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Pop-Up Mechanisms as a Means of Visual Expression in Card Design

ABSTRACT

A pop-up card combines graphics with a three-dimensional and interactive form, enriching the way content is presented. The purpose of this article is to analyze the use of moving mechanisms as a means of visual expression in card design. The research material consists of 28 cards designed and made by students of the Department of Printing Technologies at the Warsaw University of Technology. The analysis focused on the relationships between the mechanisms used, the graphic elements, and the visual effect achieved when the card is opened. Multiple layers mechanism appeared most frequently, in 25 cards. Spirals were used in 18 cards, V-folds in 14, and flaps in 4. The most common combination was multiple layers and spirals, used together in 15 cards. The results indicate that these mechanisms serve functions that go beyond mere construction: multiple layer mechanisms create depth and organize the compositional planes, V-folds bring selected elements forward toward the viewer, and spirals introduce a sense of movement and dynamism.

Ewa Kołodziejuk
Joanna Izdebska-Podsiadły

Department of Printing Technology, Institute of Mechanics and Printing, Faculty of Mechanical and Industrial Engineering, Warsaw University of Technology, Warsaw, Poland

KEY WORDS
Pop-up cards, moving mechanisms, paper engineering, visual expression, graphic design

1. Introduction

The history of pop-up mechanisms dates back to the Middle Ages, when scientific manuscripts used movable elements to visualize astronomical or medical data (Smithsonian Institution Libraries, n.d.). Rotating discs were already in use as early as the 13th century by the English monk Matthew Peris (The Ancient Origin of Pop-Up Books, 2023). Although Lothar Meggendorfer is considered the true pioneer of moving mechanisms, having popularized their use in the 19th century (Ptaszek, n.d.; Krahé, 1980). Today, pop-up mechanisms are most commonly associated with children's books and greeting cards, but they can also be applied in other design forms: packaging, advertising materials, or foldable structures, such as architectural models. Moving mechanisms not only serve a structural function but also shape the composition, direct the viewer's attention, and enhance the visual message through movement, depth, and the element of surprise.

A pop-up card combines traditional graphic design with a three-dimensional structure that is revealed when the card is opened. The pop-up mechanisms in these cards are not only an attractive decorative element but also an interactive tool that stimulates the imagination and enhances the message. The recipient activates the mechanism, causing the visual message to unfold from a flat surface into a three-dimensional form. The way the elements appear and move becomes part of the narrative and the design experience. Based on how three-dimensional elements are displayed, two types of pop-up cards can be distinguished: 90-degree and 180-degree (Iizuka et al., 2011). The second type is generally considered more difficult to design, although this largely depends on the number of elements comprising the moving mechanism. Problems often arise during their design and prototyping, such as collisions between elements and parts of the structure sticking out after the card is folded (Okamura & Igarashi, 2009).

Designing pop-up cards requires combining appropriate structural solutions and graphic elements to achieve the desired visual effect. The mechanisms must allow the card to be opened and closed repeatedly and at the same time create a cohesive composition with

the graphic layer. Additionally, it is necessary to take into account the structural limitations of the mechanisms. Three-dimensional elements must not stick out beyond the dimensions of the closed card, and when combining multiple mechanisms, care must be taken to ensure that the elements do not interfere with one another, which could lead to damage to the structure or malfunction. Equally important are the proper selection of the substrate and the size of the bonding surfaces. A bonding area that is too small may cause the elements to come apart, and improperly selected paper may delaminate as a result of the stresses generated when opening and closing the card.

The aim of this article is to analyze the ways in which pop-up mechanisms are used as a means of visual expression in card design. The research material consists of a series of cards created by students. The analysis focuses on the relationship between the mechanism used, the graphic elements, and the effect achieved when the card is opened.

2. Characteristics of Basic Pop-Up Mechanisms

Among the many different pop-up mechanisms, three can be identified as the foundation for building more advanced and complex solutions. These include: multiple layers, V-folds, and spirals, which, when combined, create more advanced and visually striking solutions (Sánchez & Rodríguez, 2014).

The multiple layer mechanism uses paper elements with parallel folds that can be glued to the card base or cut directly from it. The three-dimensional effect is created when the card is opened and closed, and at a 90° angle between its parts, the individual layers form planes parallel to one of the card's base panels. The gluing points should be parallel to the card's center fold. When cutting elements out of the base card, it is recommended to reinforce it with an additional layer of paper, which increases the structure's rigidity and creates a color contrast between the base and the cut-out elements. The multiple layer mechanism allows you to create a sense of depth and build multi-plan compositions, such as landscapes, castles and other buildings, multi-level scenes, or three-dimensional lettering.

