# Exploring Kaleidocycles with LUX

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## Abstract

Participants can experiment with building a series of dynamic linkages, mainly triangular and cubic kaleidocycles with the LUX construction system. In order to make the required movements with LUX, a new LUX module has been developed. The new module will be introduced in the workshop, and participants will be asked to assess the further educational, artistic and creative potentials this module offers to the LUX system. After the introductory activities, participants will experiment on how to study these topics in multidisciplinary settings by using LUX in the mathematics classroom. The workshop combines hands-on geometry learning with other subjects, like arts, engineering and design.

## Introduction

LUX (www.luxblox.com) is a US manufactured construction system produced by Lux Blox LLC. It is used both as a construction toy and as an educational tool [1]. It utilizes snapping pinless, hermaphroditic connectors that form revolute joints. Also called pin joints or hinge joints, a revolute joint is a one-degree-of-freedom kinematic pair that is used in mechanics. They provide a single-axis rotation function and are commonly used in door hinges, folding mechanisms, and other devices with uniaxial rotation. When LUX are connected together they form linkages. The rigid bodies, connected via links, are constrained by their connections to other links. LUX are able to model with a relatively small inventory of shape pieces many polyhedra including Platonic, Archimedean and Johnson Solids. In this workshop paper, we examine the geometric principles and progression of transformations of LUX linkage constructions in singular and manifold triangular and cuboid kaleidocycles.

(a) (b) (c)

**Figure 1:** *Three different LUX pieces: the Square (a), Trigon (b), and Lynx (c).*

There are three different LUX pieces. They are called the Square, Trigon, and Lynx. The Square LUX has a square shape with a LUX joint along each of its four edges (Fig. 1a). The LUX Trigon is arranged equilaterally, has the same thickness as the square, and the same edge length, with a LUX joint along each of its three edges (Fig. 1b). The LUX Lynx was developed during the run-up to the conception of writing this paper, and it has two back-to-back joints that would allow two LUX shape pieces to join and bend until they lay flat against each other (Fig. 1c).

## Kaleidocycles

Kaleidocycles are traditionally paper transformers, which can be made of a variety of geometric shapes. Kaleidocycle constructions have been widely popularized by the classic book of *M. C. Escher Kaleidocycles* by Doris Schattschneider and Wallace Walker [4]. At the heart of its construction method is a combination of double-action hinges, the tritetraflexagons and the cubes. The tritetraflexagons are modules, which have three surfaces. One of these surfaces are hidden in the folds of the structure, and after successive inversion becomes visible. As the one surface becomes visible, two previously exposed surfaces are folded in upon and are covered up.

To construct Cubo-kaleidocycles (Fig. 3.) it is required to make in advance 4 double hinge action and 4 cubes. The cube shown in the diagram shaded indicates a change in the position of the model depending on the stage of its making (Fig. 2).

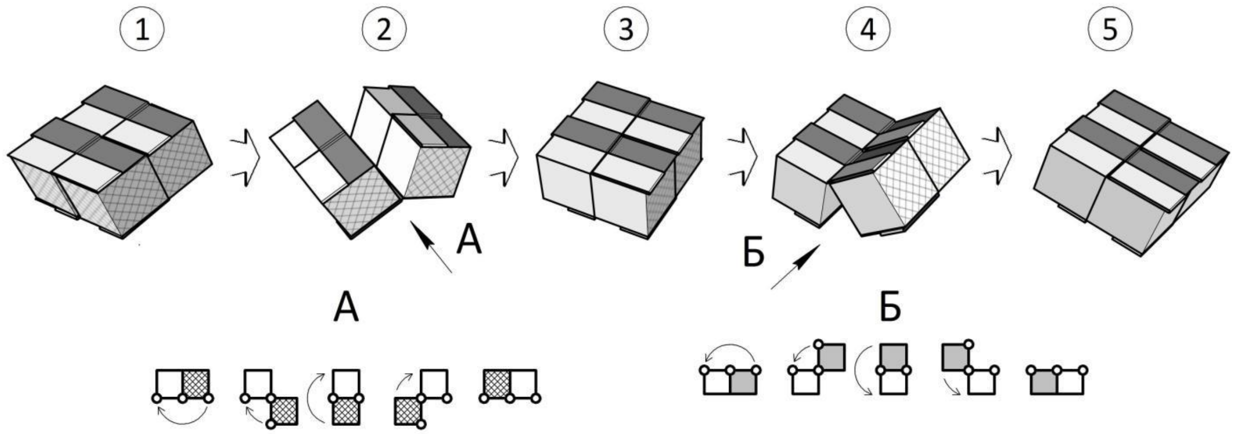


**Figure 2:** *The principle of the transformable cubo-kaleidocycle.*

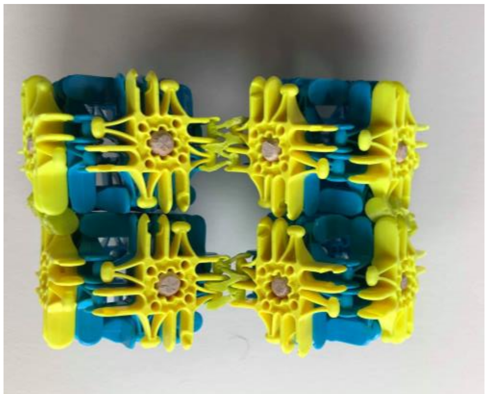

**Figure 3:** *The LUX cubo-kaleidocycle.*

For the triangular kaleidocycle, 6 double-acting hinges and 6 cubes are needed. The LUX cubes are made with 6 LUX squares each. The cubes are then attached by means of the addition of outer Square LUX modules, connected to the cube using dowel rods. These square LUX pieces are then connected to the Square LUX pieces of the neighboring cube with a LUX Lynx connector (Fig. 4). The resulting triangular kaleidocycle is a fascinating transformation (Fig. 5) as it exhibits a circular toroidal-like rotational motion similar to the motion observed in a convection current.

