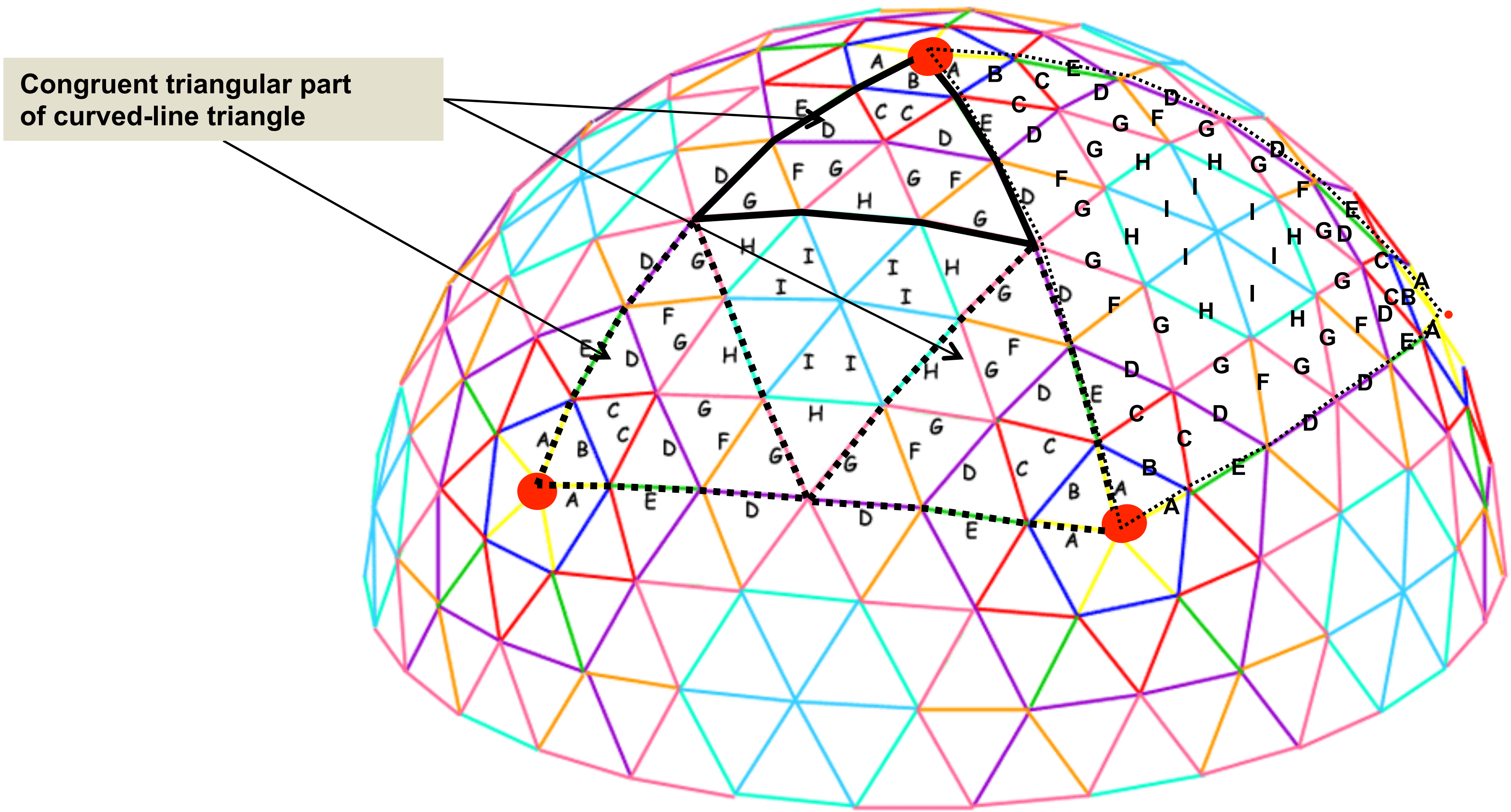


These two curved-line triangles are congruent to each other.
Also the inner connecting structures are exactly same.
The central vertex (red point) of the top pentagon has
5 congruent curved-line triangles and can be covered by these
5 triangles exactly. It means that by the rotation of 72 degree, these c
urved-line triangles are same in the Geodesic-dome.
Similarly, other 3 curved-line triangles can be obtained by
further rotational transformations.

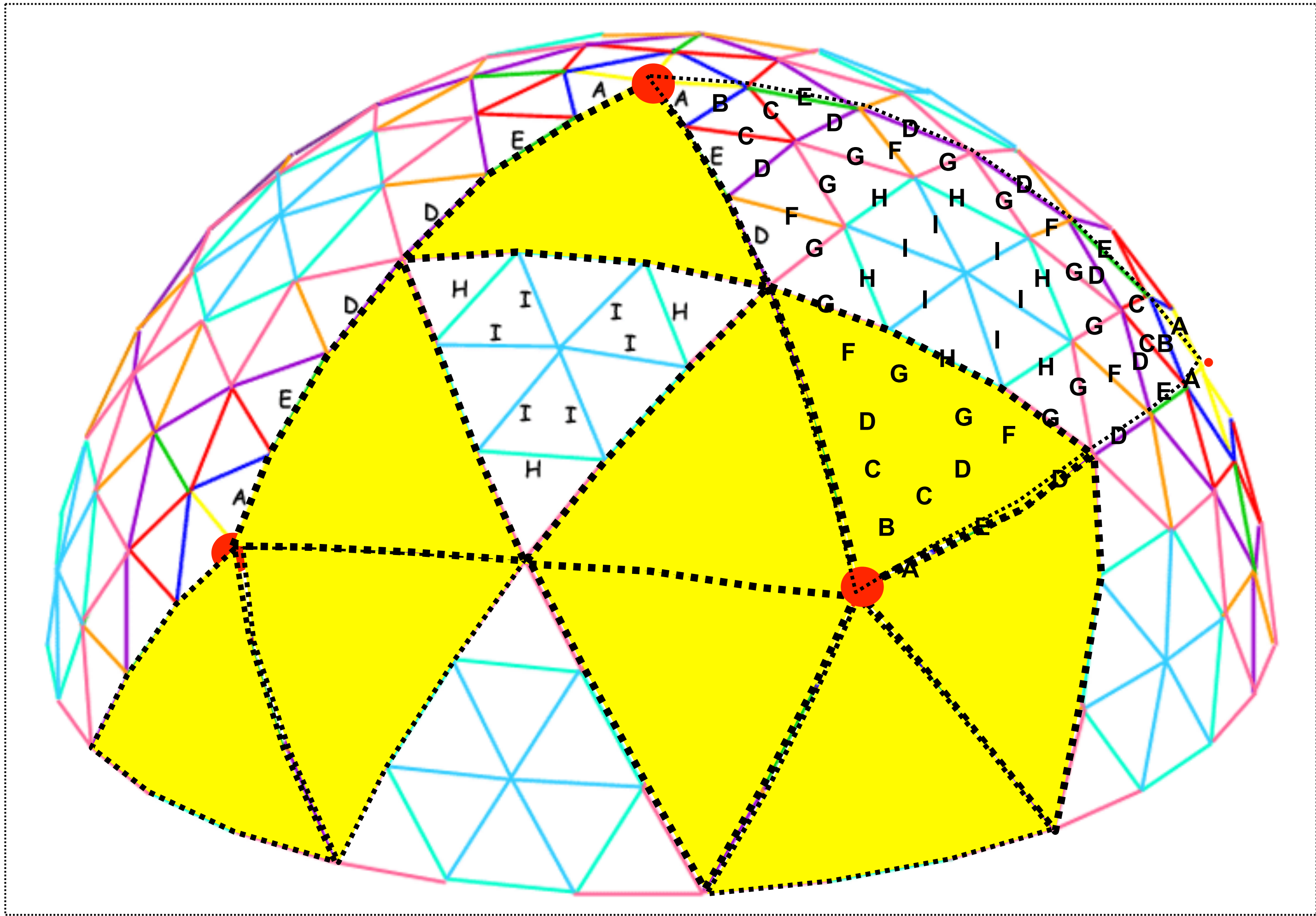



Inside part of the below shaded region have the same connecting structure with that of left curved-line triangle.
A curved-line triangle


Inside part of the below shaded region have the same connecting structure with that of left curved-line triangle.
A curved-line triangle


Congruent triangular part
of curved-line triangle

These all yellow-shaded regions (curved-line triangles) are congruent to each other by adequate t ransformation (flip, or 72 degree rotation).



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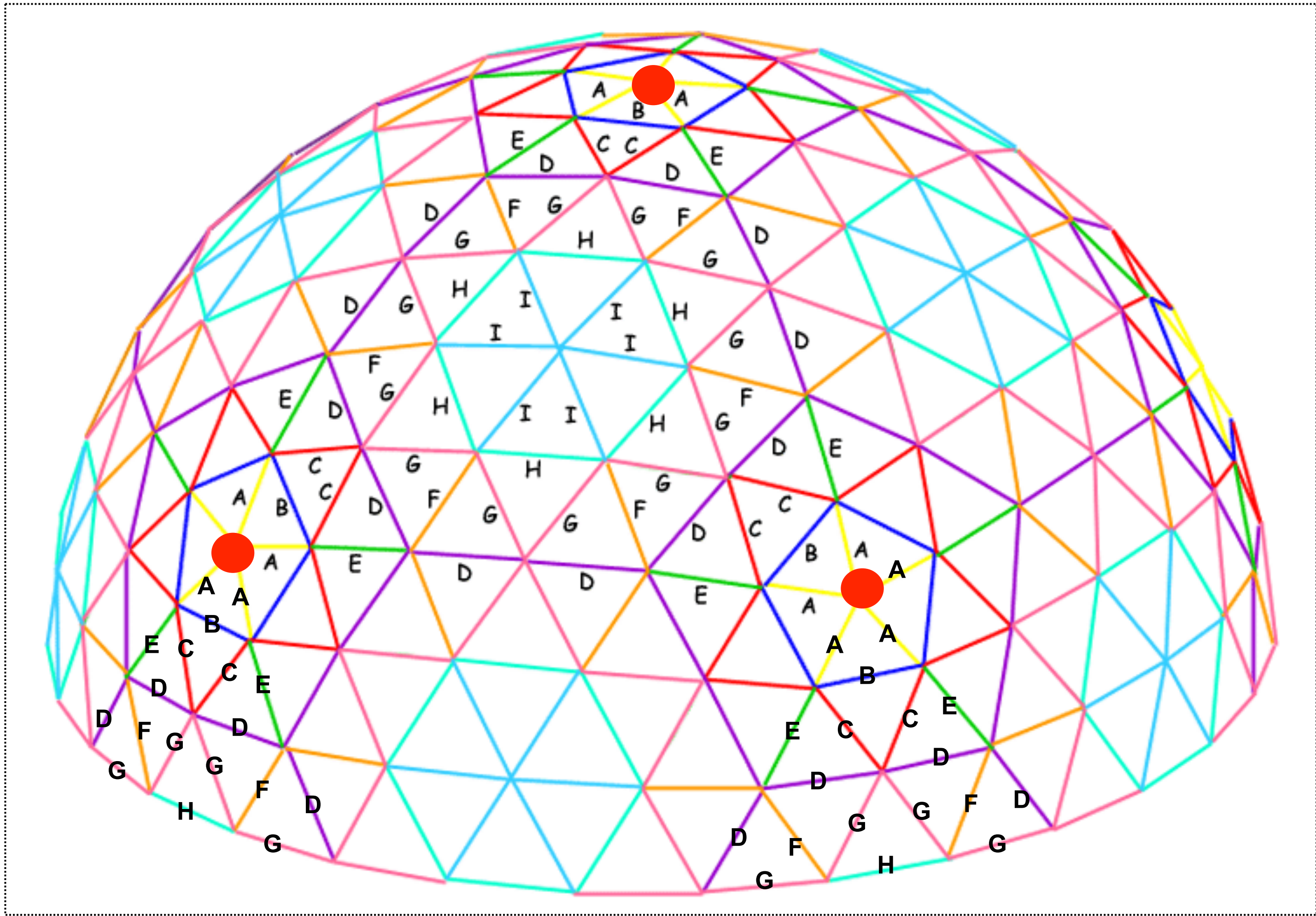
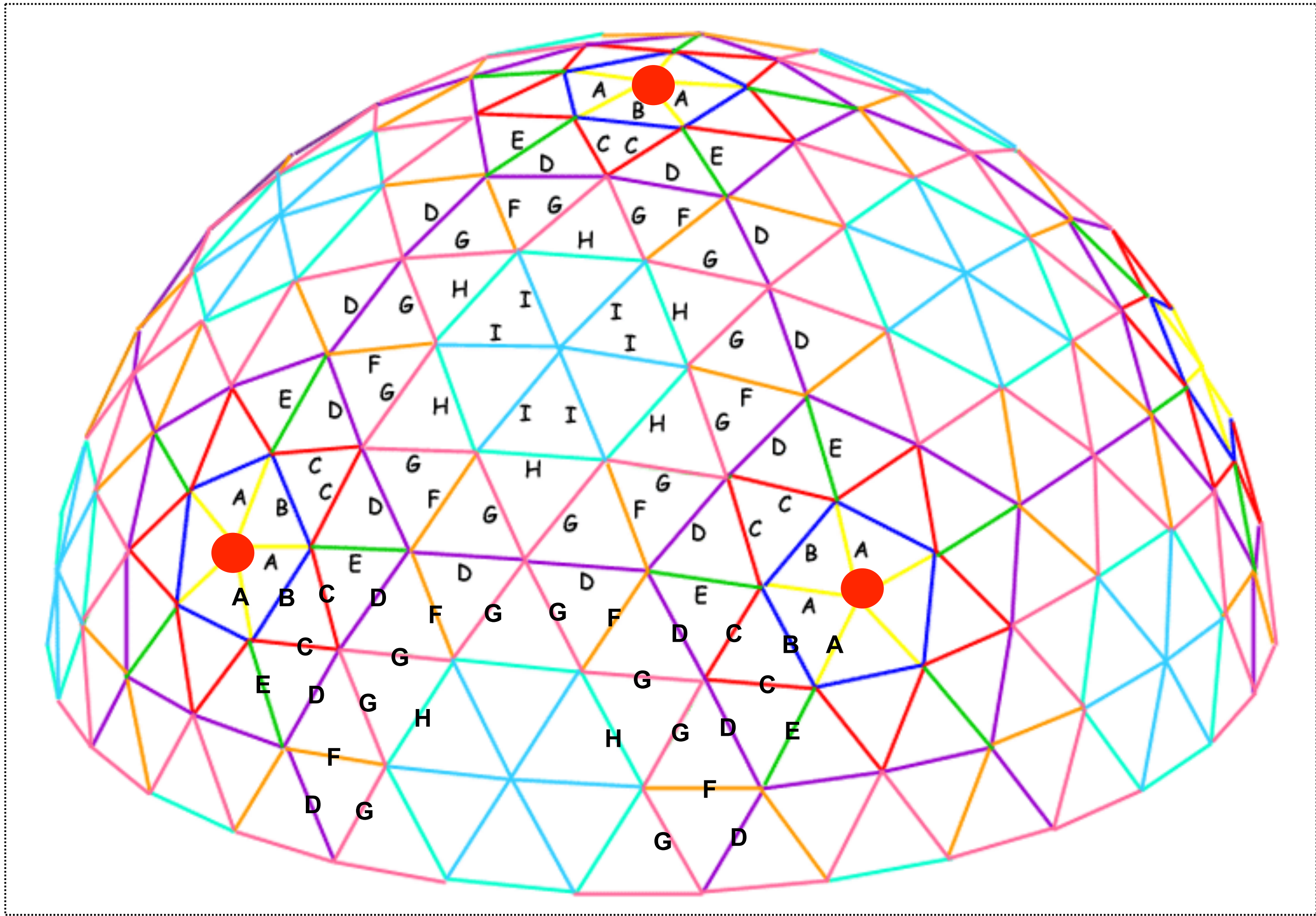
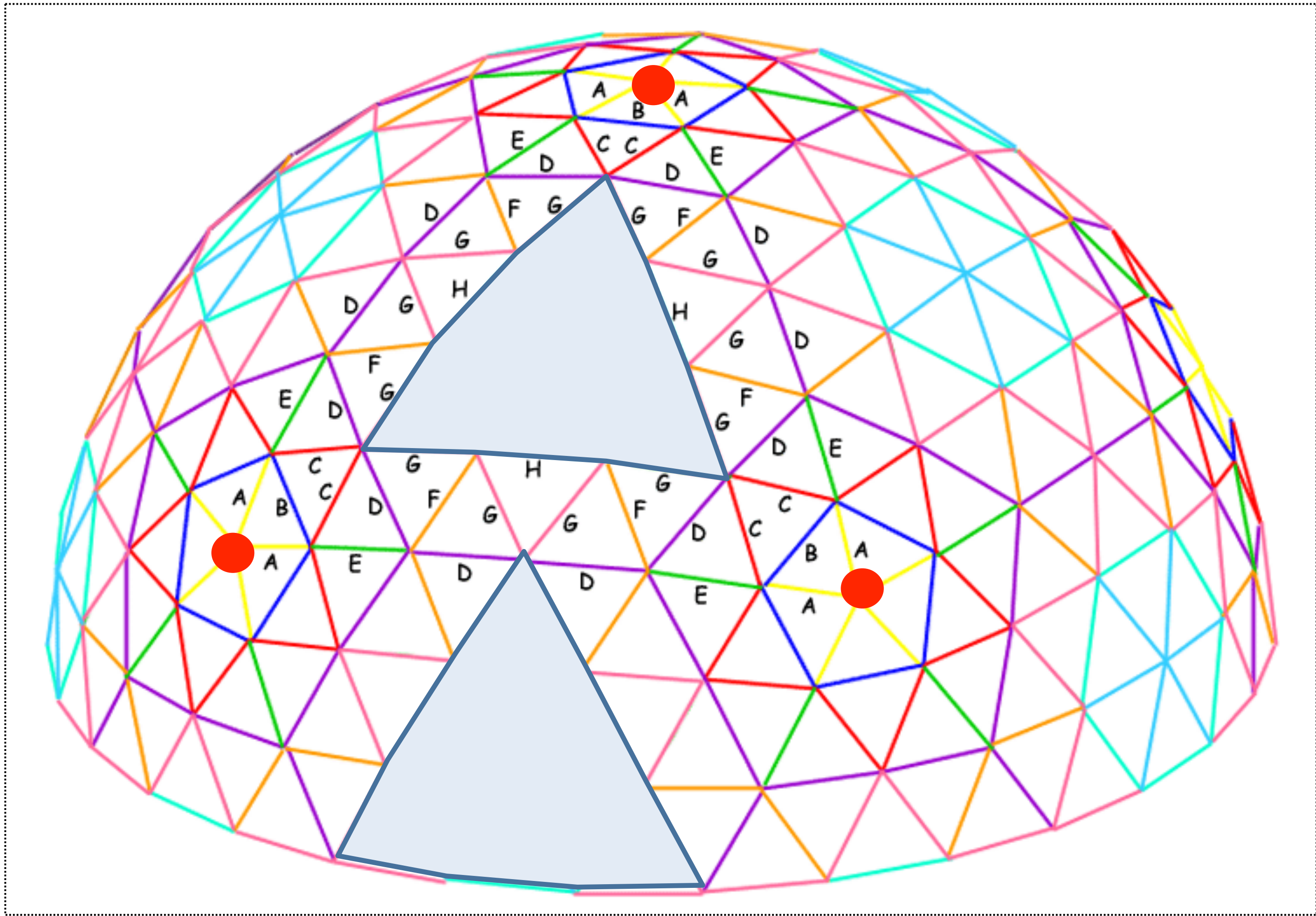