The V-fold mechanism gets its name from the shape of the elements attached to the base card, which can form the letter V or its inverted version. The angles on both sides of the card's central fold can be set to any value, maintaining symmetry or creating an asymmetrical arrangement. A three-dimensional effect is created when the card is opened to 180°, and this effect is particularly pronounced with elements of significant height. Three-dimensional elements can be glued to the base card or cut directly from it. The V-fold mechanism allows for the creation of objects positioned perpendicular to the base card, such as castles and other structures, pyramids, tents, facial features, or animal jaws. Combining two V-folds creates a zigzag mechanism, enabling the construction of more complex forms, such as figures with raised hands or birds with outstretched wings. A modification of the V-fold is the moving arms mechanism, which uses four articulated triangles forming a parallelogram. This allows the arm attached to one of the triangles to move in an arc as the card is opened and closed.

The spiral mechanism is a simple yet visually appealing solution. It is created by cutting out a spiral of any shape, starting from its outer edge and ending at the center. Both ends of the spiral are attached to the inner sides of the base card so that when closed, the card lies flat, and when opened, a three-dimensional effect is created. The spiral can take on various shapes, such as a circle, square, heart, or hexagon. Combining it with appropriately selected graphics enhances the visual effect — for example, by depicting a flower, a coiled snake, or a hexagonal honeycomb near a beehive.

All three pop-up mechanisms described earlier can be combined, e.g., multiple layers with a spiral, a V-fold with a spiral, or several V-folds. A greater challenge is combining a V-fold with a multiple layer mechanism, because the three-dimensional effect is achieved in the first case when the page is opened to 180°, and in the second case at a 90° angle. These differences must be taken into account during the design process to ensure that the complete structure functions properly.

3. Research Methodology and Project Implementation

3.1. Card Projects

The pop-up cards were designed by third-year students in the Paper and Printing Technology program as part of the course 'Computer-Aided Packaging Design', taught by Ewa Kołodziejuk, M.Sc. (Eng.). The assignment involved designing and creating a prototype card on any theme, using at least one of the three proposed mechanisms: multiple layers, a V-fold, and a spiral; a combination of several mechanisms; or other additional solutions used independently.

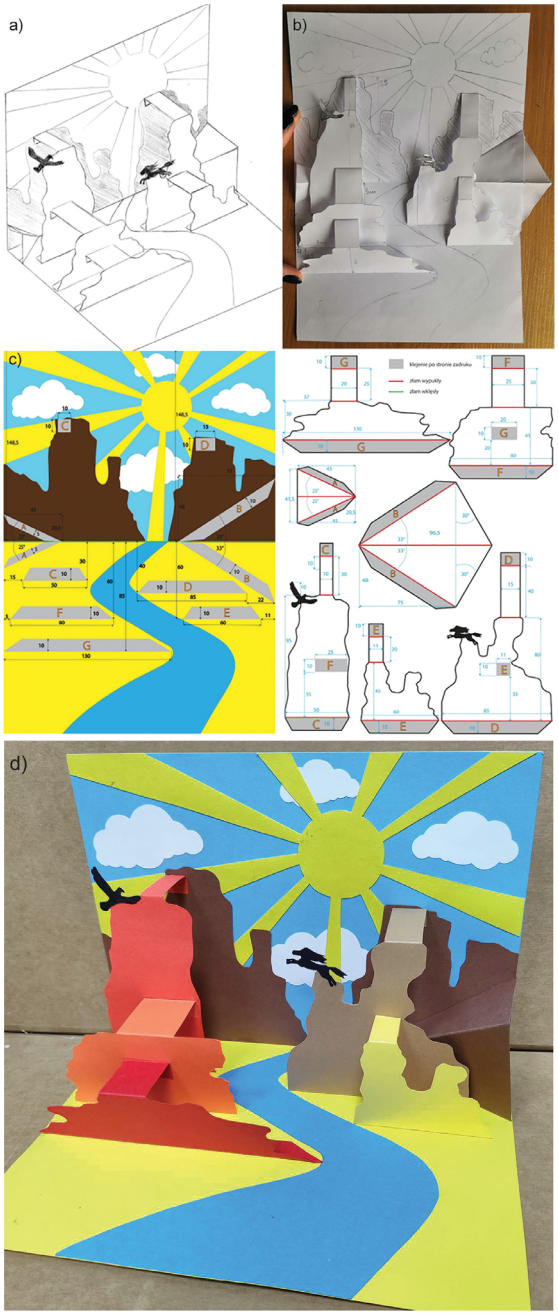
The design and manufacturing process consisted of the following stages:

a) developing a concept in the form of a sketch (Fig. 1a) that took into account the arrangement and shape of the 3D elements as well as the mechanisms used; planning the graphic layer using graphics or shapes cut out of dyed paper;

b) constructing a prototype from white paper and correcting design errors (Fig. 1b);

c) developing a 1:1 scale construction grid (Fig. 1c), either in a vector graphics program or by hand, with dimensions and markings for cut lines, folds, and glue joints;

d) creating a 3D model of the card using cardboard with a basis weight of 160–230 g/m² (Fig. 1d), including cutting out, folding, and gluing the components.



