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BioForm – learning at the intersection of science and design

BioForm – aprendiendo en la intersección entre ciencia y diseño

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Reflection paper

Abstract

Our future designers have much to learn from the complex and highly functional systems found in nature. Creating design products that are not only human-centred but also in tune with the natural world requires our designers to be exposed to natural phenomena and scientific principles. To provide design students with a starting point, we have created BioForm: a bio-inspired design module run as part of the Product Design curricula at the National College of Art and Design (NCAD), Dublin, Ireland. The module is delivered by an interdisciplinary team of designers and scientists who expose students to biologically inspired theory and practice through a series of lectures, workshops and site visits, aimed at encouraging bio-inspiration in their design practice. The students, with their growing understanding of bio-inspiration, are then challenged to design a chair, which allows them to playfully explore form and function, and to consider its impact on their design. We hope that by encouraging bio-inspiration in students' practice they produce designs that are innovative and more environmentally sustainable. This paper reflects on the BioForm project's pedagogical approach, its impact on the student's design practice and proposes further developments for the module.

Keywords: bio-inspired design, biomimicry, product design, learning beyond the studio, design and science, cross-disciplinary team

Resumen

Nuestros futuros diseñadores tienen mucho que aprender de los sistemas complejos y altamente funcionales que se encuentran en la naturaleza. Crear productos de diseño que no son solo antropocéntricos, sino también sintonizados con el mundo natural, requiere que nuestros diseñadores estén expuestos a los fenómenos naturales y a los principios científicos. Para proporcionar a los estudiantes de diseño un punto de partida, hemos creado BioForm: un módulo en diseño con una bio-inspiración, el cual forma parte del programa de Diseño de Producto del National College of Art and Design (NCAD), en Dublín, Irlanda. El módulo es dictado por un equipo interdisciplinario de diseñadores y científicos que exponen a los estudiantes a una teoría y práctica basada en la biología, a través de una serie de conferencias, talleres y visitas a sitios, con el objetivo de fomentar la inspiración biológica en su práctica de diseño. Los estudiantes, con su creciente comprensión sobre la bio-inspiración, son entonces desafiados a diseñar una silla, lo que les permite explorar la forma y la función lúdicamente, y considerar el impacto en su diseño. Esperamos que al fomentar la bio-inspiración en la práctica de los estudiantes, produzcan diseños innovadores y sostenibles desde el punto de vista medioambiental. Este trabajo analiza el enfoque pedagógico del proyecto BioForm, su impacto en la práctica de diseño del estudiante y la propuesta de futuros desarrollos para el módulo..

Palabras clave: diseño con bio-inspiración, biomímesis, diseño de producto, aprendizaje más allá del estudio, diseño y ciencia, equipo multidisciplinario.

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Introduction

Nature, through billions of years of trial and error, has created organisms that are highly fit for their place in the world. Outstanding examples of such organisms include, Darwin's bark spider, which spins silk tougher than steel, the Golden-fronted woodpecker with its shock absorbing tongue that wraps around its skull, and octopuses, which are capable of changing their skin colour to create perfect camouflage and communicate with potential mates. Organisms such as these have long inspired scientific and technological discovery (Bar-Cohen 2005). More recently, there has been growing recognition among the design community that nature can inspire innovative and more sustainable product design (Myers 2012).

Perhaps the most famous example of biologically inspired (bio-inspired) design is the hook-and-loop fastener Velcro, invented by Swiss engineer George de Mestral in the 1940s. The story goes that de Maestral discovered the mechanism behind Velcro after noticing some burdock plant seeds attached to the hair of his dog. Close inspection of the seeds revealed that they were comprised of small hooks, which had latched to the loops formed by the dog's hair. Since Velcro, a growing number of bio-inspired designs have been commercialized such as ultra-quiet and efficient wind turbine blades inspired by the bumpy protrusions on humpback whale fins (Howle 2009), shape-optimized automobile components inspired by the growth and structure of trees and bone (Mattheck 1990) and extreme winged suits inspired by flying squirrels (Higgins 2015).

Despite growing interest in bio-inspired design, design departments still focus by on Human Centred Design (HCD) to uncover unmet opportunities. By working with scientists to develop and deliver engaging bio-inspired course content, design educators can empower students to integrate bio-inspiration in their practice to support the design of innovative and more sustainable products and systems. In this paper, we present BioForm, a bio-inspired design module run as part of the Product Design curricula at the National College of Art and Design (NCAD), Dublin, Ireland. Herein, we present an overview of the module's pedagogical approach and consider its impact on the student's design practice.

Module overview

BioForm is a two-week bio-inspired design module that exposes second-year students to biological principles and recent advances in bio-inspired design practice. The modules' content is delivered through a series of lectures, workshops and site visits aimed at igniting the student's recognition, wonderment and respect of biology; and ultimately encourages bio-inspiration to be included in their design practice.