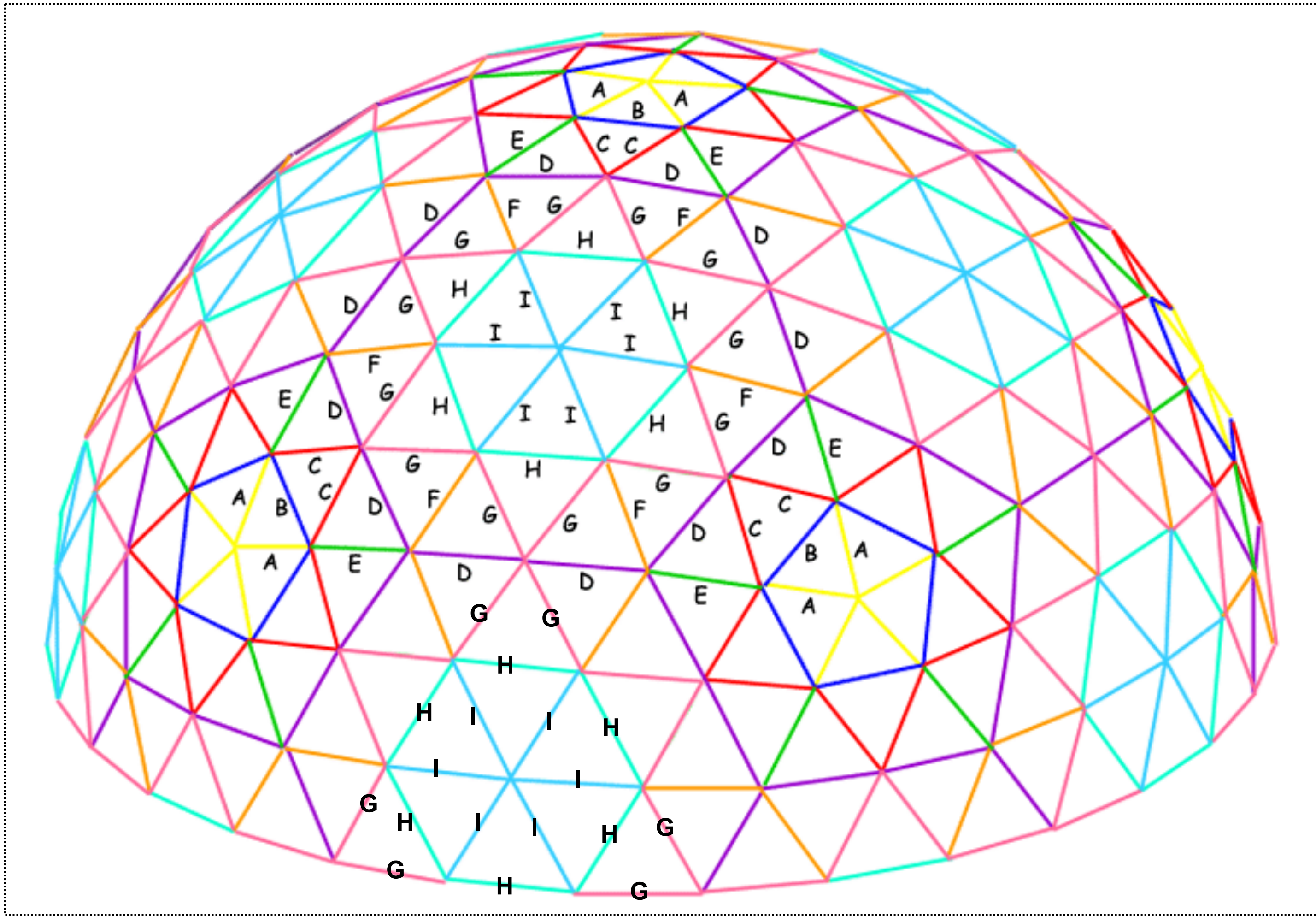
These all yellow-shaded regions (curved-line triangles) are congruent to each other by adequate t ransformation (flip, or 72 degree rotation).



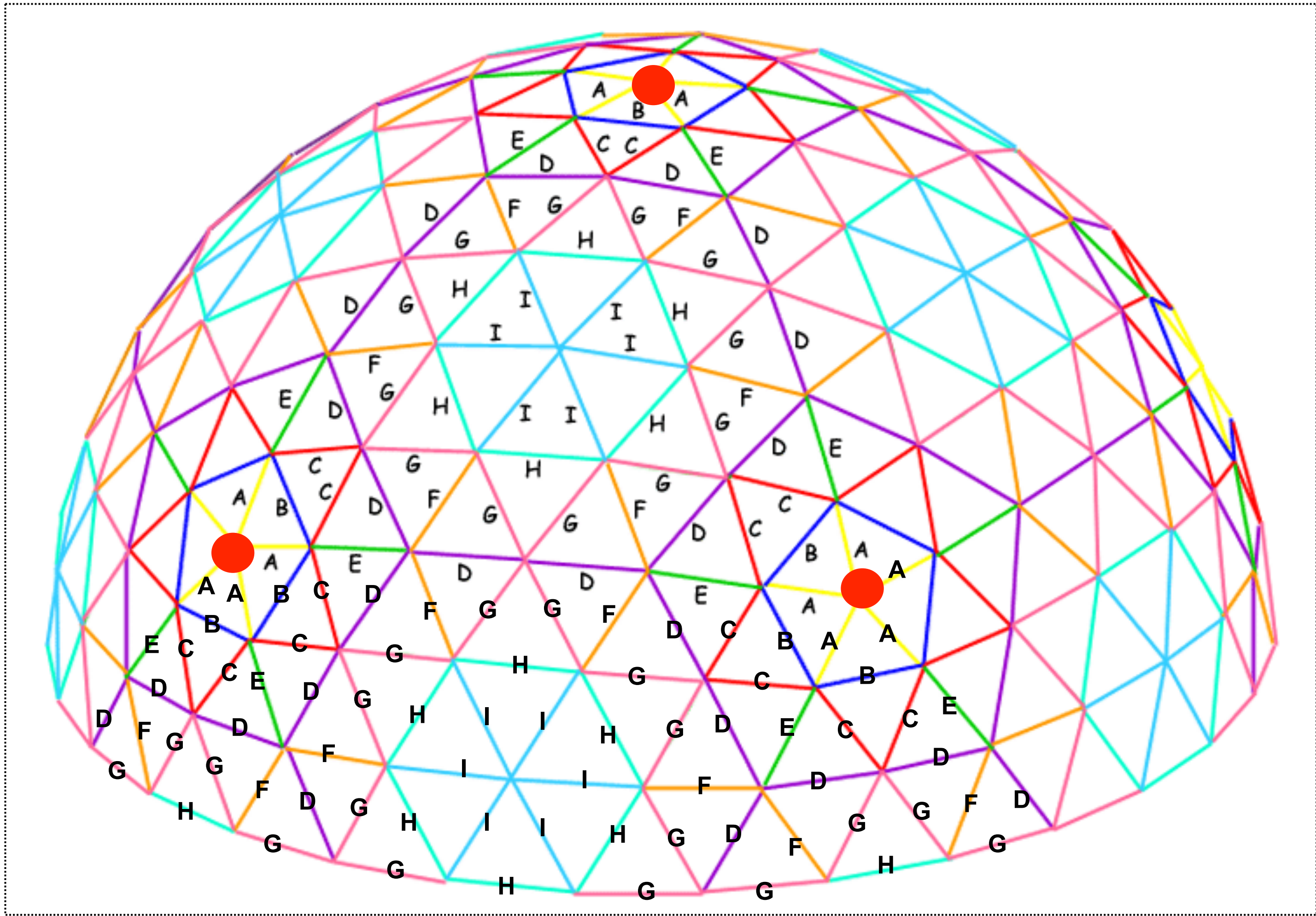
These two blue-shaded regions (curved-line triangles) are congruent to each other by adequate transformation