» **Figure 1:** *Stages of card design and manufacturing: a) conceptual sketch, b) white prototype, c) structural grid, d) finished 3D card model*

The students created a total of 28 pop-up cards. A video showcasing the pop-up card prototypes can be downloaded from: https://www.facebook.com/share/v/14uZbqUutwz/ or via the QR code (Fig. 2). The video was edited and the soundtrack was created by third-year student Mateusz Staśkiewicz.

» **Figure 2:** *QR code*

3.2. Analysis of Research Data

The study analyzed the use of pop-up mechanisms in student designs for 3D cards, with particular emphasis on their visual and compositional functions. The analysis is descriptive and comparative in nature and covers 28 cards. Based on video documentation, each card was described, identifying the mechanisms and defining their visual and compositional functions. The classification identified the dominant mechanism—the one that most significantly shapes the card's spatial composition—as well as additional mechanisms that complement its layout, deepen the scene, or introduce further moving elements. The use of different construction principles within a single card was considered a combination of several mechanisms. The repetition of several elements based on the same principle was treated as the use of a single type of mechanism, rather than several different solutions.

4. Results and Discussion

Table 1 describes all the cards, identifying the mechanisms they contain and specifying the functions they perform. Selected examples of the cards are shown in Fig. 3.

Table 1
Characteristics of Pop-Up Cards

No.	Card description	Number and types of pop-up mechanisms used	Visual and compositional function
1	GPS Map	1) multiple layers, 2) V-fold, 3) flap	Creates a three-dimensional scene and enhances the sense of depth.
2	Castle at Night	1) multiple layers, 2) spiral	Builds depth and combines a graphic motif with a three-dimensional form.
3	Nighttime City Panorama	1) multiple layers, 2) spiral	Varies the heights of the buildings and creates an urban perspective.
4	Card with Egyptian Symbols	1) multiple layers, 2) spiral	Brings the main theme (the pyramid) to the foreground.
5	Pink Castle with Green Bushes	1) multiple layers, 2) flap with V-fold	Highlights the castle and creates a fairy-tale-like, multi-layered scene.
6	A stronghold with flying dragons	1) multiple layers, 2) spiral	Highlights the architecture and suggests movement within the scene.
7	Red-and-yellow buildings	1) multiple layers, 2) V-fold	Gives the building a three-dimensional form and creates spatial scenery.
8	A Real Madrid fan card	1) multiple layers, 2) flap with V-fold	Enhances the typographic message and reveals additional content.
9	A soccer fan at the stadium	1-2) combination of multiple layers and V-fold, 3) spiral	Creates a central, prominent accent and contrasts it with a flat background.
10	Birds in a tree	1) multiple layers, 2) spiral	Introduces depth and places the birds on different planes.
11	A birdhouse	1) multiple layers, 2) V-fold (x2)	Places the birdhouse in the foreground, creating a three-dimensional scene.
12	Pink multi-tiered birthday cake	1) multiple layers, 2) spiral	Builds a central motif (the cake) and reinforces the impression of height.
13	Pink and red cake	1-2) combination of multiple layers and V-folds	Focuses attention on the cake and emphasizes its celebratory nature.
14	Card with a bouquet and hearts	1) V-fold, 2) spiral	Brings the bouquet to the foreground and reinforces the celebratory theme.
15	Valentine's Day card with a teddy bear and the words 'I love you'	1) multiple layers, 2) spiral	Combines the text message with the three-dimensional teddy bear.
16	Tulips in a wooden box	1) multiple layers, 2) V-fold (hidden under multiple layer)	Highlights the box and the flowers.
17	'LOVE' card with a heart	1) multiple layers, 2) spiral	Creates a multi-layered composition — combining letters and a heart symbol.
18	A piano with musical notes	1) multiple layers, 2) spiral	Gives the instrument a three-dimensional quality and evokes associations with the music scene.
19	A coffin with a zombie inside	1) multiple layers, 2) flap (combination with steering bar)	Highlights the central object and creates a sense of interior space.

