Title:
Geometry in Motion: A Craft Perspective for Design and Teaching. Case Study: The Hinge

Authors:
Dina Rochman, drochman@cua.uam.mx, Metropolitan Autonomous University-Cuajimalpa

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Introduction :
Geometry in motion is a fundamental concept that analyzes the behavior of lines, surfaces, and geometric figures when they move or rotate in three-dimensional space. This approach considers the position of points in relation to the X, Y, and Z axes, establishing a direct connection with kinematics. Kinematics, focused on studying the movement of bodies without considering the forces that generate it, shares key concepts with descriptive geometry, such as rest, associated with position; trajectory, related to displacement; and movement, linked to rotation.

In the traditional teaching of descriptive geometry and kinematics, there is a disconnect between theoretical concepts and their practical application in mechanism design. This limits students' ability to understand and design functional systems in areas such as robotics, mechanics, and 3D printing. Therefore, it is necessary to implement didactic strategies that integrate theoretical concepts with accessible practical methodologies, promoting meaningful and contextualized learning.

The objective of this project is to develop a craft methodology that allows students studying design to understand and apply concepts of geometry in motion and kinematics through the construction and analysis of functional mechanisms such as hinges, integrating theory and practice in an innovative and accessible approach.

Main Sections:
The essential principles of geometry in motion include analyzing the position, translation, and rotation of geometric bodies. This analysis begins with studying lines and surfaces in space and their transformations through movements such as rotation and plane changes, necessary to determine the true shape and magnitude of geometric elements when they are not aligned with two coordinate axes. In practical applications, such as orthographic projection and isometric drawings, the concept of the centroid becomes crucial for understanding the principles of movement, joints, and electromechanical systems.

Likewise, the five main kinematic movements (uniform linear motion, uniformly accelerated motion, uniform acceleration, circular motion, and parabolic motion) find a more robust analytical framework when studied from a geometric perspective.

Relationship between Descriptive Geometry and Kinematics
The intersection between geometry and kinematics is manifested in the analysis of mechanical, robotic, and natural systems. For example, joints, essential in robotics and mechanical design, illustrate how movements can be generated and controlled in different contexts. From hinges to gears and transmission systems, geometry in motion provides tools to optimize the design of functional mechanisms.

Innovative Educational approaches

The teaching of geometry and kinematics has been enriched with the use of new technologies and practical methodologies:

- VPL and Rapid prototyping

Carota and Tomalini (2023) [2] highlight how tools like Rhino and Grasshopper help understand complex geometric shapes by combining theory and practice.

- Visualization and Embodiment

Anderson and Wall (2015) [1] show how technologies like Kinect and 3D visualizations promote understanding of kinematic concepts through physical interaction.

- Robotic Kinematics with Virtual Reality

Xu et al. (2020) [4] proposes a system that combines simulation and remote control to teach robotic kinematics, fostering flexibility and safe learning.

Moreover, accessible tools like LEGO Technic demonstrate how creativity and experimentation can be enhanced through accessible technologies, as exemplified by Isogawa (2016) [3] in his book *The LEGO Power Functions Idea Book*.

However, despite these technological advances, it is crucial to remember that craft technology has been a constant throughout history, from prehistory to the present. Today, it remains an invaluable resource in university education. Disciplines like ceramics, carpentry, and jewelry show how hands-on and craft teaching is still essential for understanding design and creation principles through geometry and kinematics.

In our case, we have implemented a craft methodology in the Teaching Support Laboratory (LAD) at the Metropolitan Autonomous University-Cuajimalpa, so that students in their fourth semester of the Design program can understand geometry in motion through the construction of hinges.

Initially, students faced challenges in understanding theoretically how a hinge works and is constructed, but by transferring this experience to the workshop and working with materials such as foam and wooden sticks, they were able to internalize these concepts.