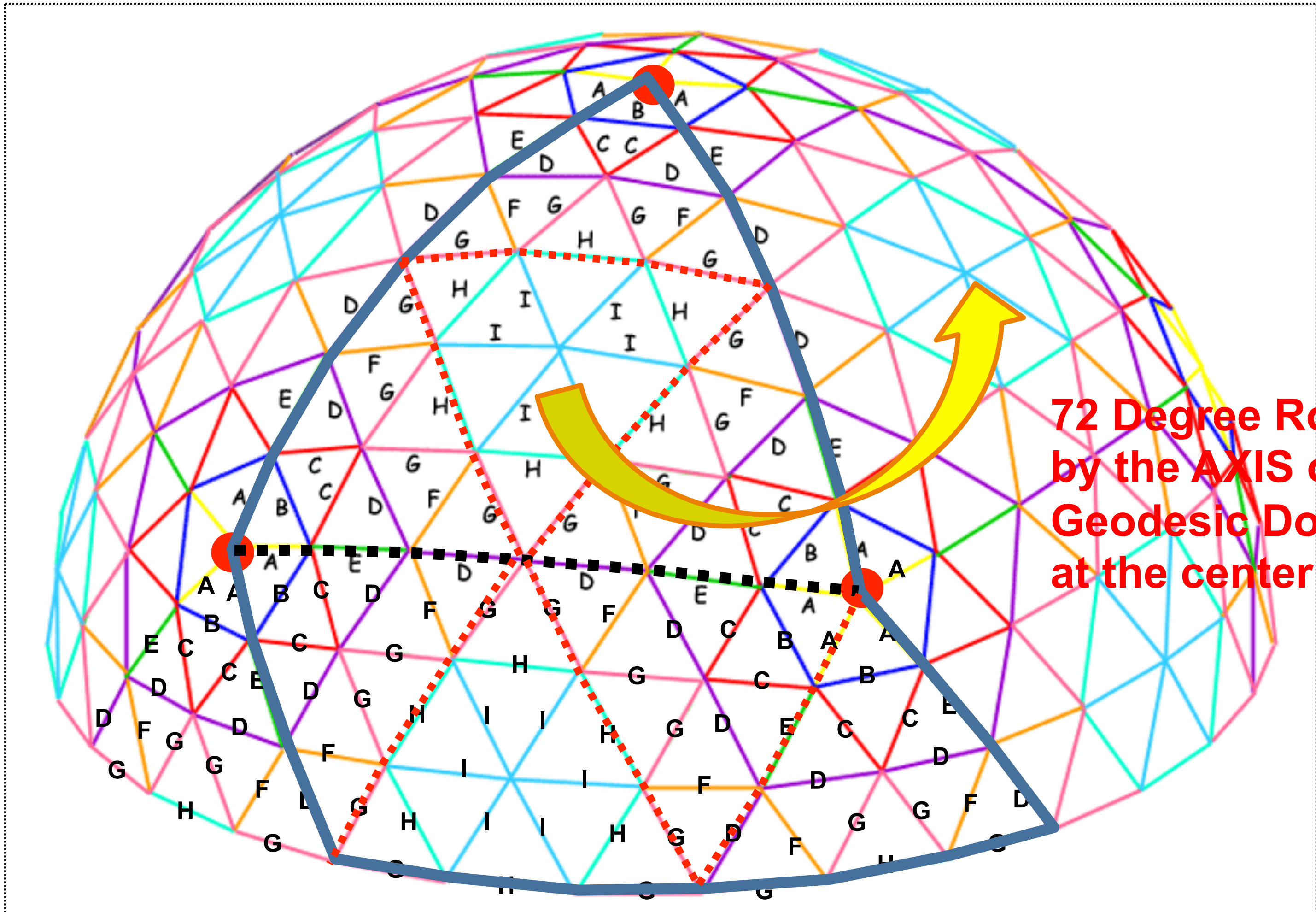
These two blue-shaded regions (curved-line triangles) are congruent to each other by adequate transformation



ONE OF THE 5 congruent parts of Geodesic Dome



CONCLUSION



72 Degree Rotation by the AXIS of Geodesic Dome at the center of Top Pentagon

Material Setting

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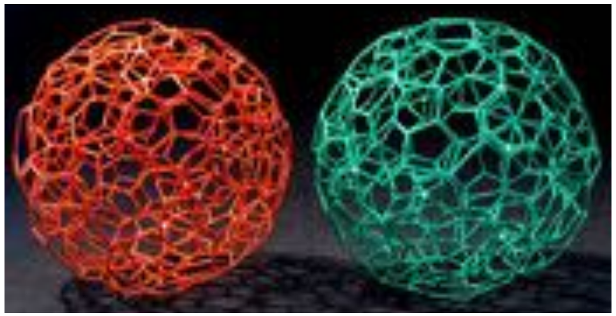
Introduction of 4D Frame

For Free Imagination and Infinite creativity



4D Land Corporation / 4D Math and Science Creativity Institute, KOREA

SEOUL 2014

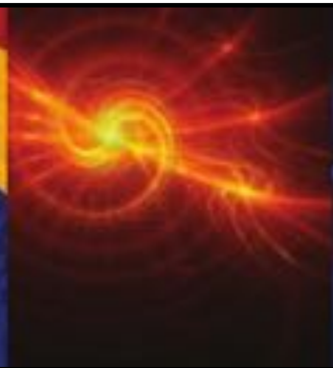
BRIDGES

August 16

SEOUL 2014 BRIDGES

August 16

SEOUL 2014 BRIDGES August 16

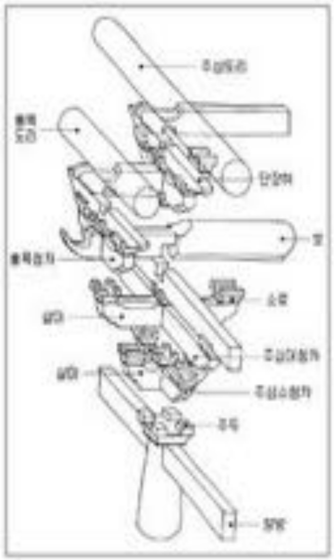


SEOUL 2014
BRIDGES
August 16

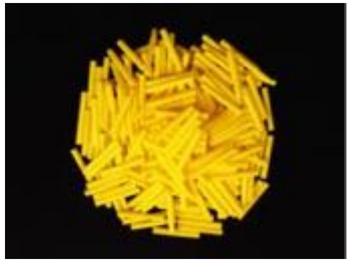
The Brand : 4D Frame

- ❖ Motivation: from traditional Korean wooden architecture style
  which is not using any nails
- ❖ Effective tool for STEAM learning in 21th century, based on ancient Korean-architecture

Traditional Korean Wooden Palace



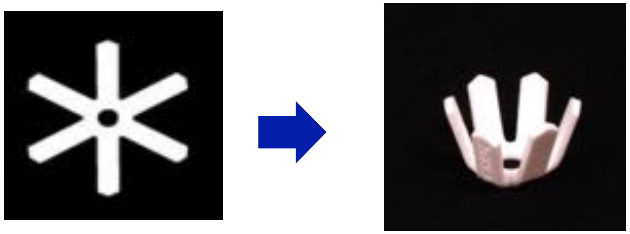
Principle of Architecture

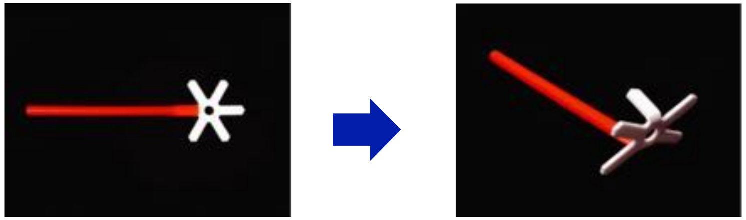


4D Frame Tube

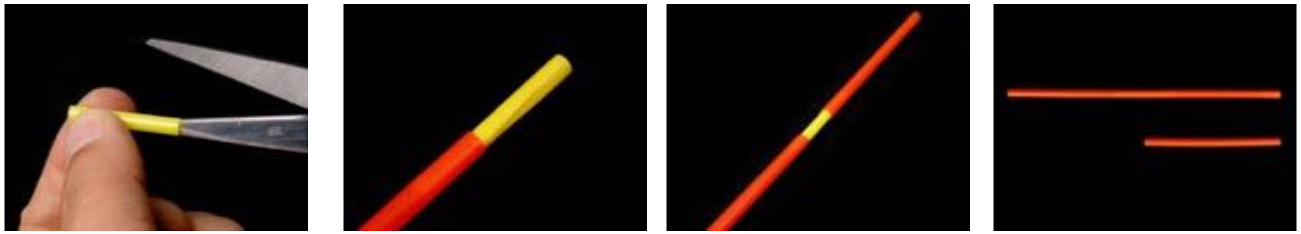
4D Frame Connector

Character : Flexibility





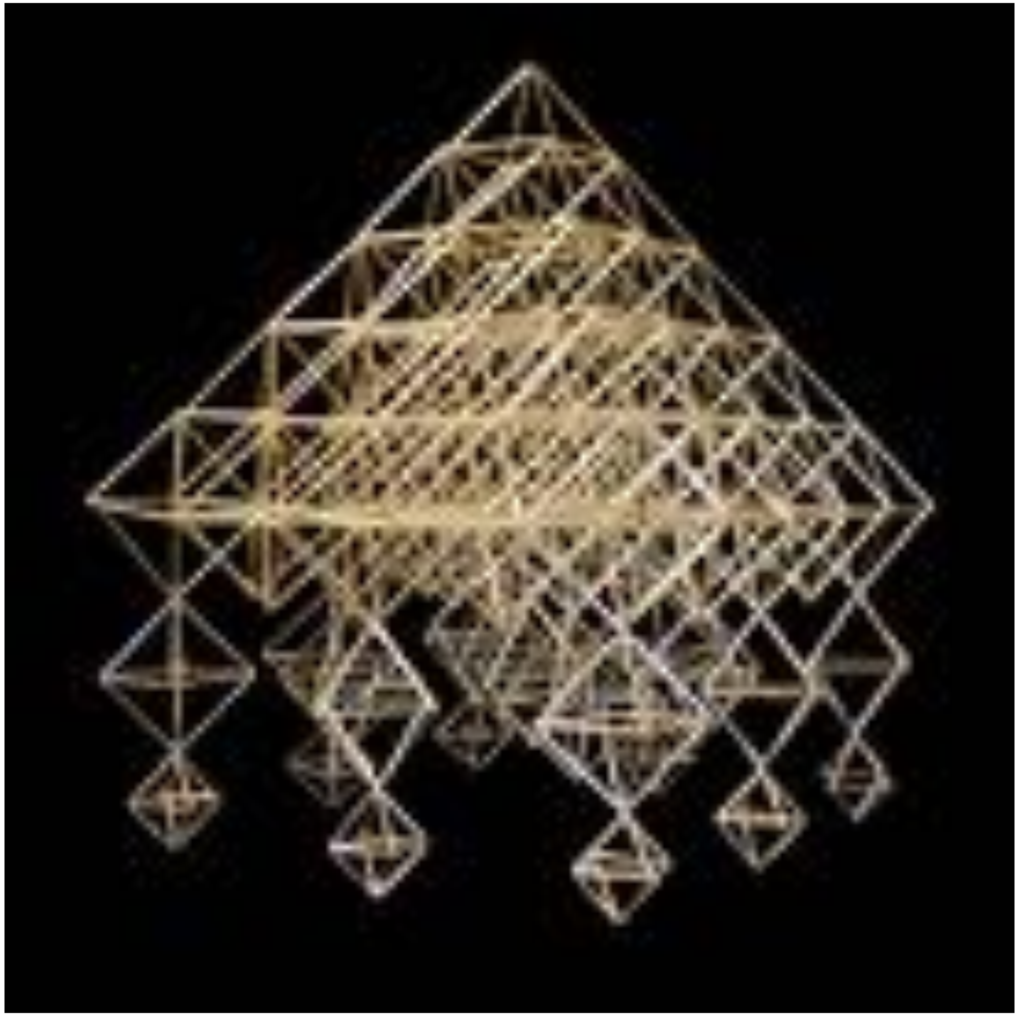
Bending, Cutting, Connecting, Pasting, etc.



Character : Infinite Expansion

4D프레임

Character : Infinite Expansion

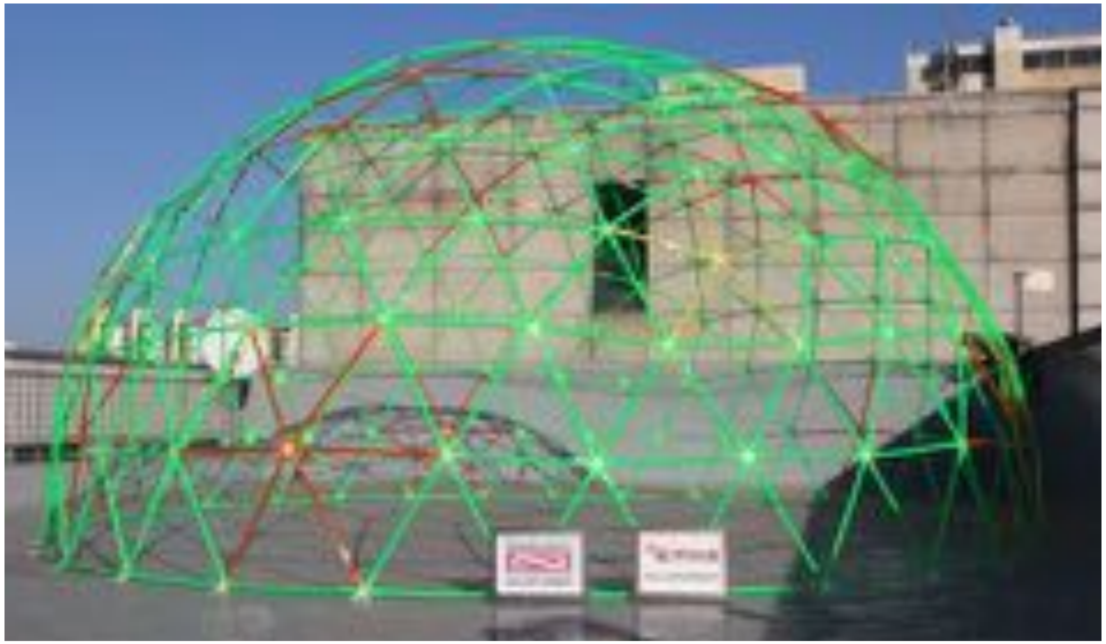


4D프레임

4D프레임

Preparing materials-setting : Cutting each super frames into 9 categorical pieces (from A to I).