The modules main theoretical content is delivered through a series of lectures. In 'What is bio-inspired Design?' and 'Learning from Nature: How biology can inspire innovative design and engineering solutions', Damian Palin, a bio-inspired material scientist, introduces bio-inspired design theory, and presents examples of inspiring organisms and cutting-edge design practice. This includes his own work on the development of casting (Myers 2012), bacteria-based self-healing concrete (Palin et al. 2016; Palin et al. 2017) and bio-inspired material synthesis (Figure 1a). In 'Bio-ideation' and 'bio-inspired materials and processes', Enda O'Dowd, a material scientist and lecturer at the NCAD, presents strategies for how nature can be used as a creative tool for idea generation. Students are introduced to AskNature: an online database of biological design and system strategies created by the Biomimicry Institute (2019). They are then asked to explore the database to find examples of how nature solves particular design challenges. Students are also introduced to biological materials, including chitin, cellulose and calcite and are shown how to compare their properties with more conventional materials using the CES Edupack (Figure 1b; Granta Design 2019).

In the lecture *From Architectural Design to Molecular Scale: A Collaboration Between the Arts and the Sciences*, Ferdinand Kohle, a materials scientist, shared how a team of artists, designers and scientists developed iridescent window panes for the sculptural installation titled *A Needle Woman:*

Figure 1. Module content. Images of: a. The lecture 'Learning from Nature: How biology can inspire innovative design and engineering solutions'; b. A screenshot from the CES EduPack presented in the lecture 'Bio-inspired materials and processes' (Granta Design 2019); c. 'A Needle Woman: Galaxy was a Memory, Earth is a Souvenir' (Chong 2015) from the lecture 'From Architectural Design to Molecular Scale: A Collaboration Between the Arts and the Sciences'; and visits to d. The Botanical Garden; e. The Natural History Museum, Dublin, Ireland; and f. The Mindful Nature workshop.

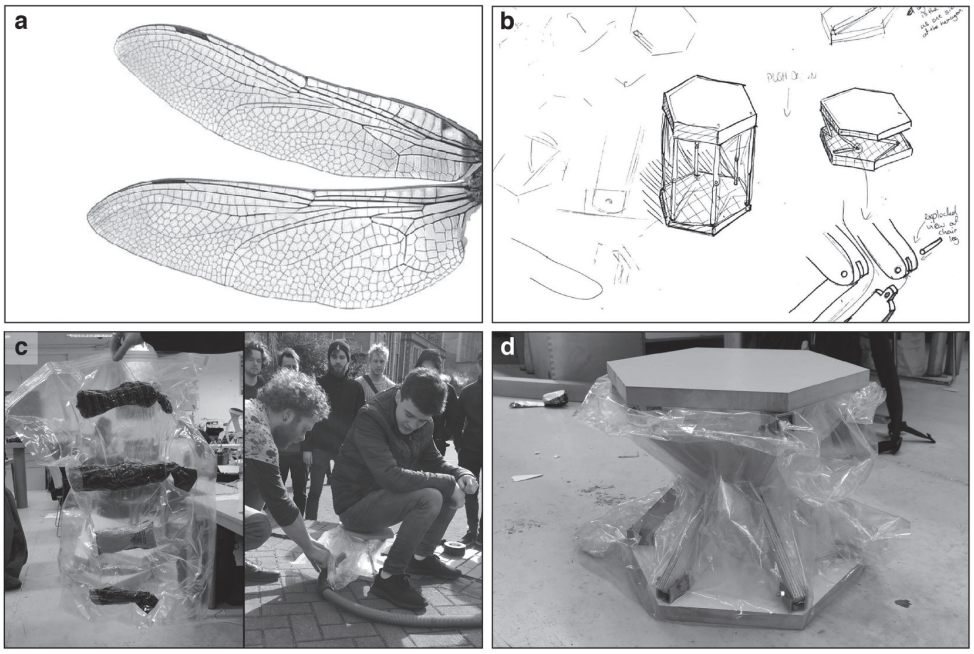

Figure 2. An example of a student groups design process and output. The group's chair was inspired by sprouting insect wings, which they abstracted to vacuum forming. Images of the groups: a. Research; b. Ideation; c. Prototyping, process; and d. Final chair.

Galaxy was a Memory, Earth is a Souvenir (Figure 1c; Chong 2015). The panes were produced by applying a novel iridescent polymer coating — inspired by the structural colour found in bird feathers and butterfly scales — to clear a plastic film via a simple screen printing-like process. The project highlighted how conversations between the arts and the sciences can vastly extend the creative space of artists and designers, while, at the same time, provide scientists with new perspectives for their own research.