For the LUX Triangular Kaleidocycle we need 6 LUX cubes. These LUX cubes are made of six Square LUX each. The cubes are then attached by means of the addition of outer Square LUX modules, connected to the cube using dowel rods. These square LUX pieces are then connected to the Square LUX pieces of the neighboring cube with a LUX Lynx connector (Fig. 5).

Once the LUX Kaleidocycle is assembled, it is possible to change its spatial shape without losing integrity (Fig. 5).

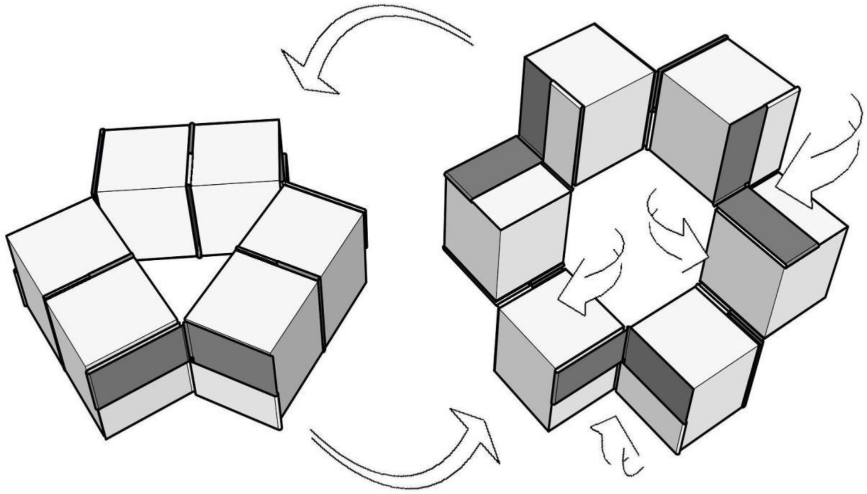

**Figure 4:** *The principle of operation of the triangular kaleidocycle.*

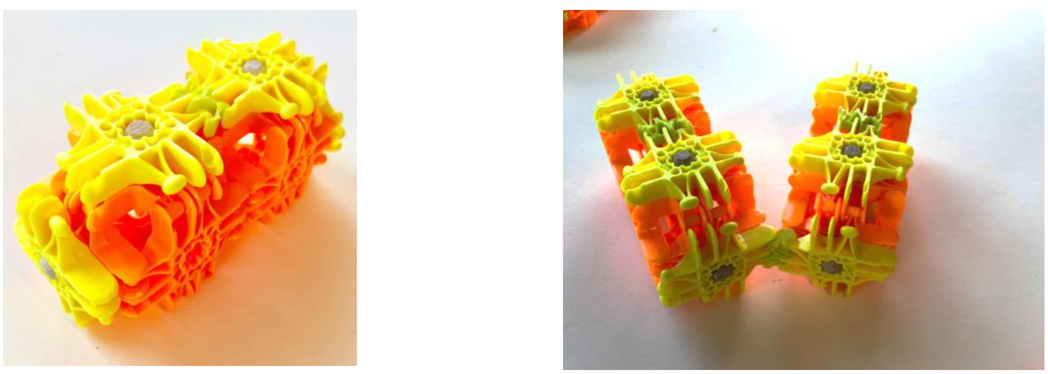

**Figure 5:** *Making the LUX triangular kaleidocycle.*

**Figure 6:** *Various LUX triangular kaleidocycles.*

**Figure 7:** *The LUX Kelvin Cell.*

This kaleidoscopic LUX construction can be expanded. By attaching two more kaleidocycles, as shown in Figure 6, the linkage will begin to fold up into a Tetrakaidecahedral, or Kelvin Cell structure. The Kelvin Cell is a polyhedron, which has a relationship with space filling shapes and minimal surface areas. It has 14 faces (6 quadrilateral and 8 hexagonal) and 24 vertices. In 1887, Lord Kelvin studied foams and bubbles and proposed that this polyhedron was the ideal shape for filling all space of equal sized objects. For over a hundred years it was thought that Kelvin's conjecture was settled mathematics, until Dublin physicists Denis Weaire and Robert Phelan in 1994 showed that Kelvin's foam uses more surface area per bubble than an alternative, somewhat less symmetrical arrangement [3]. The Kelvin Cell still draws interest for its remarkable symmetry and characteristic to fill all space (Fig. 7).

Participants in the workshop, after getting familiar with the kaleidocycle-concept, will make at least two different kaleidocycles from LUX and design their own patterns and mechanisms out of these two examples. After the individual LUX kaleidocycles are ready, participants will be asked to experiment on how to connect several kaleidocycles to make larger transforming structures. Another problem to solve is to explore further different kaleidocycles (e.g. by using resources like https://polyhedra.net/en/pictures.php?type=ka) and try to recreate them by using LUX.

## Conclusions

The transformation occurring within the kaleidocycle models is occurring in many naturally structures too, from the involution of a tubular (cylindrical) structure (which occurs in biological systems), to the motions within a convection current. Reducing complex motions and spatial arrangements into concrete physical and mechanical models, is an excellent means of introducing students to the workings of their environment and connecting experience to the disciplines of art and mathematics. The suggested workshop is in line with the main aims of the Finnish National Curriculum for Basic Education, which defines the goal of learning mathematics as developing mathematical, logical, creative and precise thinking, and recommend hands-on activities and concreteness as key elements in teaching and learning mathematics [2].

## References


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