Components	Length of each tube		Needed pieces
	before	after	
A	53	42	30
B	60	49	30
C		47	60
D		52	90
E		48	30
F		51	60
G		53	130
H		55	65
I	60	56	60
5-way connectors			12
6-way connectors			380



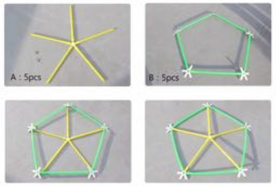
Geodesic Dome building materials for assembling

A : 42cm 30pcs
B : 49cm 30pcs
C : 47cm 60pcs
D : 52cm 90pcs

E : 48cm 30pcs
F : 51cm 60pcs
G : 53cm 130pcs
H : 56cm 60pcs

I : 56cm 60pcs
5-way connectors : 12pcs
6-way connectors : 380pcs

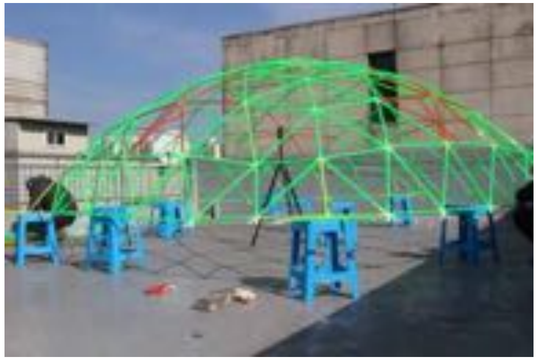
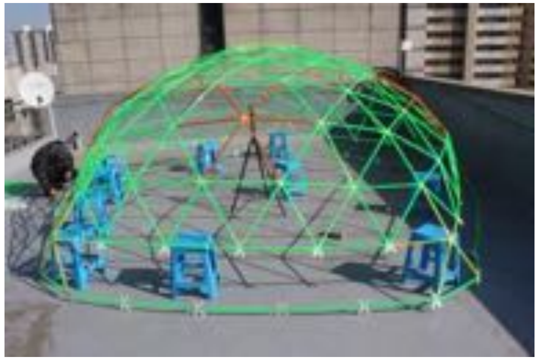
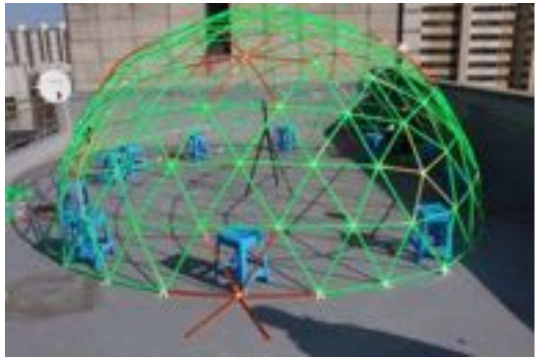
Constructing Geodesic Dome