They used tools like drills and foam cutters to create functional mechanisms, allowing them to tangibly understand the relationship between geometry and kinematics. The craft work in the LAD is designed to promote practical and experimental learning, prioritizing the construction of geometric models and functional mechanisms. Using materials like foam, wooden sticks, and basic assembly elements, students apply fundamental geometric principles to the design and manufacturing of 3D prototypes. This craft approach not only promotes creativity but also strengthens the understanding of abstract concepts by translating them into tangible solutions.

Case study: The hinge

The hinge was selected as a case study for its importance as a functional and mechanical element that combines movement and geometry. The analysis began with a theoretical introduction on how it works, illustrated by a 3D-printed model that the students carefully analyzed (Figure 1).

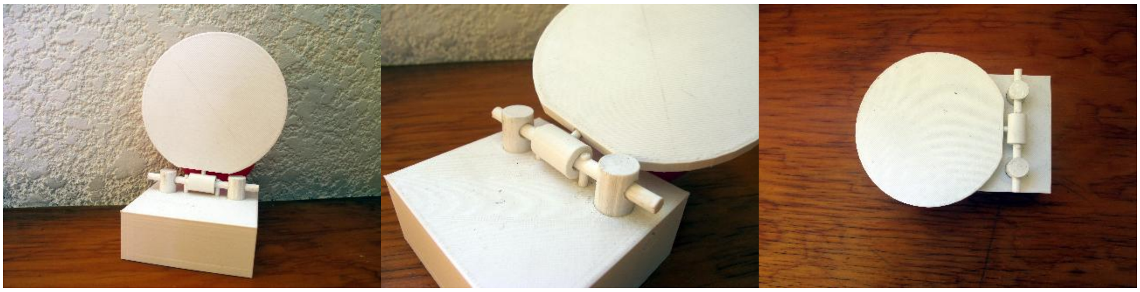

Fig. 1: 3D-printed hinge.

This model allowed them to identify the essential components that make up a hinge and the geometric principles involved in its design. During the planning stage, students sketched the movements that the hinge should perform, defining the movable and fixed parts. This process included a detailed study of the tolerances required for the parts to fit together properly without losing functionality.

During the craft construction, students used basic laboratory tools to create their models. The practical application of the geometric concepts studied previously was fundamental to ensure the accuracy of the assembly and movement of the hinges. Finally, in the evaluation stage, the completed models were analyzed to verify that they met the functional and aesthetic requirements. This analysis allowed students to understand how geometric and mechanical principles interact in a functional design, fostering a comprehensive and applied learning experience.

This craft activity not only reinforced the theoretical concepts of kinematics but also highlighted how basic principles can be applied in practical contexts, replicating in some ways the advances achieved with modern tools like LEGO Technic. Finally, students drafted construction plans of their pieces in orthographic projection and isometric projections, integrating technical and creative aspects of design, descriptive geometry, technical drawing, and rotational movement.

<u>Results:</u>

Development of Technical and Practical Skills:

- Students successfully designed and trace functional models that integrated basic geometric shapes (cone, cylinder, sphere, prism) with articulated mechanisms, meeting the set objectives.
- They learned to use tools like bench drills, sanding machines, and foam cutters, developing essential practical skills for craft construction.

Understanding and Application of Geometric and Kinematic Concepts:

- Students demonstrated mastery in representing bodies of revolution and geometric intersections, applying this knowledge to the hinge design.
- Through the construction and analysis of the hinges, they understood the geometric relationships that enable articulated movement, strengthening their ability to solve practical problems.

Innovation in Articulated Mechanism Design:

- Each student presented a unique model with creative solutions for hinge movement and support. These proposals reflected the students' ability to integrate theoretical concepts with functional designs (Figure 2).

