Paper-pop-up design as three-dimensional skillin a higher education context

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Abstract
This applied research developed within the framework of a Portuguese Higher Education Institution. Its purpose is to assess academic practice in the context of a curricular unit in a graphic design degree course. This practice has been developed within three complementary perspectives: (a) the pedagogical concept and the proposed design exercise; (b) the selection of paper processes and materials used; (c) the design and structural definition of the graphic product. The purpose of this research is to describe the activity criteria from each perspective, exposing realization guidelines presented to students in designing a specific graphic product, from ideation, design process, and estimation of a feasible production. All this from the analysis of the proposed activity and evaluation of the prototype that represents Paper-pop-up design.

Keywords
Graphic design; graphic product; pop-up; paper material; higher education

Diseño de ventanas emergentes de papel como habilidad tridimensional en un contexto de educación superior

Resumen
Esta investigación aplicada esta desarrollada en el marco de la una Institución de Educación Superior Portuguesa. Su objetivo es evaluar una práctica académica situada en el contexto de una unidad curricular del grado en diseño gráfico. Se ha desarrollado desde tres perspectivas complementarias: a) el concepto pedagógico y el ejercicio de diseño propuesto; b) la selección de procesos y materiales de papel utilizados como soporte; c) el diseño y la definición de la estructura de un producto gráfico. El propósito de esta publicación es describir los criterios de actividad desde cada perspectiva, exponiendo las pautas de realización mostradas a los estudiantes en el diseño de un producto gráfico específico, desde la ideación, el proceso de diseño, y la estimación de una posible la producción. Todo ello a partir del análisis de la actividad propuesta y evaluación del prototipo que representa el pop-up de papel diseñado.

Palabras clave
Diseño gráfico; producto gráfico; pop-up; materia papelera; educación superior
Introduction
Design is a comprehensive discipline that encompasses several processes, tools, and methodologies, to create solutions. Ideally these should be inclusive, resilient, sustainable, and adaptable. This requires research, gathering evidence, creative thinking, designing, refining, testing and, foremost, conveying an idea to a specific audience with a purpose. In addition, communication design is about expressing visual representations by means of composition, using a focal point, information hierarchy, contrast, typeface, font, readability, emphasis, repetition, balance, consistency, empty space, image, texture, alignment, to communicate a message to an audience. Design is a set of skills but above all a mindset as well.

Paper-pop-up is a self-erecting three-dimensional structure, formed by action of a folding mechanism, that folds in one or more positions and is often hidden (Paul Jackson, 1993). Paper-pop-up are used to create unique illustrations and represent complex ideas in a manner that facilitates understanding. Paper-pop-up existence can be traced back to the Middle Ages with a manuscript dating from 1121 titled Liber Floridus (France), that illustrates the orbits of planets surrounding Earth. These early interactive paper mechanisms, known as mobile books, used revolving discs to illustrate a variety of topics, including natural sciences, astronomy, mathematics, and medicine to facilitate understanding. Later in 1543, physician Andreas Vesalius (Italy) used anatomic illustrations, arranged in folded layers, to teach human anatomy.

During 1860’s publishers Dean & Son were among the first to mass produce children paper-pop-up books, at the time named toy books, with two-dimensional dissolving scenes and pull-tab effects. In 1878 illustrator and paper engineer Lothar Meggendor (Germany) created the living picture book further developing paper-pop-up mechanisms. Throughout the 1950’ and 1960’ artists like Julian Wehr (USA) and Vojtech Kubasta (Czechoslovakia) created innovative paper-pop-up books that were visually inspiring and mechanically complex.

Later in the 1960’ Waldo Hunt (USA) designed a series of comic illustration books with paper-pop-up mechanisms that influenced generations of booklovers. Paper-pop-up designs and other three-dimensional paper-based products continue to fascinate readers and viewers, these are used in marketing, advertising, art, and in design accordingly. Contemporary paper-pop-up originated in Europe during the second half of the 1800’, with complex paper-engineering that includes cutting, folding, and bonding techniques to created three-dimensional structures that emerges from within the page. We understand that the paper-pop-up is a particular form of design that transforms a two-dimensional object into a three-dimensional communication object, using complex folding and paper engineering. In addition, the unique weight and texture of the paper dictates the outcome, whether it is print, copy, recycled, tracing, wax, bond, cotton, kraft, artist or cardboard, all of which have specific characteristics and provide through handling and transformation different learnings regarding design, manufacture, and its applications.