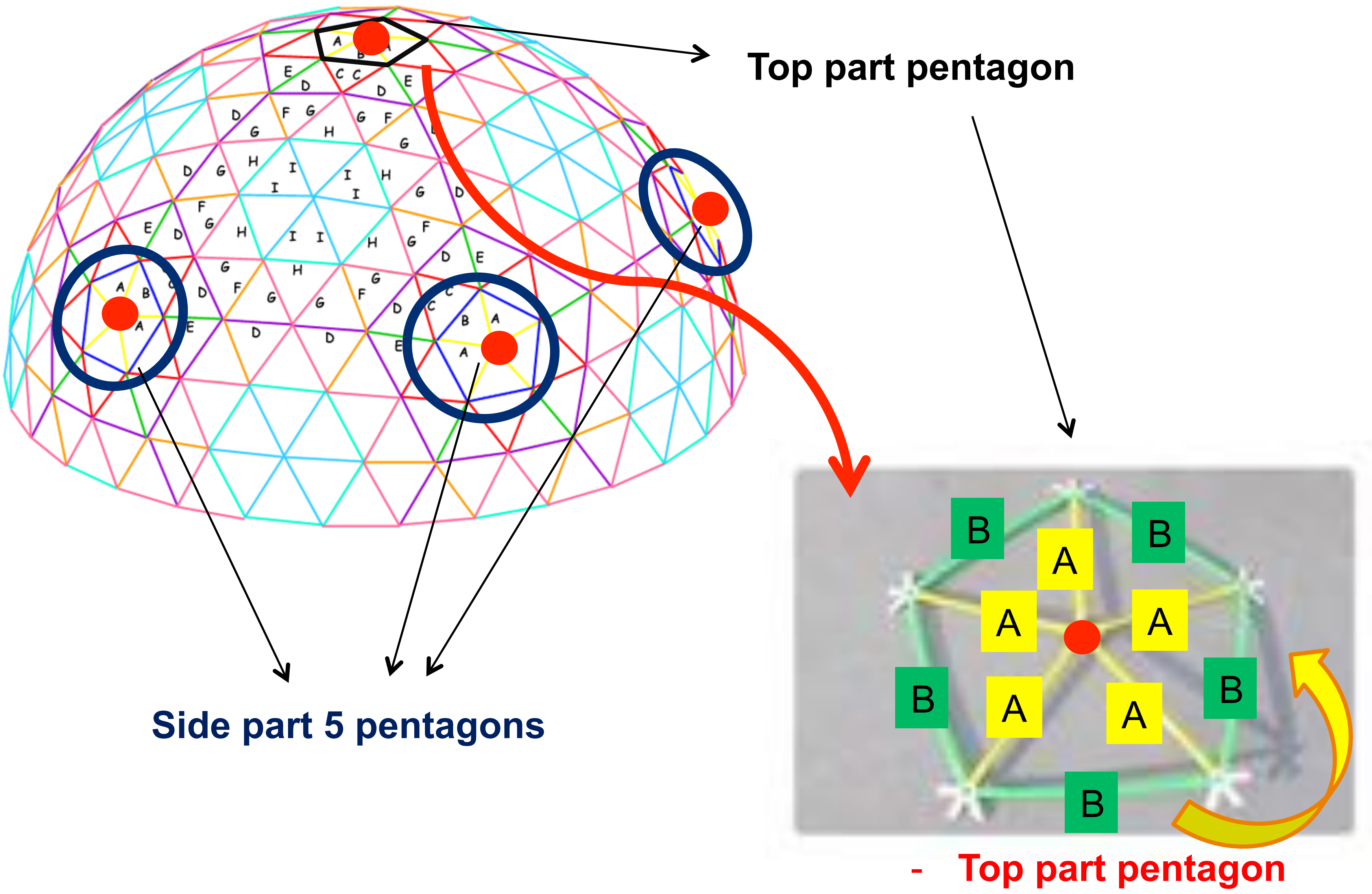




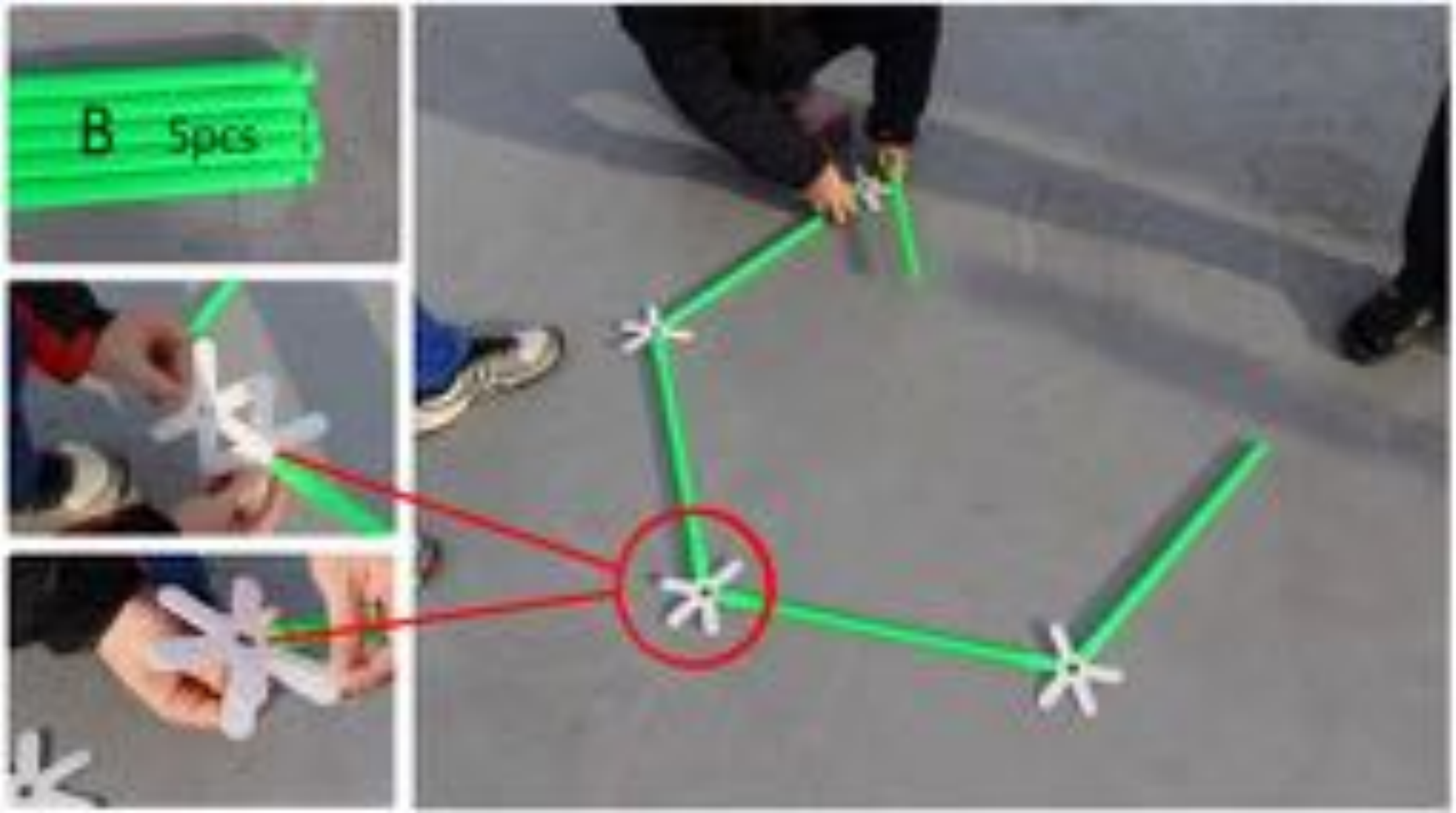




TOTAL CONSTRUCTION PROCESS OF GEODESIC DOME

Top part Pentagon

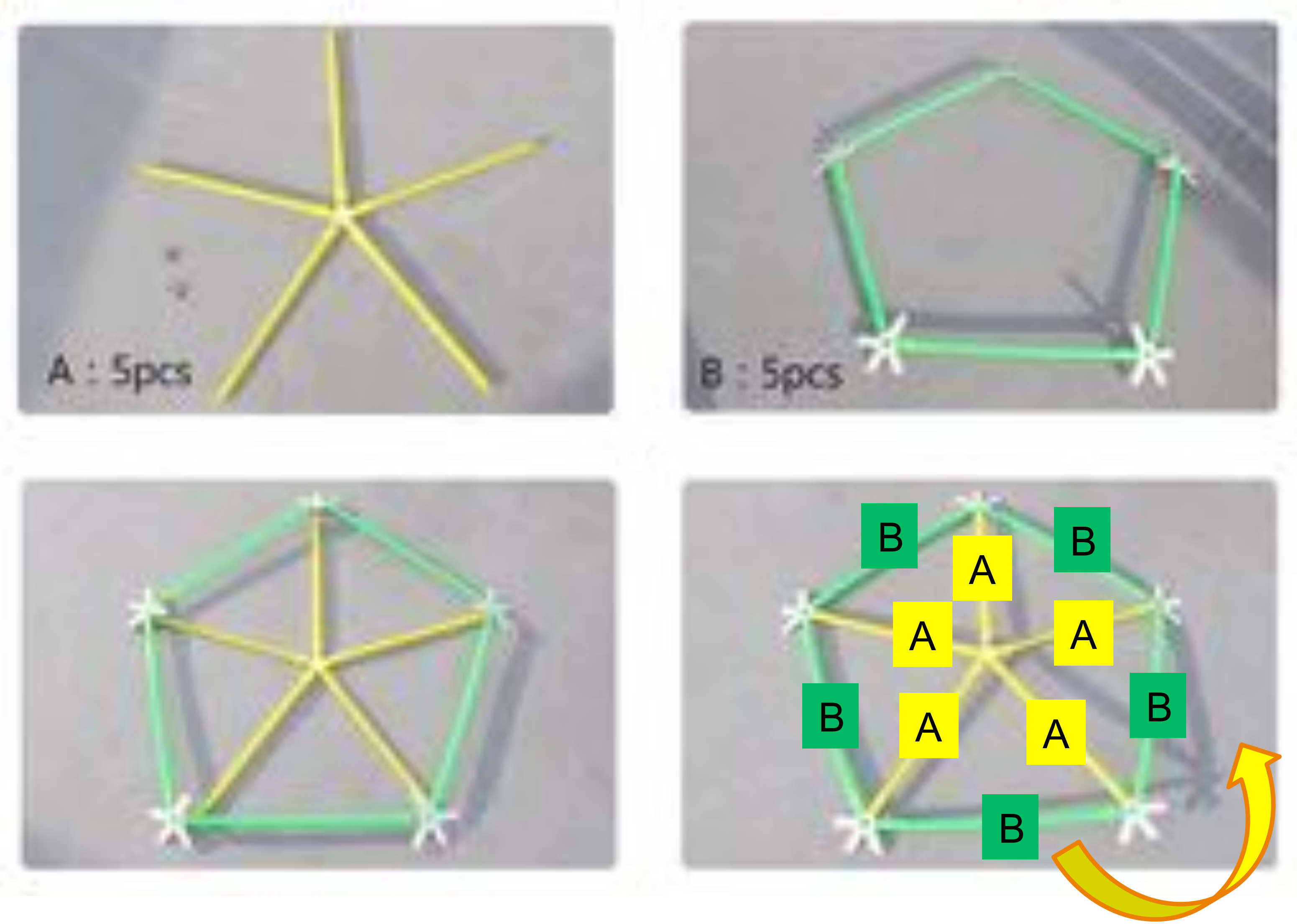


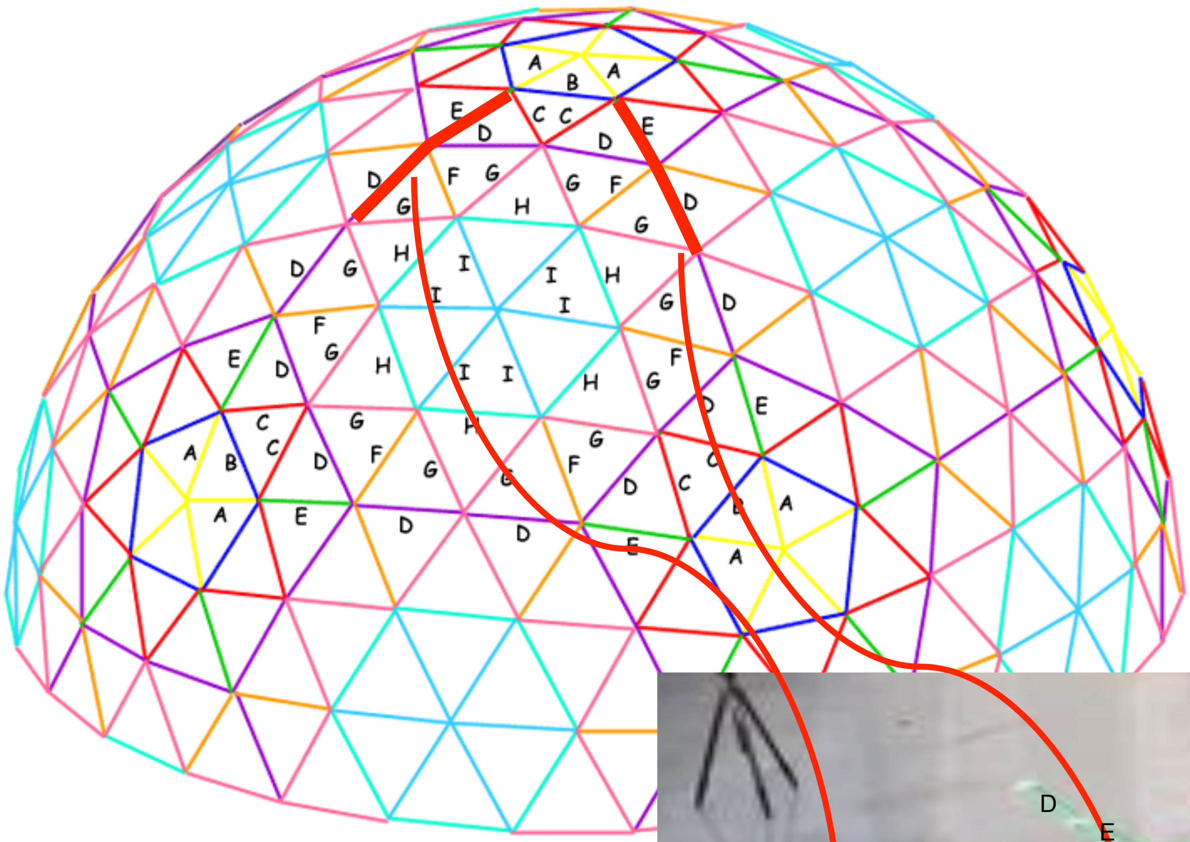
Top part pentagon

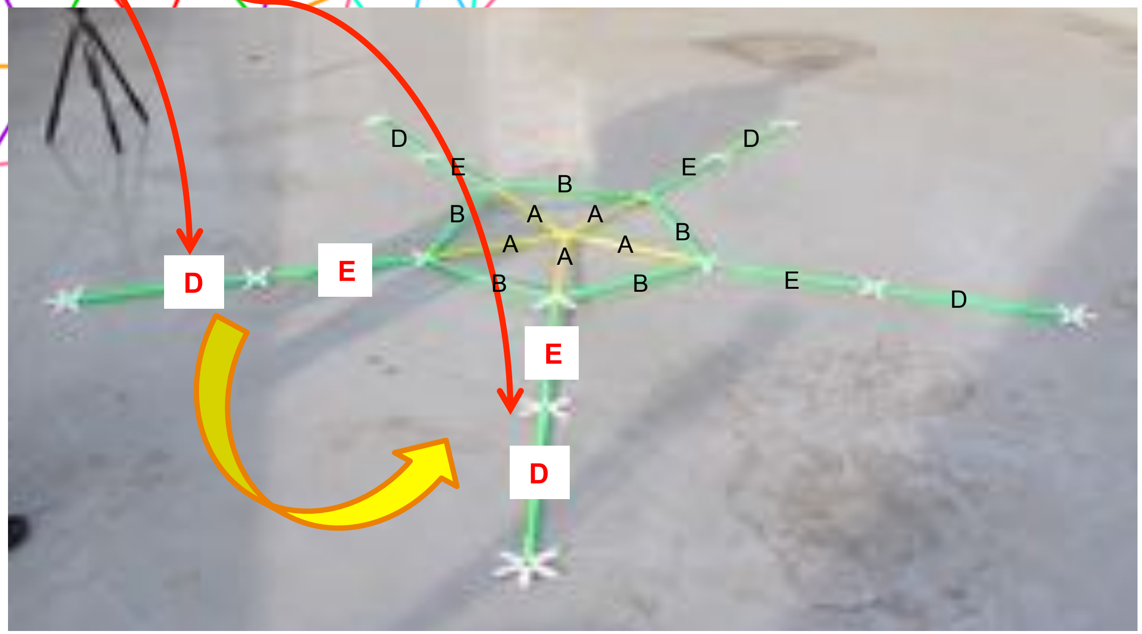


Taping method at each vertex

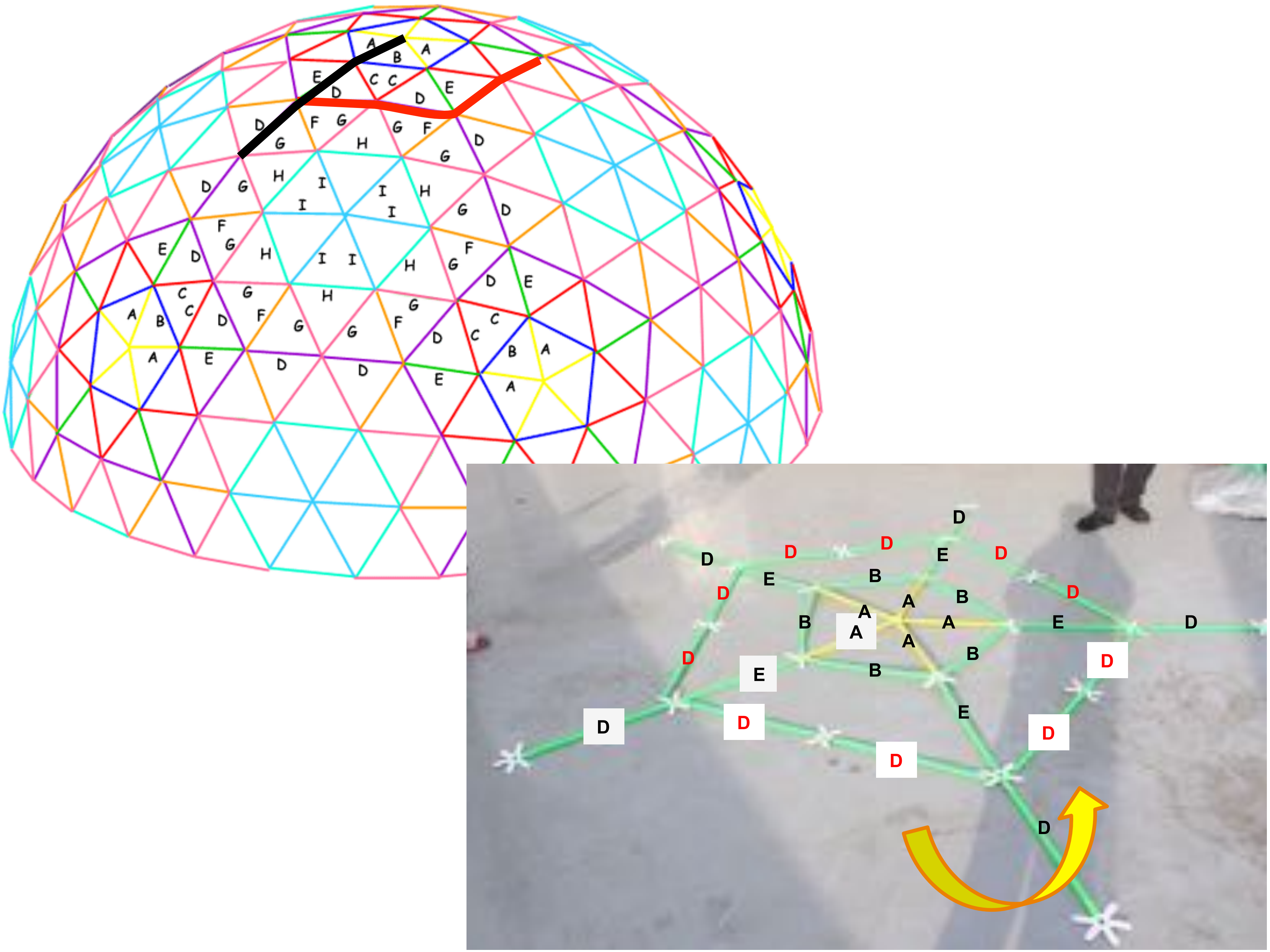