The module also seeks to encourage the student's wonderment and appreciation of nature beyond the studio. This is achieved by taking the students on curated visits of the National Botanic Gardens (Figures 1d) and the Natural History Museum (Figure 1e), Dublin, Ireland, which allow the students to experience nature first hand. To connect this experience to bio-inspiration, while on the visits, plants, animals and insects that have encouraged bio-inspired products and technologies are pointed out.

As part of the visit to the National Botanic Gardens, the students took part in the workshop *Mindful Nature* given by Yeşim Tunali: an ecologist and outdoor learning facilitator. Yeşim invited the students to do a series of mindfulness exercises including breath awareness, a short body scan, and five senses meditation, during which, they were asked to focus on different sensory inputs from their surroundings, such as hearing different bird songs and using touch to explore different textures on the ground (Figure 1f). Students were then asked to find an interesting natural artefact in the gardens and then to make a list of open questions about their artefact, without any expectation of providing answers. Afterwards, the students were invited to use senses other than vision, such as touch and smell, to explore the same artefact. Again, they were asked to generate a set of questions, to expand their sensory perception and "naturalist intelligence" (Gardner 1999). This exercise, inspired by the inquiry-based learning approach, aims to encourage child-like curiosity, creativity and big-picture thinking.

Students are then tasked to design, develop and test a chair influenced by their growing understanding of bio-inspired design (Figure 2a-d). During this process they are challenged to consider the influence that their bio-inspired approach has on the form, function, performance, production process and environmental impact of their designs. The final chairs were exhibited in the NCAD to be able to engage with colleges in the broader design community.

Pedagogical approach

This section provides an overview of common teaching and learning models associated with Product Design education and reflects on the novel aspects of BioForm's pedagogical approach.

Product Design education generally takes a practice-based teaching approach. It emphasises the hands-on application of knowledge in the context of authentic tasks: a pedagogy that is rooted in a long tradition of project-based, experiential learning (Dewey 1938; Papert 1993). Learning is often focused on problem-solving and an exploration of a particular line of inquiry (Cross 1990). Design education is centred on learning through doing and usually through the simulation of a professional situation by means of a project brief (Tovey 2015). Project briefs are generally open-ended and designed to support a wide range of outcomes. The combination of a defined starting point with open outcomes supports a balance of goal-oriented problem-solving and blue-sky thinking. Learning generally takes place in an open studio environment supported by a workshop space. This environment fosters shared and peer-to-peer learning and the development of a common body of knowledge across the student group. There is a continued focus on learning from the teachers and the group. This form of teaching aims to provoke students to generate new and innovative content through practice that values risk-taking, questioning the status-quo, empathy with human experience and environment, and informed intuition (Cross 1990).

Education at the intersection of science and design

The BioForm project assembled an interdisciplinary teaching team that includes product designers, material and biological scientists to deliver a collaborative learning experience that built on the pedagogical approach outlined above and supported learning both in and beyond the studio. The module combines lectures, workshops, group tutorials, site visits and peer-to-peer learning to provide a scaffolded learning experience for the students. In the early stages of the module, the students are exposed to scientific concepts, tools and terminology that are very different to learning generally associated with Product Design education. Embedding science education in a design module requires careful consideration in terms of how students familiar with studio-based design learning can engage with scientific phenomena. In this context, it was very important that our science educators use the right language for their audience. Examples of structured play, prototyping and real-world application of material technologies in a scientific context are introduced and linked to contexts that the students are familiar with. An example could be the similarity between the production of the bio-inspired iridescent panes and the perhaps more familiar screen printing process shown by Ferdinand Kohle (vide supra). By delivering the biological and scientific content in a more accessible and design driven way, we help students link this new knowledge to their existing design knowledge base.

Complementing a Human Centred Design process

Product Design projects often adopt a HCD approach. HCD prioritises a strong engagement with primary research to identify and understand human needs, followed by a prototyping process that is informed by user testing and feedback to develop design outcomes. Whilst this anthropocentric approach is very effective at solving design challenges associated with a human need, it does not always seek to understand and be informed by the complex and highly functional systems, structures and natural functions that already exist in nature. This approach, if overly focused on human needs, may result in a design process that misses out on innovative opportunities or is less in tune with environmental needs. The BioForm module offers a starting point for student investigation that is informed by the patterns found in nature rather than human behaviour patterns. This is not to say that the students did not consider human factors in their furniture design, instead these factors did not dominate the initial research and concept generation phase of the module. It was hoped that by taking this approach students would create designs that are more in tune with an already optimised natural world, resulting in efficient material use and reduced environmental impact.