Theoretical Basis
This work has been developed from three complementary perspectives:

a) the pedagogical concept and the design exercise proposed.
b) the selection of processes and paper materials used as support.
c) the design and definition of the structure of a graphic product.

Educational concept and design exercise
Design, whatever the medium, depicts ideas through schematics, illustrations, patterns, representations, and depictions that convey creative proposals towards an output. Paper-pop-up design is more than an exploratory and conceptual exercise in communication design. It requires transdisciplinary knowledge asset in paper-engineering, paper materials, folds, tools, fixation, movements, hinges but above all creativity to develop a communication medium. In a Higher Education Institution, the teacher’s role is to share knowledge, to inspire and challenge individual student output, providing guidance, explanations, and practical knowledge, encouraging students learning process and outcome. Students not only learn trade tools, foster collaborative work, develop empathy, flexibility, autonomy, and accountability. This requires an understanding of the audience, empathy, and the ability to communicate, encouraging students’ reasoning, fostering curiosity, teamwork, complex problem-solving aptitudes, and resilience to deliver a desired outcome. Concerning graphic design students, a paper-pop-up exercise requires a combination of technical skills, and attention to detail to create a successful communication design artefact. The design and development of a paper-pop-up should be regarded as a creative and systematic process that requires knowledge in several subjects: design, visual culture, geometry, paper resources, paper-engineering, and graphic arts to name a few. Furthermore, paper-pop-up develops cognitive abilities, such
as spatial perception, three-dimensional visualisation, understanding of paper fold and assembly, and technical knowledge to transform a two-dimensional illustration into a three-dimensional paper communication artifact in a tangible manner and adding value.

**Object of study**
In Vector Drawing class, in a Project Based Learning (PBL) setting, students were assigned to draw a series of Portuguese lighthouses from a photo reference in isometric perspective, creating detailed and proportional illustrations with distinct elevations. Moreover, these illustrations were afterwards used to design a paper-pop-up, with a basic single-layer parallel-fold paper mechanism. Students applied paper cut and fold, without detaching or gluing, emphasising the lighthouse with a crease towards the background transforming an illustration into a three-dimensional paper-pop-up, creating individual lighthouse pop-up designs, Table 1.

Starting class, students are introduced in tools, methods, and objectives. Subsequently, they are tasked a series of exercises, to develop sketching, cutting skills, and folding enhancing manual dexterity leading to the development and design of a paper-pop-up. Thus, acquiring practical knowledge on safe tool usage, paper weights and textures, features, designing and testing different mechanisms and applications, conducting applied research of tangible paper-made objects.

**Paper selection and development as support material**
Creating moving paper structures relates to three-dimensional paper-pop-up designs. Intrinsically to creating paper structures with a given movement, such as unfolding or movement when a page is opened, or turned requires specific know-how. Materials, such as paper, cardboard, and adhesive, are used to create a physical structure. Graphic design is often used in the creation of printed elements such as paper-pop-up books, namely illustrations and text.

