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HOW DO DESIGNERS IMPACT THE BIOMIMETIC CONCEPTS TYPOLOGY?

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ABSTRACT
Biomimetics has undergone an increasing development over the last decade. Most of the conducted research relative to its operational practice has focused on the formalization of biomimetic processes and the development of tools adapted to the specificities of biomimetics. Here we adopt a complementary point of view: the analysis of the impact of the profiles composing the biomimetic design teams. This article focuses more particularly on the analysis of the impact of the involvement of designers from artistic and industrial backgrounds, on the typology of biomimetic concepts generated from biological information. This study was carried out through a student experiment that compares the biomimetic concepts generated by teams composed either of engineers or a mix of designers and engineers. We studied these concepts according to 4 criteria: the number of concepts generated, originality, feasibility and finally their contextualization.
This analysis allowed us to identify new relevant skills – designers skills -to be integrated in the training of biomimetic practitioners and especially in that of a new profile: the biomimetic "mediator" profile.

Keywords: Biomimetics, interdisciplinarity cooperation, design education, designers' skills

1 INTRODUCTION

Biomimetics, which involves solving practical problems "*through the function analysis of biological systems, their abstraction into models, and the transfer into and application of these models to the solution*" [1], has undergone increasing development over the last two decades. Such growth can be illustrated by the multiplication of scientific papers and the exponential evolution of related patents [2], [3]. In order to make biomimetic a standardized innovation strategy, most of this research effort has been targeting the formalization of biomimetic processes [4]–[7]. Based on these initial studies, further works have established a global process for the generation of biomimetic concepts [7]. In parallel, tools adapted to biomimetics' specificities have been developed. They can be sorted into four main functional categories : (i) analysis tools, to study and understand, the initial problem or biological models, (ii) abstraction tools, to guide the modelling of biological data, (iii) transfer tools, to facilitate the iterative transfer from biological knowledge to technological knowledge, and (iv) application tools, to formalize bio-inspired concepts [7]. Despite this significant progress, research studies investigating the question of biomimetic design teams' composition are still limited. Such research axis however appears fundamental since collaboration between professionals from design and biology is underlined in the literature as a key success factor during biomimetic projects [8]–[10]. The difficulties linked with the implementation of collaboration appear to be associated with the lack of a common language and common methodologies between disciplines [8], [9]. Therefore, we believe that the establishment of an interdisciplinary language to translate and transfer knowledge between the different actors and experts during a biomimetic project is a key success factor.
Biomimetics is a complex approach that goes beyond simple share of knowledge and ideas [8]. Indeed, beyond this exchange, there is a need of understanding and assimilation by the entire project team to efficiently generate innovative biomimetic concepts. Therefore, it seems important to study, as a complement to current research axes, the role and impact of the profiles which compose biomimetic teams and thus attempt to identify some key levers that favour interdisciplinary cooperation.

In the literature, a few profiles have recently been studied: biologists [10]–[13], architects [6], [14] or engineers [15]. However, only few studies focus on designers with an artistic and industrial background. Indeed, in the framework of biomimetics, designers seem to be often considered along engineers and seen as one and the same profile in biomimetic projects. In this article we underline that this grouping prevents researchers from highlighting the richness that these two profiles can bring to biomimetic design. Based on these observations, the research question arising is: does the designer impact differently than the engineer the typology of biomimetic concepts generated from biological information?

Therefore, we propose to explore, through an experimentation, the differences between biomimetic concepts generated on one side by teams only composed of engineers and on the other side by teams composed of engineers and designers. The objective of this research is to understand whether the presence of designer (from artistic and industrial backgrounds) impacts the typology of biomimetic concepts generated from biological information. Therefore, these results should also lead to the identification of key elements to be considered for the development of education and training programs in biomimetics.

2 FOCUS ON DESIGNERS' PROFILE

This article focuses on designers for two main reasons:

- First, according to literature, designers acquire, during their training, a set of skills of interest to improve interdisciplinary collaboration and communication. They (A) create cognitive bridges between different knowledge [16] ; (B) overcome cognitive fixations [17] ; (C) materialize and contextualize ideas and knowledges through artefacts, representations or use cases [18]–[21] ; (D) challenge other profiles' perceptions on their data by being exposed to designers' representations [18] ; (E) help other profiles to understand and generate ideas [18] ; (F) Facilitate the communication and the outreach of the project [18] ; (G) identify appropriate stakeholders for the smooth-running of the project [22].
- Second, modules dedicated to biomimicry have been integrated in design universities. In North America, five of the nine universities partnering with the American Biomimicry Institute are art and design universities [23]. In France, the first master's degree in biomimicry and design opened in January 2020 at ENSCI Les Ateliers, a school of industrial design. This master's degree combines courses delivered by interdisciplinary experts from biological and design fields with the so-called "classical methods" of design education.