Experiential learning beyond the Studio

Learning during the module took place both in and beyond the studio space. Whilst much of the module was delivered in a studio-based learning space, we also wanted to make sure that the project would be grounded in real-world engagement with nature. To support this, we developed a series of site visits and associated taught-content designed to help the student groups engage with different natural phenomena and contexts (vide supra). In each of these visits, students were provided with a series of methods and tools that they were required to use to document and reflect on their experiences. For example, the exercises delivered by Yeşim Tunali sought to support an enhanced sensory engagement with natural surroundings. This form of experiential learning positioned students outside a more familiar HCD process and sought to help them better engage with the natural world as a means of informing their concept generation.

Reflecting on Practice

The BioForm the project culminated in students designing and developing a series of chair prototypes inspired by some element of biology. The students publicly tested their final designs on campus and discussed the functionality, strength to weight ratio and level of bio-inspiration of their designs. They were asked to reflect on their practice, the context within which they worked and their final design outcomes. This informal public testing (in some cases to destruction) and showcasing of successes and failures, facilitated shared learning and knowledge exchange for both the teaching team and student group.

Project feedback and learning

This section reflects on a series of interviews with students who have completed the Bioform module. It considers how the module has affected the student's design practice and how the teaching and learning environment could be improved in future.

Impact on the student's design practice

The primary goal of the BioForm project was to empower students to have the confidence to investigate bio-inspiration to help their design. In order to reflect on this goal from a student perspective, we conducted interviews with two student groups that had completed the module in the past two years. We asked the students about their understanding of bio-inspired design, their perception of the value a bio-inspired approach might have for design and how they might incorporate this approach into their work. When asked about the students understanding of bio-inspired design, they spoke about how this had developed over the course of the module, "We started to evolve from wanting to mimic natural forms, to more about learning from nature and translating this understanding into physical forms" (A. Hennessy, personal communication, May 13, 2019) and "We thought initially that the design had to look bio, look like nature. Then we realised that it could be inspired by principles in nature rather than just look like nature" (A Kelly, personal communication, May 13, 2019). The students had developed a clear sense of the value that a bio-inspired approach could bring to design. "If you have a certain problem to solve in design then you can look at how nature has solved that problem before" (D Keating, personal communication, May 13, 2019) and "Nature works completely as a system, everything has its place, it all feeds into each other. Humans don't currently fit into that system. We can look at nature and design to fit back in where we should be" (A Conneely, personal communication, May 13, 2019). However, what was less evident was a sense that they had incorporated bio-inspiration into their subsequent design projects. Students spoke of needing more explicit direction towards a bio-inspired approach in subsequent briefs, "It would be good to have a checklist before starting a project 'Why not look into this area…'" (A Conneely, personal communication, May 13, 2019) and also how they found it difficult to engage with nano/micro scale structures due to their general lack of visibility, "It's difficult to see because a lot of it happens on a minor level. Maybe the availability of high definition images of structure might help. You can't see the micro level" (A Coleman, personal communication, May 13, 2019). These interviews suggest that whilst the students gained an understanding of a bio-inspired design approach, the module may benefit from some changes to support a deeper integration of this approach in their design learning and practice.

Proposed module developments

Based on the student's feedback and our own experience, we feel that the module would benefit from some changes to the teaching approach and learning environment.

The learning environments associated with the two-week BioForm module supported a wide range of teaching methods and modes of engagement for the student group. However, in order to better support learning at the intersection of design and science, we feel that a more collaborative approach might be required that supports the design students to engage with students from other disciplines such as biological sciences. Similarly, the students, for the most part, remained within a familiar design-school-learning-environment and did not have access to scientific analytical equipment. Future BioForm modules should consider linking students to biological disciplines and environments such as the Nano Research Facility in Dublin City University, Ireland (Nano Research Facility, 2019). Further, the increased democratisation of science labs and equipment, as evidenced by Brooklyn's citizen lab Genspace (Genspace 2018) and the biohacker movement, suggest scope for integrating some of the scientific tools and techniques, previously limited to established scientific labs, in a design workshop setting. This would provide students with a more accessible platform to explore biological systems and structures, and, in doing so, further integrate bio-inspiration into their ongoing design practice.

Conclusion

In this paper, we have presented BioForm: a bio-inspired design module run as part of the Product Design curricula at the NCAD. The content is delivered by an interdisciplinary team of designers and scientists through a series of lectures, workshops and site visits aimed at inspiring the student's recognition, wonderment and respect of biology, and ultimately encouraging bio-inspiration in their design practice. We have found that the students gained a meaningful understanding of bio-inspired design and that they see the value of integrating it into their design practice. As we look to evolve and improve the BioForm module, we envisage BioForm 2.0 to be a collaboration with a biological science department, which takes the shape of a shared project between product design and biological science students. This type of shared project would provide design students with a platform to explore biology, and, in doing so, further integrate bio-inspiration into their ongoing design practice. We feel that the integration of bio-inspiration in design curricula can enable future designers to become the agents for a more sustainable future. Furthermore, we hope that by sharing this module we can help other design departments incorporate bio-inspiration into their curriculum.

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