Process of connecting



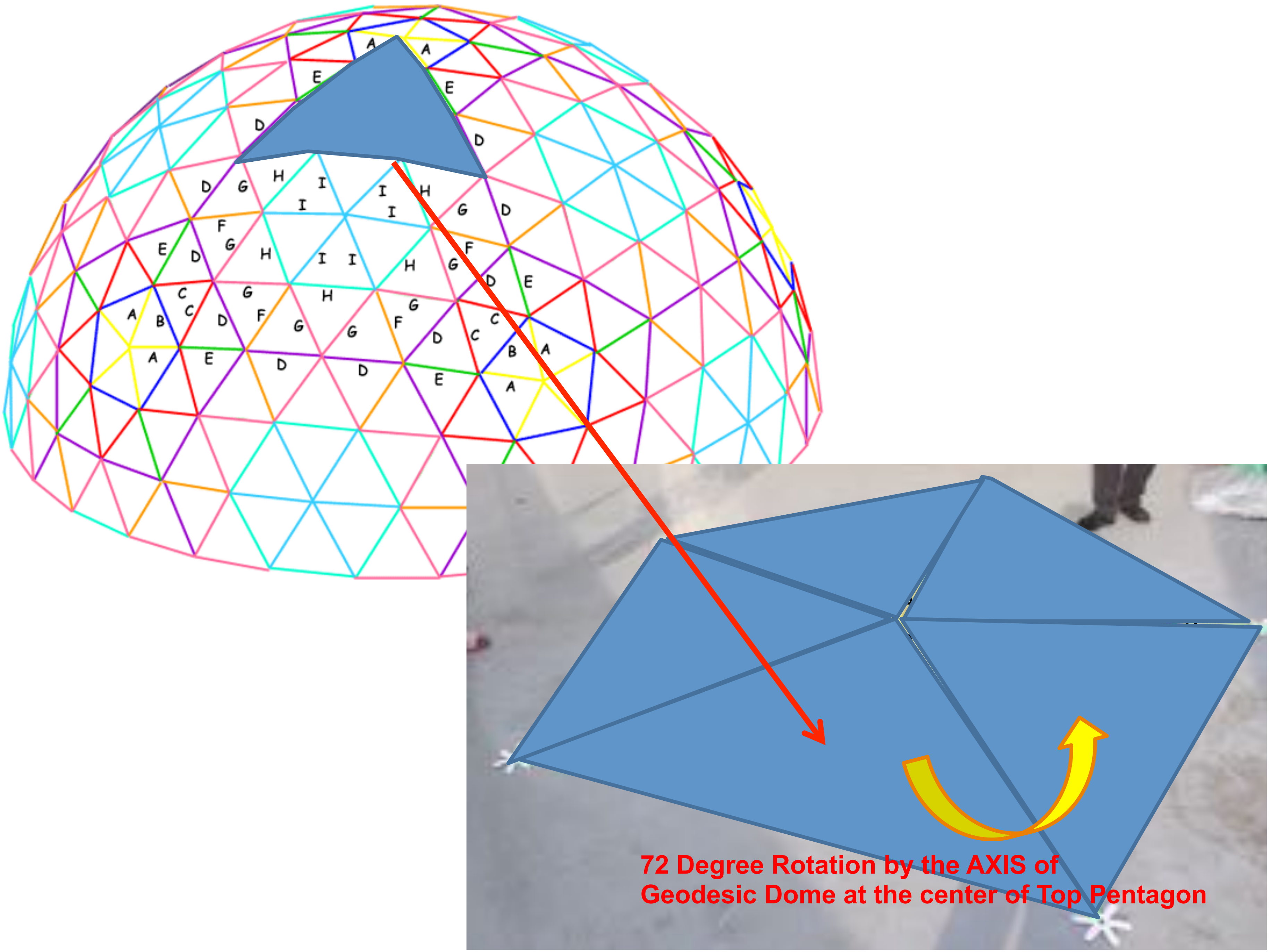


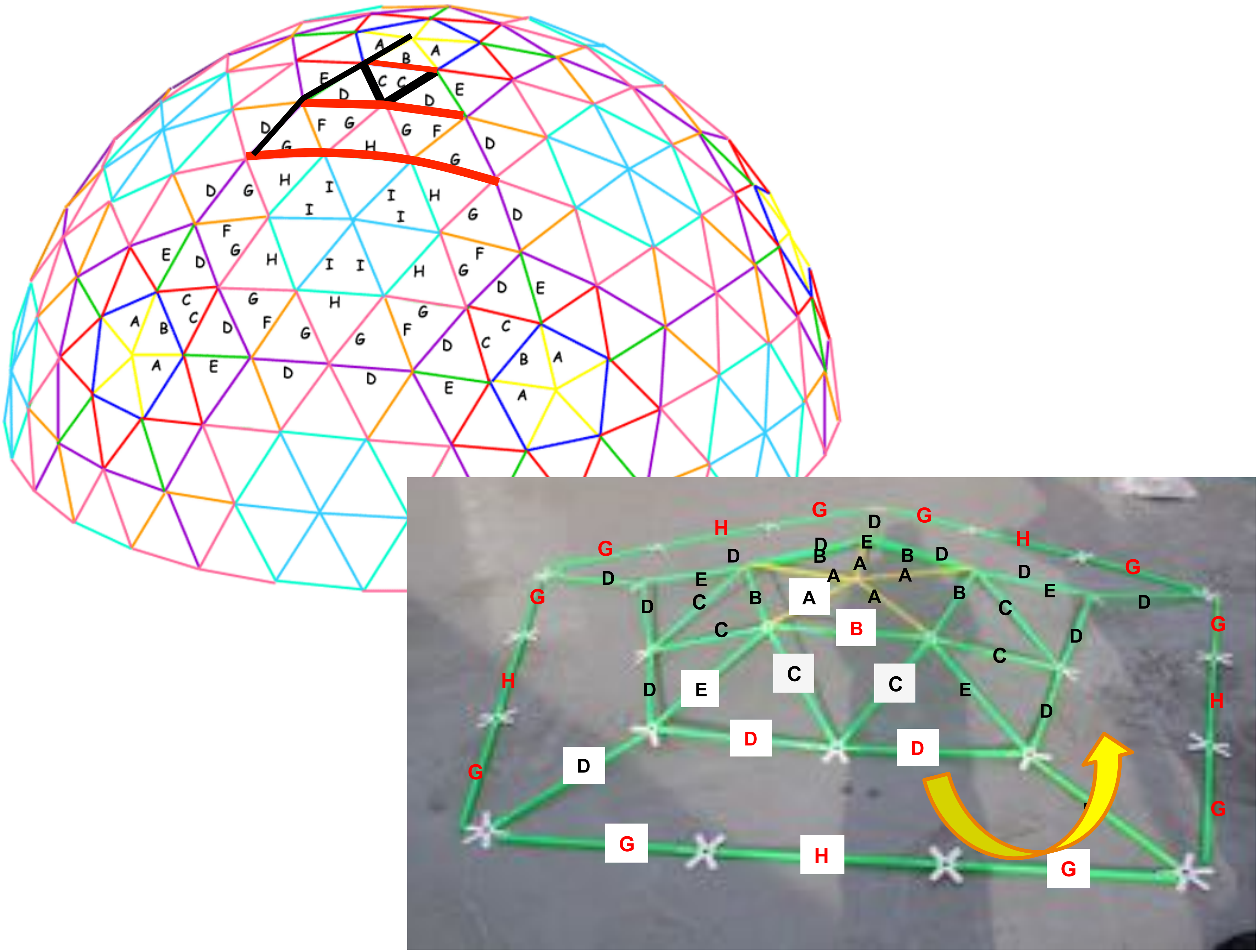


Each side parts have the 5 symmetric shapes
congruent to the letter-wise symbolized
figure part on the above figure.
It means that if you understand
the connecting structure on the forepart,
then the remaining part for connecting
can be done similarly.