Nonetheless, the designer must consider material properties being employed, such as weight, thickness, and texture when designing the structure, housing different illustrations and typography that balance the design and fit within the structure. Therefore, materials must be chosen carefully to ensure that they can withstand the stress of repeated folding, opening, and closing, and compatibility with printing and assembly processes. Adequate paper weight selection is vital, for instance heavier paper is best used for handling and providing greater resistance, and in contrast, lightweight paper affords flexibility.
Design and graphic product
Design and developing of a graphic product such as a paper-pop-up, a mobile book, a paper-pop-up object, or interactive book (common definitions), is perhaps one of the most exciting and complex graphic design projects. Paper-pop-up books like The Elements of Pop-up (1999), One Red Dot (2005), and 600 Black Spots (2007), author David Carter (USA) exhibits intricate paper-engineering, and exquisite paper-pop-up design applications of folding paper. The Pocket Paper Engineer, Vol 2: Platforms and Props: How to Make Pop-Ups Step-by-Step (2008) by Carol Barton (USA) presents several techniques as does author Jackson in Cut and Fold Techniques for Designers (2014), where he explains cutting and folding techniques for paper-pop-up designs and its application towards structural packaging design. Interactive paper mechanisms resort to paper engineering and paper malleability as a support element towards creating a diversity of models that support the sharing of visual information, both written and iconographic. Despite massive digitalization of information, the paper-pop-up medium, is and most certainly will continue to be an area of design development due to its three-dimensional characteristics of archiving and displaying information, presenting an emotional visual experience on every occasion. Most paper-pop-up ignite emotions between subject and spectator, thus creating added value. It is worth mentioning students surprise when observing, creating, assembling, and finishing a paper-pop-up. As with any design project, the methodology used is known notwithstanding technical variables, experience, and acquired knowledge, towards a desired narrative that dictates the design process.

Methodology
This research has been developed through a qualitative methodology to explore and describe the bases of the problem that exists between artistic and creative knowledge interpreted in three-dimensional structures, and how these are related to graphic design, guiding it through a practical activity, such as the creation of a paper-pop-up and transfer of this knowledge to graphic design students. As Thomas (2000) mentions, it is appropriate to use a PBL methodology, based on project-based learning, to develop the professional skills of students, acquiring knowledge and applied methods, materials and techniques towards future designs and graphic creations. This pedagogical approach involves research, experimentation and communication to design and develop an original paper pop-up.

Paper-pop-up design
Design usually starts with sketching an idea, illustrating a concept and its variations, and further developing an idea, highlighting the process towards solutions. This requires understanding, intuitive problem-solving, purpose-driven solutions, towards flexible and sustainable solutions. Paper-pop-up design is more than an exploratory and conceptual exercise, it requires transdisciplinary knowledge in materials, tools, mechanisms, fasteners, movement constraints, and therefore developing creativity, spatial perception, and critical thinking towards the design of a folding three-dimensional memorable piece of communication. In a higher education context, specifically in a graphic design course, devising a paper-pop-up requires comprehensive skills such as: visual culture; creativity; sketching, descriptive and operative geometry; understanding of paper and cardboard properties; paper engineering; glues and fixation processes; vector drawing; modelling and prototyping; design an artwork; print and assembly; finishing process; and attention to detail throughout the process developing observation, interpretation, and representation skills, maturing creativity and design thinking. Students are encouraged towards exploration and problem-solving, through trial and error, research, reflection, and applied work to overcome challenges. In addition, sketching paper-pop-up design develops critical-thinking and problem-solving, consolidating learning outcomes regarding materials, methods, tools, processes, and designs, developing individual abilities in a practice learning sequence, Table 2.

Preparation and achievement
Regarding materials to build a paper-pop-up, one must consider structural strength and adequate folding and movement. Material selection is a critical factor for the success of your pop-up. It must be strong and resistant enough to support the movement and weight of the different parts of your pop-up. Before selecting one or another quality, it is important to carry out previous tests to be able to choose the most suitable one according to the

1. Related links: Pop-Up books, artist books, tunnel books, carousel books by Carol Barton (popularkinetics.com), Pop-Ups and Paper Construction | Carle Museum The Surprising History of Pop-Up Books | DailyArt Magazine 60 Paper Cut Artworks to Enhance Your Creativity Muscle | Inspirationfeed
The format of the paper: To make a prototype we will often use scraps of paper left over from other occasions. But in industrial production it is necessary to know the paper format and where the fibre direction is arranged to optimize the different pieces in the format of the selected material. We must consider that the different pieces will be arranged in the format to be printed, once the format has been printed: the surface treatment “varnish or lamination” will be applied to protect the print; the pieces will be die-cut to separate them; and in the consecutive finishes they will be manipulated and assembled to articulate the pop-up.

Bonding the parts: Adhesives and glues used to assemble the paper-pop-up are crucial, considering resistance of the parts and the flexibility and articulation of the parts. When considering the design of a pop-up, it may seem a complex task at first, but with due care and caution in our work it will be a rewarding task. To this end we should consider the criteria shown in Table 3.