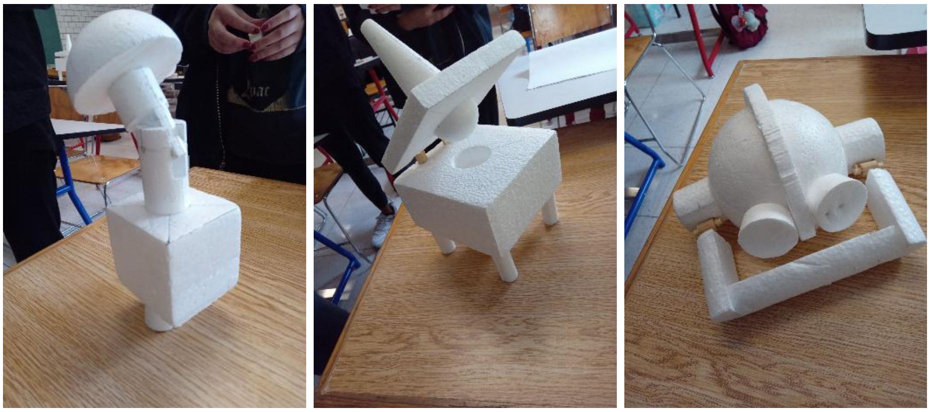

Fig. 2: Students' hinge movement model.

- Prototypes made of clay and foam allowed visualization and adjustment of designs before final construction, encouraging an iterative approach in project development.

Success in Hinge Functionality:

- The final analysis of the models showed that the hinges built met the required movement specifications. Precise movements were observed in forward/backward or up/down directions, according to the students' individual proposals.
- Practical interaction with the models allowed them to assess the impact of geometric tolerances and adjust their designs to improve functionality.

Teamwork and Self-management:

- During activities in the Teaching Support Laboratory (LAD), students demonstrated collaboration and organizational skills, working autonomously in building their models (Figure 3).

Fig. 3: Students working in the LAD.

- They followed safety protocols and optimized the use of available resources, highlighting their responsibility in project development.

Visual and Conceptual Impact of the Models:

- The results showed a high level of detail and finishing, achieving models that were not only functional but also aesthetically attractive (Figure 4).

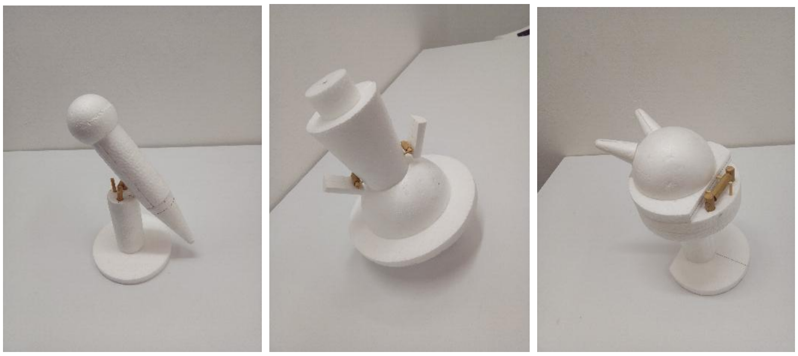

Fig. 4: Functional and aesthetically pleasing student models.

- Students expressed a greater understanding of the importance of geometry in design and its practical application in articulated mechanisms, connecting theory with the physical world.

Conclusion:

The study is framed within Project-Based Learning (PBL) and experiential learning models, demonstrating improvements in conceptual understanding, technical skills development, and problem-solving abilities. Additionally, the study was limited to a single case study (the hinge), but it was applied to a broader sample of 95 students over three different academic terms, strengthening the validity and consistency of the approach. This study lays the foundation for exploring innovative educational strategies that reinforce the connection between geometry and its practical applications in design education, demonstrating the effectiveness of an experiential, hands-on approach in developing technical and conceptual skills. Geometry in motion is not only a key concept for the analysis and design of mechanical systems but also an integral educational tool that links theory, practice, and technology. From craft construction to the use of advanced technologies, this approach fosters deep and applied learning, preparing students to face complex challenges in design and robotics.

Dina Rochman, http://orcid.org/0000-0001-8902-3513

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