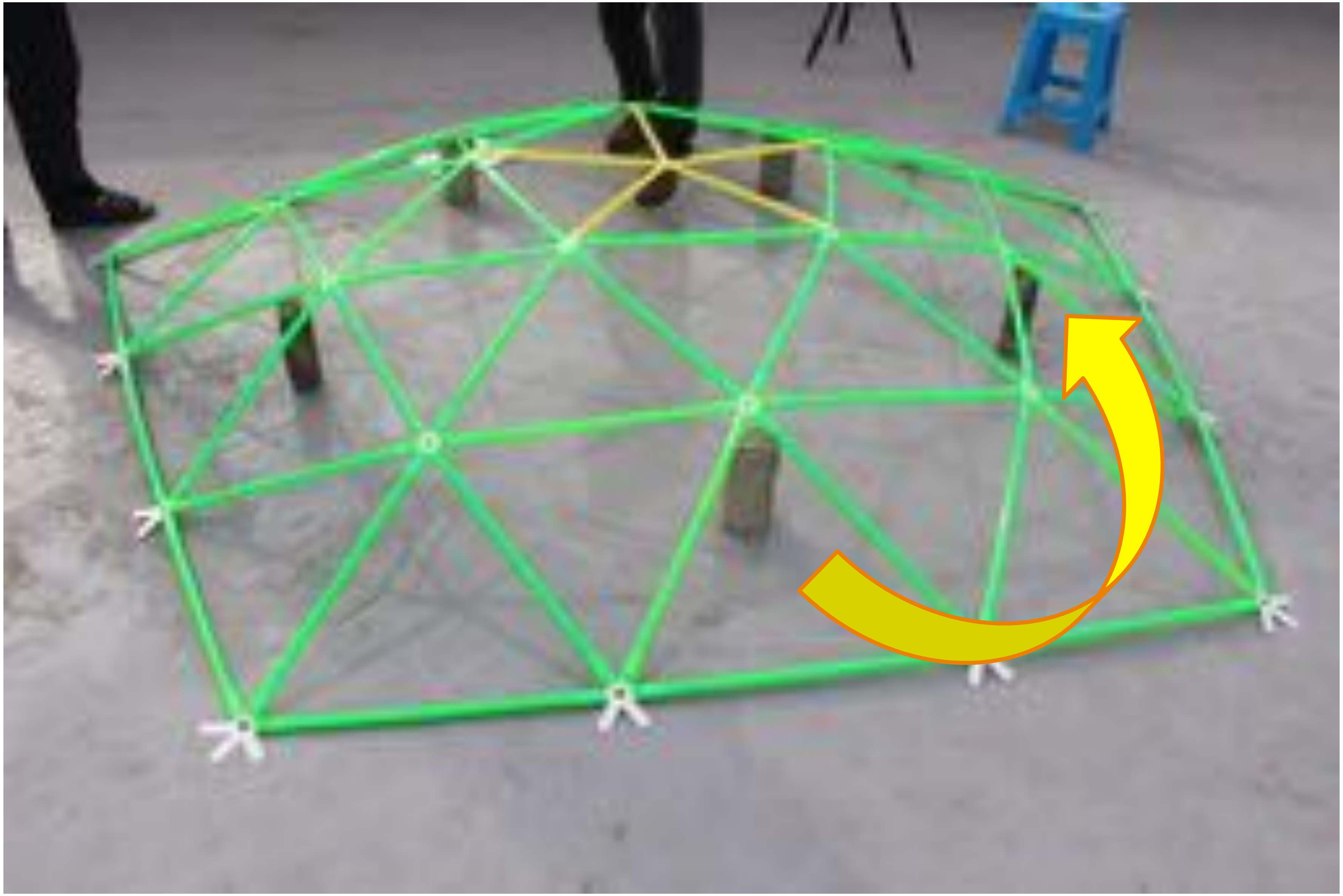


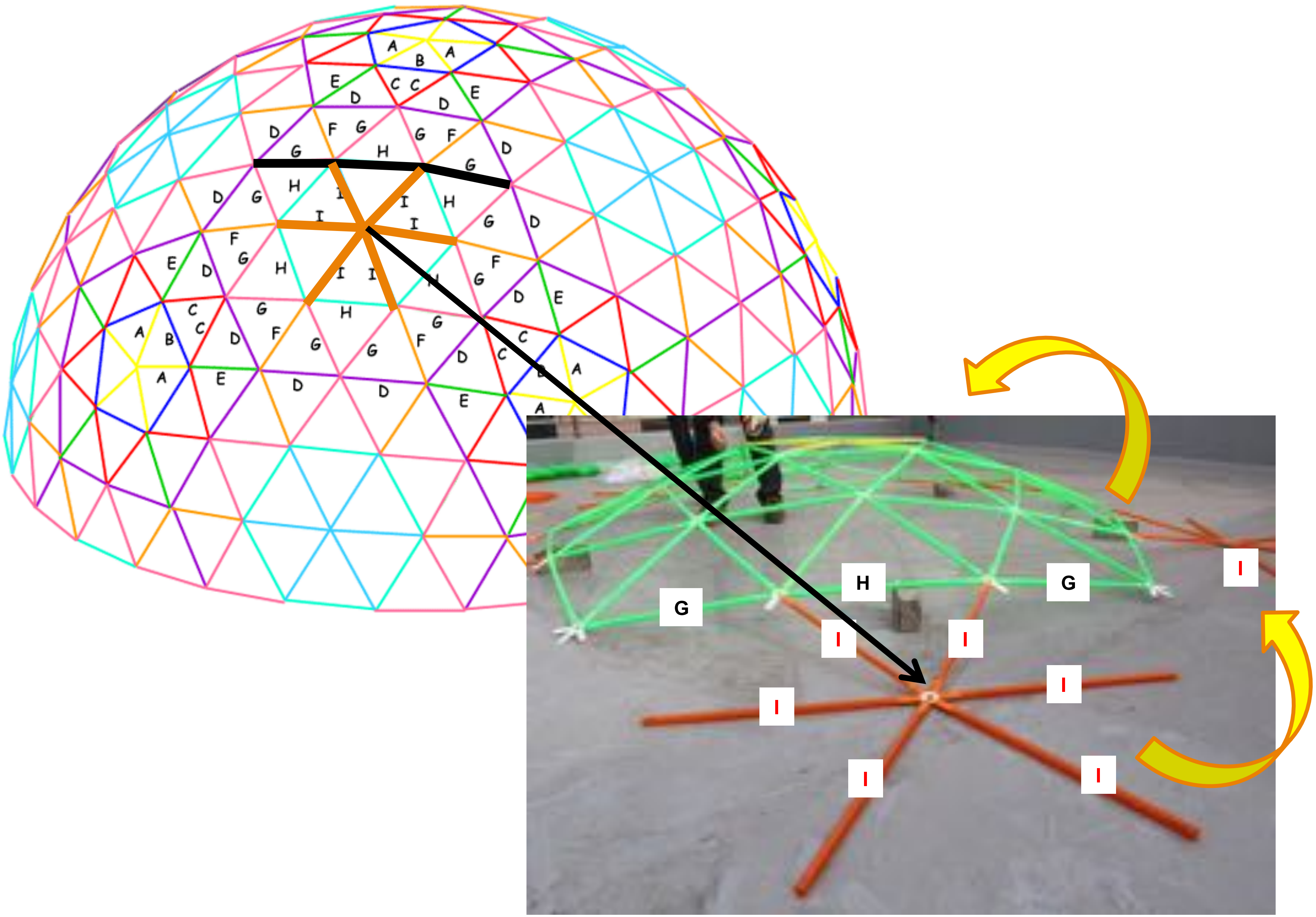
A
E
D
D
D
D
D

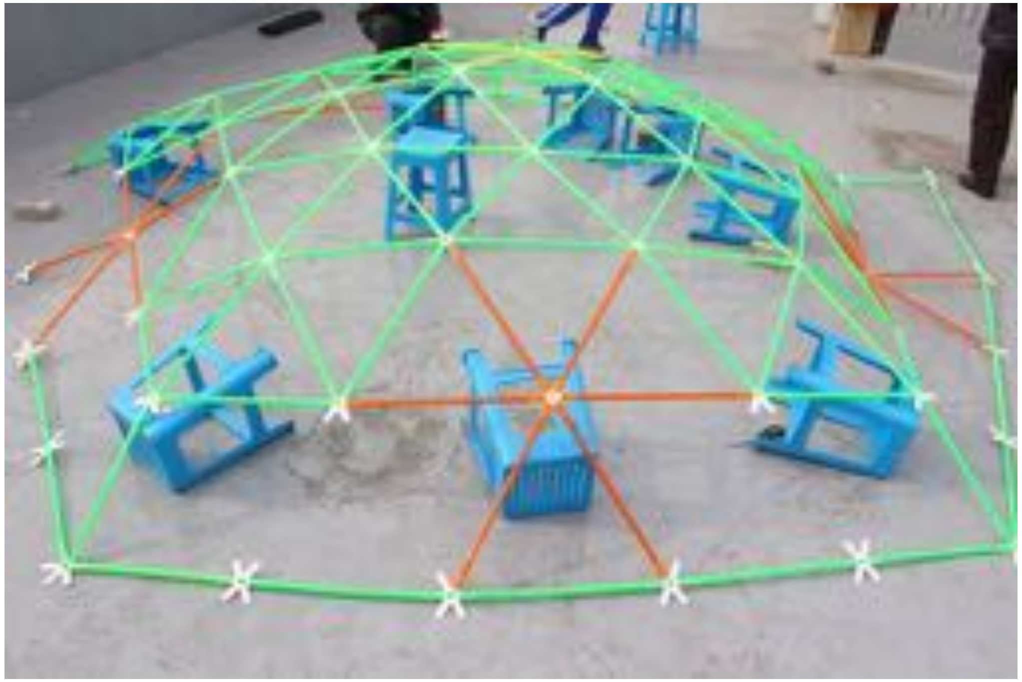

72 Degree Rotation by the AXIS of
Geodesic Dome at the center of Top Pentagon

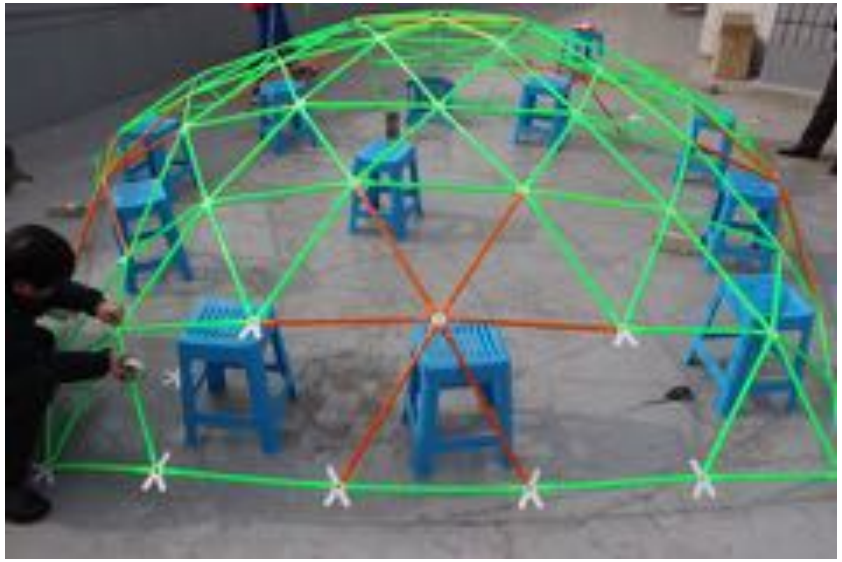


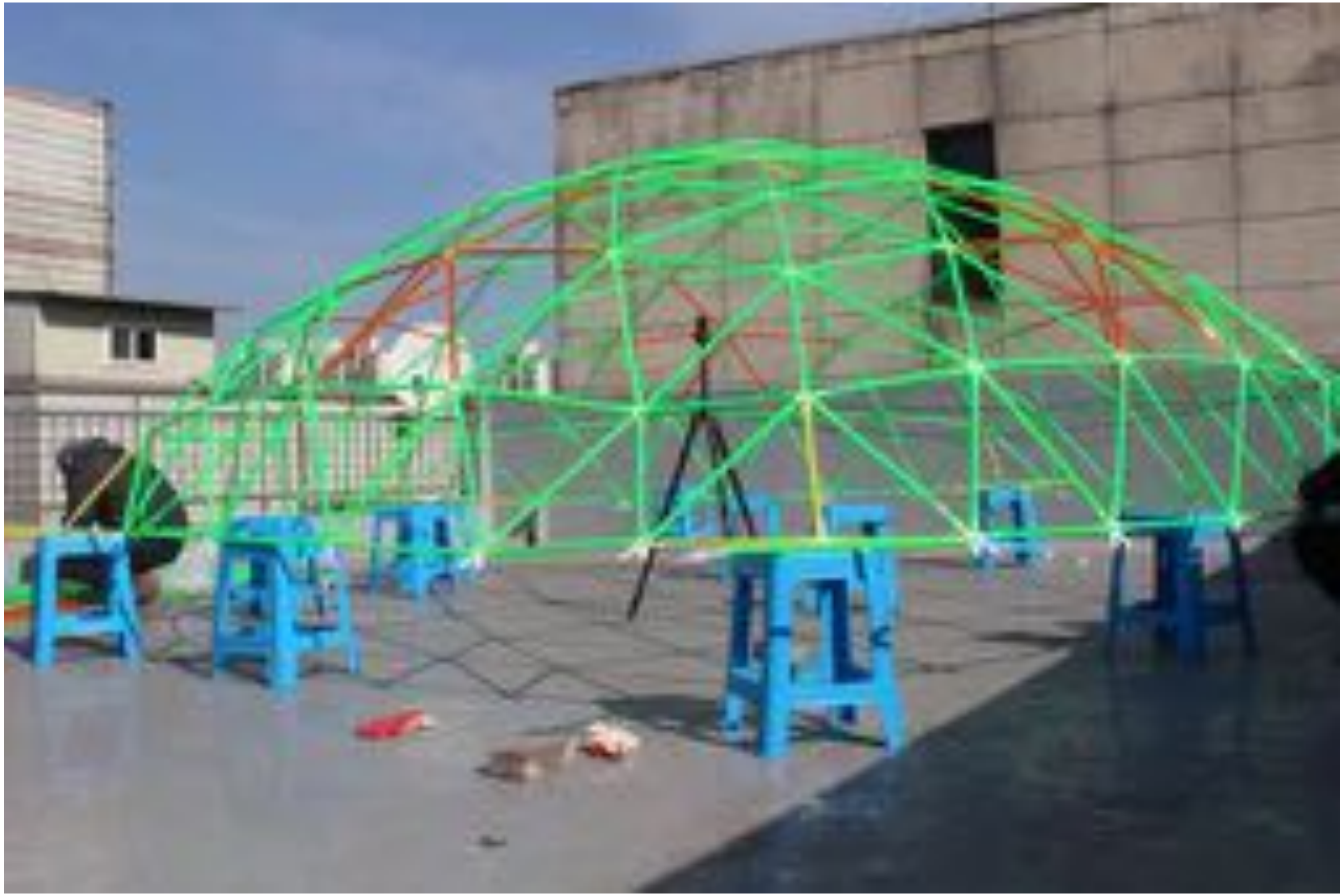
A
B
C
C
E
D
D
D
G
H
G

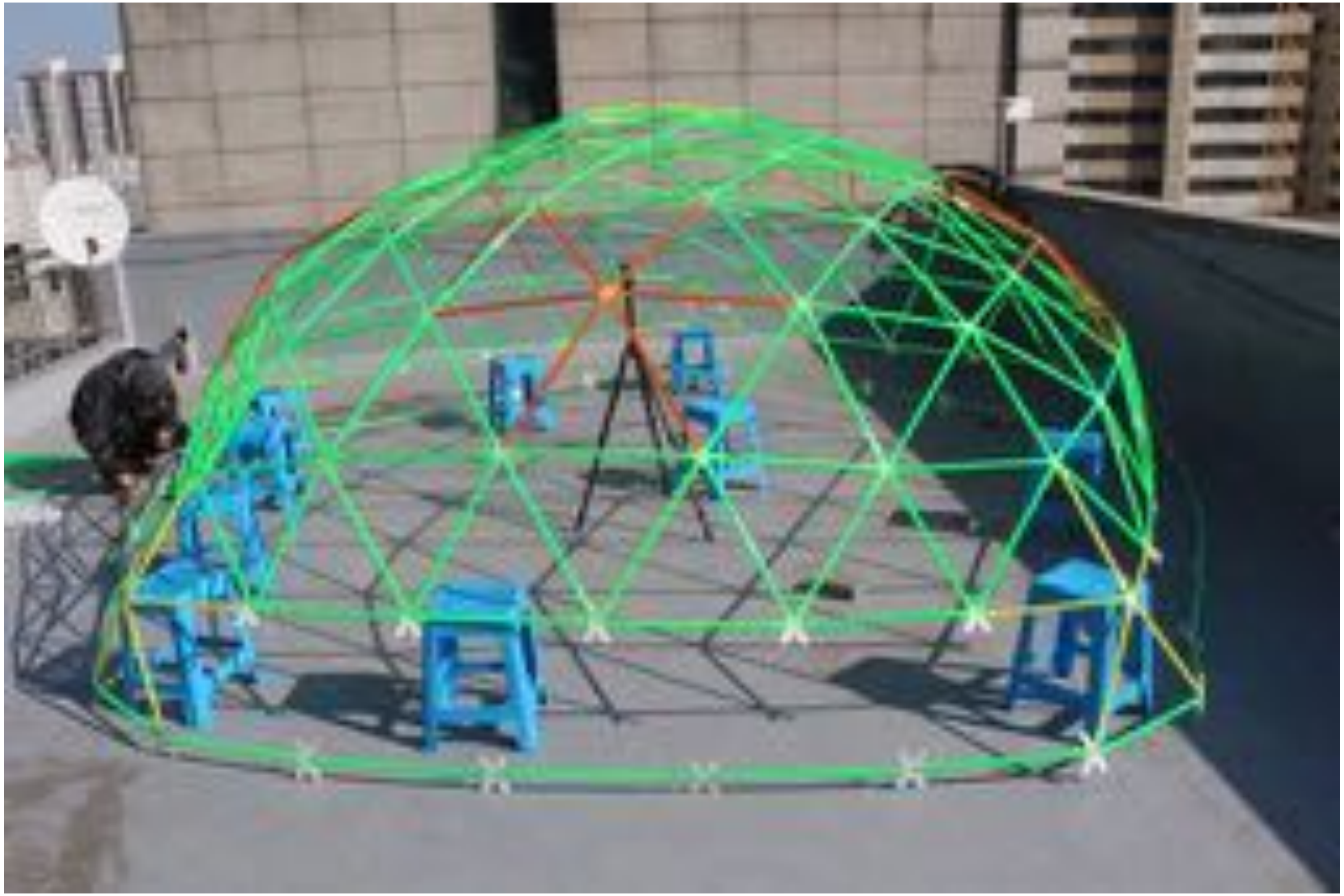


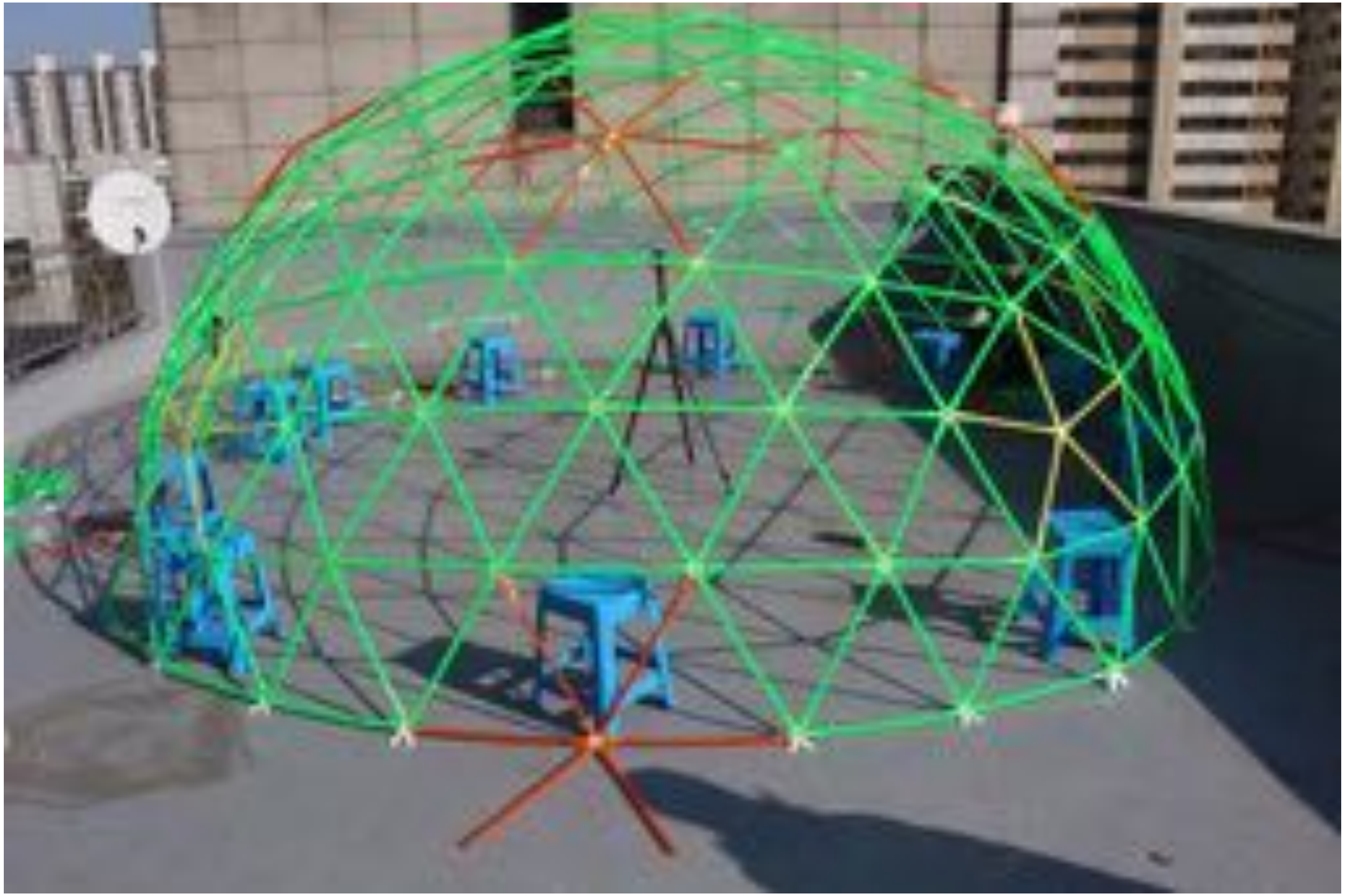

G
H
G
I
I
I
I
I
I
I

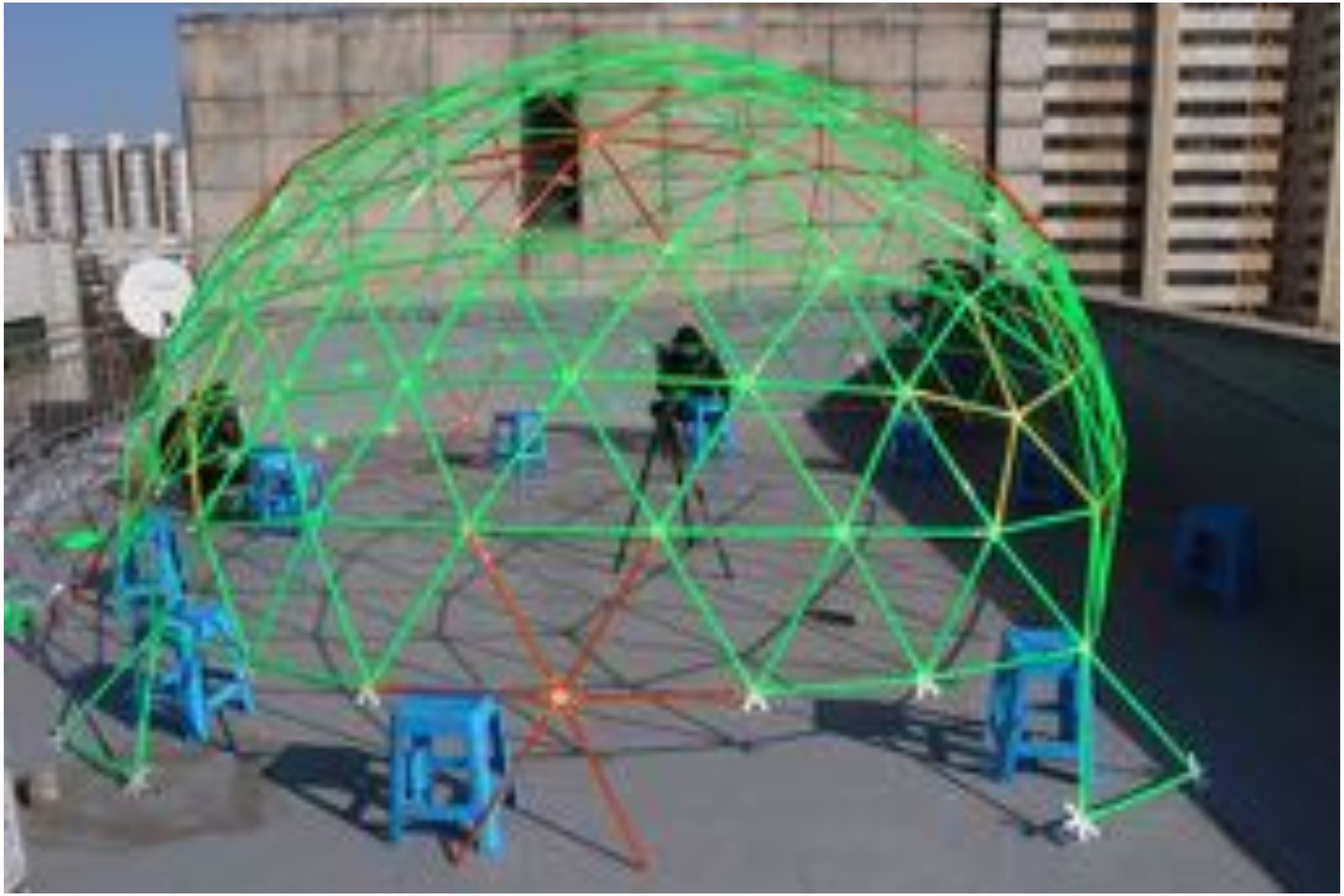




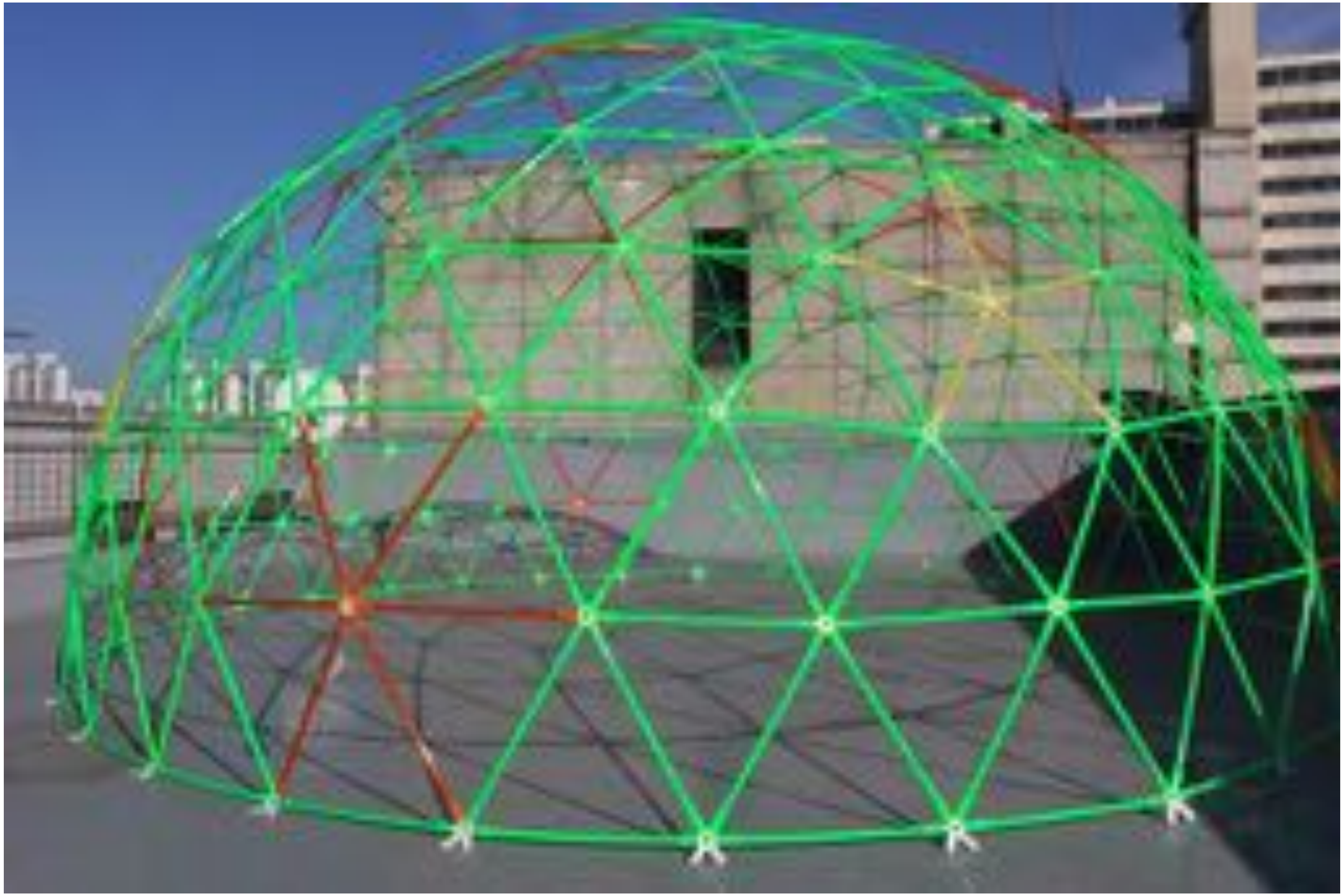


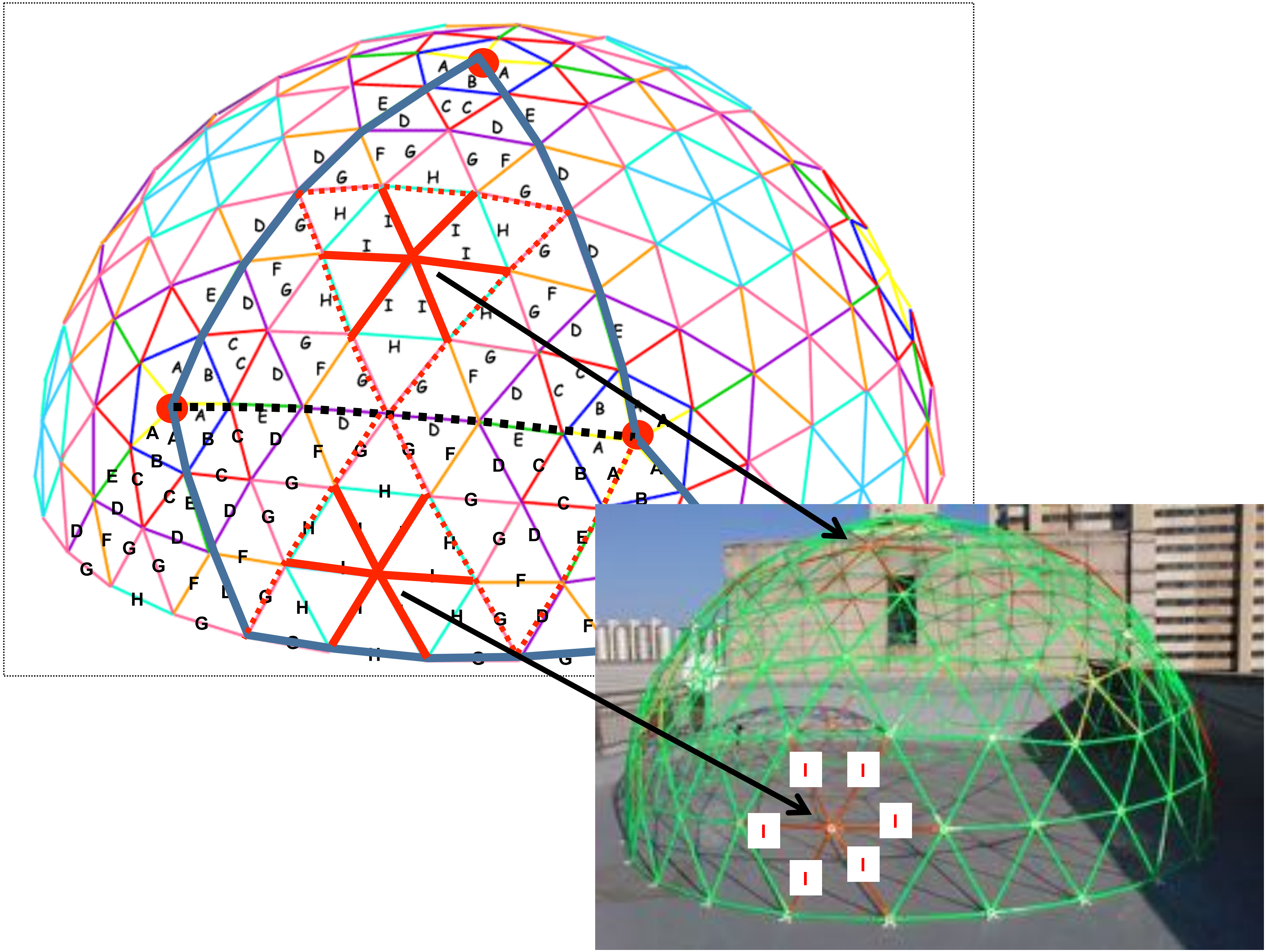






CONCLUSION





A
B
C
D
E
F
G
H
I