No.	Card description	Number and types of pop-up mechanisms used	Visual and compositional function
20	A cemetery at night	1) multiple layers, 2) spiral	Establishes a foreground and enhances the scene's atmosphere.
21	A multicolored face with geometric patterns	1) V-folds (x3), 2) spiral	Create a sense of volume and draw attention with color and form.
22	A blue dragon	1) V-folds (x2), 2) spirals (x2)	Highlight the figure and suggest movement, creating a unique energy in the scene.
23	An anniversary card for the Volunteer Fire Department (OSP)	1) multiple layers, 2) spiral	Establish an appropriate hierarchy.
24	Café: a teapot, a cup, and croissants	1) multiple layers (x2), 2) flap with spiral, 3) flaps with V-fold (x2)	Organize the composition, bring objects to the foreground, and create a unique atmosphere.
25	A sailboat on the waves	1) multiple layers, 2) spiral	Builds a maritime scene and creates a sense of movement.
26	A landscape with a dam on a river	1) multiple layers, 2) spiral	Establishes multiple planes and guides the viewer's gaze along the river.
27	A capybara	1) multiple layers, 2) V-fold	Combines text and illustration, establishing a clear hierarchy between the title and the character.
28	A dog and a butterfly	1) multiple layers, 2) combination of V-folds (moving arms) 3) pulling tab	Creates a sense of depth, hides part of the illustration behind the foreground, and allows movement.

In the case of cards nos. 1, 11, 21, 27, and 28, it is difficult to identify a dominant mechanism; all the solutions used should be considered equivalent.

Based on an analysis of the mechanisms used, it was found that 24 cards (approximately 86%) utilized two types of mechanisms, while 4 (approximately 14%) combined more than two. In the analyzed set, multiple-layer layouts were used most frequently, appearing in 25 cards (89.3% of the set). Spirals were noted in 18 cards (64.3%), and V-type folds in 14 (50.0%). Flaps appear in 4 designs (14.3%) and were used primarily to combine, within a single design, a multi-layer mechanism—which requires opening the card at a 90° angle—with a V-fold mechanism, which requires the card to be laid flat (180°). One design featured an additional pulling tab mechanism (3.6%). The most common combinations are multi-layer layouts and spirals, which co-occur in 15 cards. Multi-layer layouts combined with V-fold mechanisms were found in 11 designs, and V-fold mechanisms combined with spirals in 5.

Multilayered layouts are the most commonly used solution and, in many projects, form the spatial foundation of the composition. V-folds, spirals, and flaps serve as elements that contribute to the layout: they highlight selected elements, introduce additional planes, or provide the composition with a more dynamic quality. The compilation also notes specific solutions: a flap connected to a control strip, movable arms created using double V-folds, and a pulling tab in the guide. However, these are features of individual designs.

An analysis of the designed cards confirms that the mechanisms used fulfill their intended functions: multilayered layouts create depth and organize the compositional planes; V-fold designs bring selected elements forward toward the viewer, giving them spatial clarity, and spirals create a sense of movement and lightness while directing attention to key elements of the scene.

The cards analyzed (Fig. 3) demonstrate a variety of ways to use pop-up mechanisms. The 'GPS Map' card features a three-dimensional layout of the route and navigational markers. The raised blue line guides the viewer's gaze along the route, while the elements that pop up further capture the viewer's attention. Similarly, in the 'Stadium' design, the central element—a fan wearing a scarf—protrudes toward the viewer, drawing the observer's attention and clearly dominating the composition. The 'Blue Dragon' card also utilizes a three-dimensional figure and additional elements that emphasize the scene's dynamism and expressiveness. In the artwork 'Café', the varying heights of the objects create the impression of a small, three-dimensional scene, highlighting the relationships between the depicted items. Additionally, the flaps reveal croissants served with coffee. The 'Sailboat' card combines layered waves with the three-dimensional form of a boat, creating depth and highlighting the main element of the composition.



» **Figure 3:** *Examples of pop-up cards: a) GPS Map, b) Stadium, c) Blue Dragon, d) Café, e) Sailboat, f) Dog and Butterfly*

In turn, the 'Dog and Butterfly' card uses overlapping layers of plants to create an effect of hiding and revealing the creatures, engaging the viewer in observing the scene. Additionally, the pulling tab engages the viewer and animated the pet, further enhancing its charm.

These examples show that pop-up mechanisms are not only used to create a three-dimensional effect, but also to organize space, direct the viewer's attention, and aid in the interpretation of the depicted subject.

5. Conclusions

An analysis of the presented designs indicates that the pop-up mechanism can serve both a structural function and as a means of visual expression. It influences the way the composition is organized, how depth is created, and how the viewer's attention is directed. The most frequently chosen and dominant mechanism is the multiple layer arrangement. V-fold, spiral, and flap mechanisms appear as elements that contribute to the overall composition. Furthermore, among the analyzed designs, the most common combination is that of multiple layers and spirals, found in 15 cards. Multiple layer mechanisms create a sense of space and depth; V-folds bring an element forward toward the viewer; and spirals introduce movement and dynamism into the composition. Selecting these mechanisms and combining them with other solutions makes it possible to adapt the spatial form to the theme and intended message of the card. The results of the observations indicate that designing a pop-up card requires treating the mechanism as an integral part of the visual concept, rather than merely as a technical means of achieving three-dimensionality.

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