### Table 3. Criteria for designing and creating a paper-pop-up.

<table>
<thead>
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<th>Safety induction</th>
<th>Work methodologies</th>
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<td>Complexity we are considering. Consider papers with long wood or vegetable fibres, which in principle will provide us with more flexibility and dimensional stability. It is also important to consider the porosity of the paper if we want the pieces to be printed.</td>
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### Table 2. Paper-pop-up practice learning sequence.

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<td>Material selection</td>
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<td>Paper folding techniques</td>
<td>Preliminary design and testing regarding movement, fold, paper-engineering, and three-dimensional communication piece</td>
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<td>Precision design</td>
<td>Accuracy is fundamental and facilitates several movements and folding’s of designs</td>
</tr>
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<td>Consider simplicity</td>
<td>Consider the movement of all parts and the overall look. Understand the limitations of the final paper assembly</td>
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<td>Design specifications</td>
<td>The design should describe ideas and messages distinctively in three-dimensions, and fold back into a two-dimensional structure</td>
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regarding mechanisms functionality should minimise resistance and enhance durability. Design of mechanisms requires accuracy and afford tolerances, in the end these depend on production, ultimately the quality of the pop-up is presented with fluid movements and exceptional craftsmanship considering paper or cardboard resistance. A paper-pop-up should communicate its structure and manipulation procedure clearly, identifying its information hierarchy flow. Furthermore, high-quality appearance reflects the quality of the materials used, printing technique, assembly, and finishing, thus captivating the audience.

The foundation for developing a paper-pop-up is the narrative, which specifies different mechanisms and functionalities, that need to be built, prototyped, and tested, regarding the relation with other elements and the overall page layout. Prototyping is a crucial stage to verify the narrative, checking tolerances, verifying adequate material resistance, seamless movement of the parts, and validating design adjustments. Adjustments are usually necessary and precede final artwork, this serves to test and guarantee that the paper-pop-up works appropriately.

Finalizing a paper-pop-up project requires specifications of materials, production processes, and assembly procedures, with technical drawings and images and auxiliary text. This allows validation and production and acknowledges competence of those involved, both in the design and execution, whether digital or offset print, regarding the choice of materials and finishes, and durability. Finally, production and assembly are conditioned by pre-press and printing. In this phase the production of the project’s elements, such as printing, cutting, assembling, and gluing the elements towards a viable paper-pop-up object.

Conclusions

Our applied research observed that paper-pop-up is a design technique used to create three-dimensional structures from flat materials such as paper or cardboard. The process of designing and building a pop-up involves a combination of technical and creative skills, which makes it an exceptional exercise in a HEI context. The pop-up offers students a tactile, hands-on design experience, as it involves manipulating materials and developing three-dimensional objects. This requires critical-thinking skills, curiosity, problem-solving skills, exploration through trial and error, research, reflection, and applied work. Design, whatever the medium, depicts ideas, devising concepts, and creative representations towards an output. In the end, a paper-pop-up is an efficient didactic exercise for design students, combining technical and creative skills, encouraging problem-solving and experimentation, providing a tactile, hands-on experience. Paper-pop-up exercises affords a series of skills, in a project-based learning context, 3D visualization and representation (sketching, schematics); tool dexterity and assessment (cutting, folding, attaching, etc.); understanding of paper mechanisms (fold, rotate movement and constraints); method; and eventually, a portfolio (book, greeting/celebration card, etc.). This encompasses material selection, detailed measurements, folding techniques, paper-engineering, and involving a wide array of design skills and promotes problem solving. From designing the tabs and folds to creating a sturdy structure, the pop-up design process requires the designer to identify and solve a range of complex technical and aesthetic challenges. It encourages experimentation and offers multiple creative and aesthetic possibilities, allowing designers to experiment with different materials, folding techniques and cutting techniques to create unique and attractive structures. Any higher education institution’s mission is to prepare individuals towards becoming future citizens, actively taking part in society, applying tools and methodologies, consciously solving human-centred issues towards an inclusive future for mankind and sustainable development, mirroring these into the curriculum.
Bibliographic References