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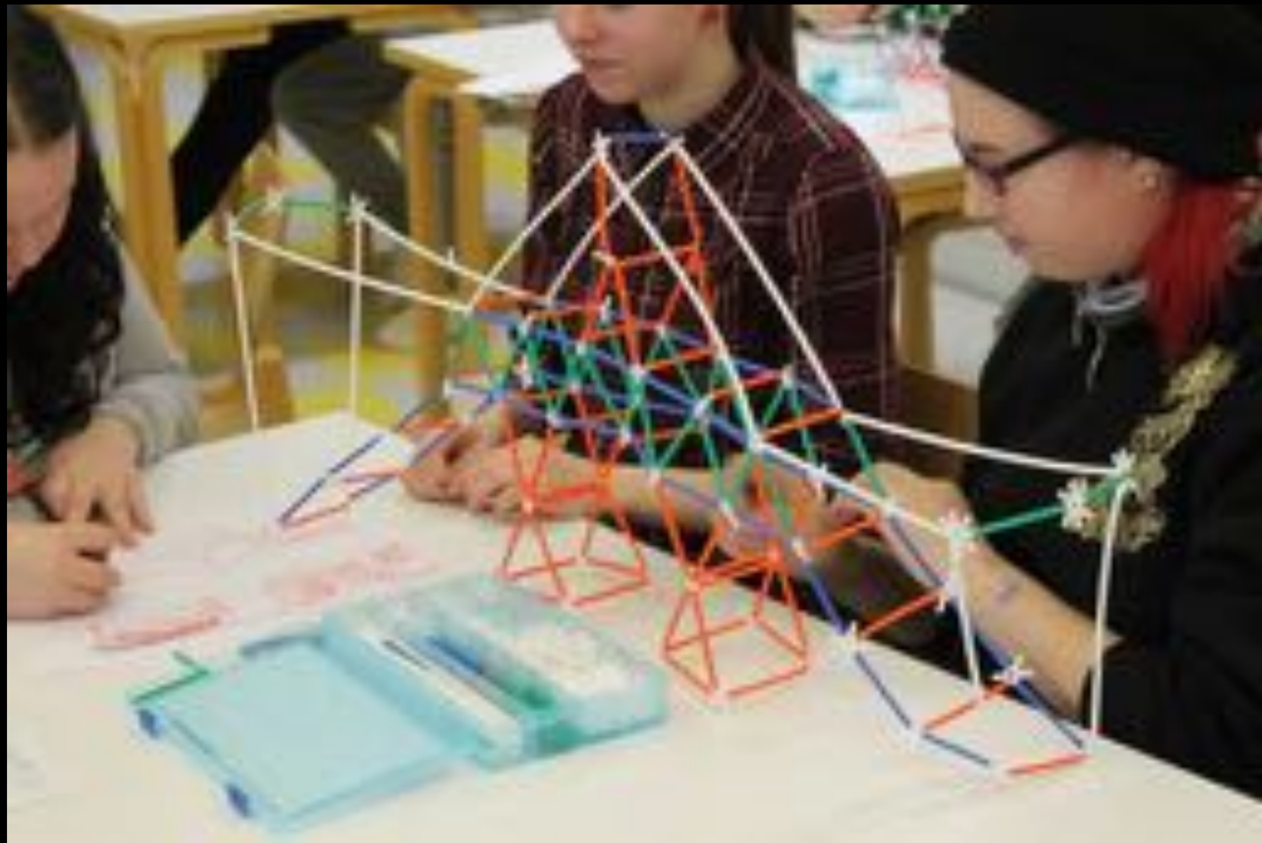

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Is this Science? Is this Technology? Is this Engineering ? Is this Art? Is this Mathematics?

No. It is a T-Rex!

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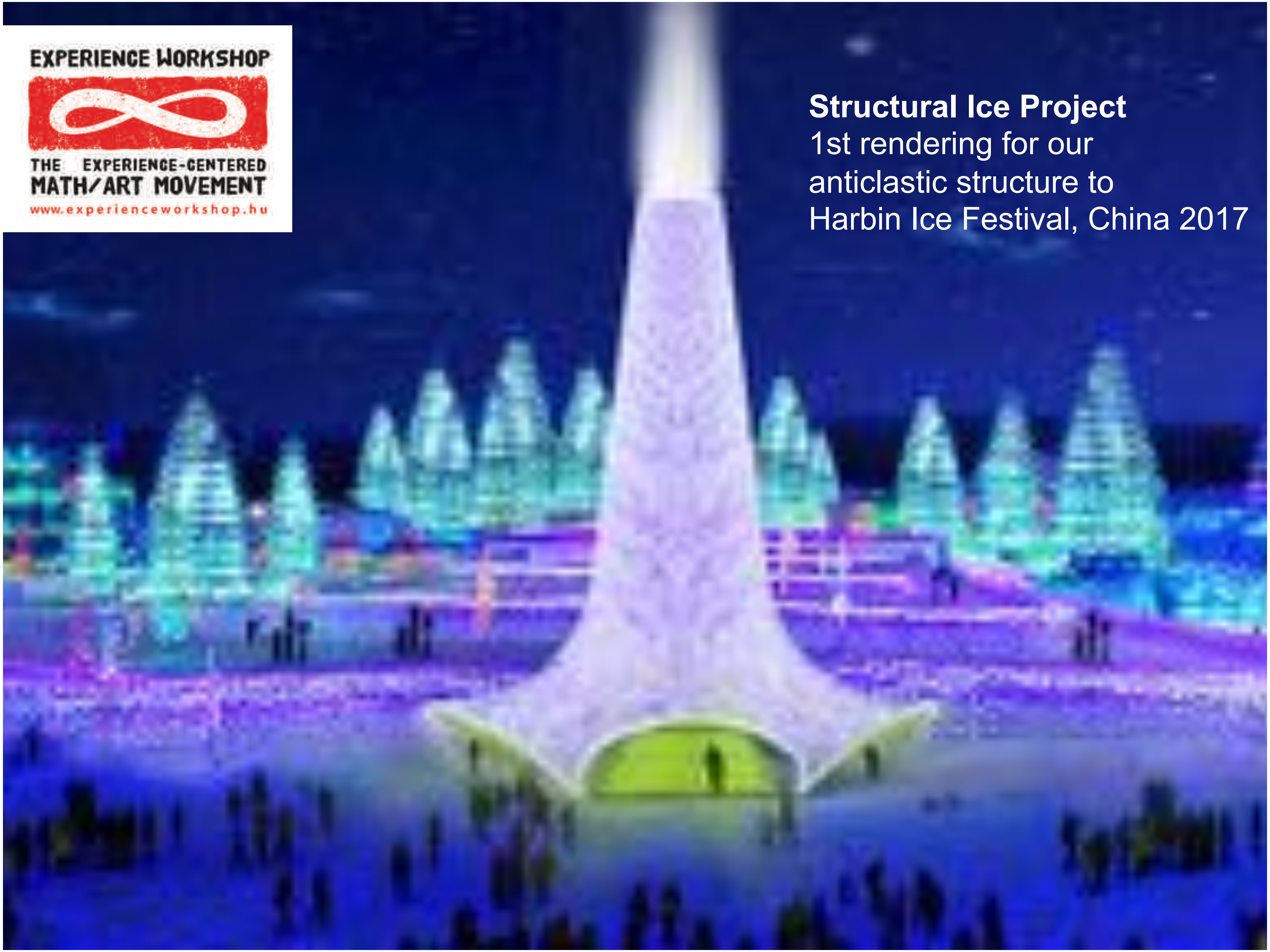
https://www.youtube.com/watch?v=IcLvH-SgjnQ&feature=youtu.be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1st rendering for our
anticlastic structure to
Harbin Ice Festival, China 2017


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