Although, previous research studies have already underlined designers' contribution in companies [24], in particular with regard to innovation [24], no research has yet been conducted to determine their contribution in the specific framework of biomimetics. In this article we will study the following research question: **do designer impact differently than engineer, the typology of biomimetic concepts generated from biological information?**

In this context, we designed an experiment involving a set of students.

3 PROTOCOL

We conducted an experiment with 46 students divided into 14 groups during 3 half-day workshops. On these 14 groups, 7 groups included designers as well as engineers and 7 groups consisted only of engineers.

Each session was conducted with the same protocol. A week before the experiment, a set of bibliographic references on biomimetics was sent to the students. Then during the experiment the students were asked to address the topic of "the future of packaging design" by following the eight steps of the unified problem-driven process of biomimetics [7]. For this purpose, they were provided with a set of worksheets detailing these steps and the associated questions.

This article only focuses on step 7 (Transpose to technology) and step 8 (Implement and test in the initial context) of this process [7]. In this study, we want to analyse whether the presence of a designer has had an impact on the number and typology of concepts resulting from a biomimetic process.

To do so, we compared the results according to 4 criteria. We focused on (1) the number of concepts generated by each group in order to determine their capacity to generate solutions [17], (2) the originality (i.e., the quality of the produced ideas[17], [25]), (3) the feasibility of each idea sheet and finally (4) their contextualization (i.e. to consider concepts within their context). It should be noted that none of the students were informed of these analysis criteria.

The analysis was performed by 8 experts (researchers in biomimetics), who evaluated each idea sheet on a 6-point Likert scale, from 0 ("not at all original" / "not at all feasible") to 5 ("very original" / "very feasible"). They were also asked to indicate whether the concepts were contextualized.

4 RESULTS

The results obtained from our student experiment are compared by a Chi-2 test or a T-test depending on whether the variables are quantitative or qualitative. Only the most significant statistical results are presented in this article, for the sake of readability and space:

Table 1. Number of concepts generated by groups with or without designers (left part) and Impact of designers on the contextualization of concepts (right part)

Group number	1	2	3	4	5	6	7	TT	Average
Group with designer(s)	4	3	1	3	2	3	4	20	2,86
Group without designer(s)	3	2	2	2	1	2	3	15	2,14
p-value (Unpaired; t-test) = 1,67.10-01									

Ideas with context	Ideas without context
97	63
38	82
p-value (Chi-Square Test of Independence) = 2,89.10-06	

Regarding the number of solutions (Table 1, left part) that were provided by each group, the unpaired t-test did not reveal a significant difference between groups with designers and groups without designers. Regarding the contextualization of concepts (i.e. to consider concepts within their context) (Table 1, right part) the Chi-Square test of Independence indicates a significant difference between groups with and without designers. As a result, groups who integrate designers showed a significantly higher ability to contextualize and give a holistic vision of concepts.

Table 2. Impact of designers on concept originality and feasibility

	Originality					Feasibility				
Likert scale	1	2	3	4	5	1	2	3	4	5
Group with designer(s)	8	34	36	55	27	23	46	37	44	10
Group without AID	23	29	44	16	8	18	32	28	29	13
p-value (Chi-Square Test of Independence)	4,24.10-07					7,04.10-01				

Regarding originality (see Table 2., left part), the Chi-Square test of Independence indicates a significant difference between groups with artistic and industrial designers and groups without designers, group with designers obtaining a better evaluation. This seems to show that the integration of a designer has a significant impact on the originality of the generated biomimetic concepts. Regarding our results on feasibility (see Table 2., right part), the Chi-squared test of Independence do not suggest any differences between groups with or without designers.

Four major impacts emerged from this investigation:

- Groups with and without designers show differences in the quality of generated concepts.
- As described in the right part of Table 1, groups with designers have mostly presented their ideas within a context, and they thus bring a systemic vision of the solution (link with environment, user, the use, practice …).
- Groups with designers proposed statistically more original ideas than groups without designers (Table 2., left part).
- For other criteria, number of concept and feasibility (Table 1., left part and Table 2., right part) no significant difference between both groups was observed.

5 CONTRIBUTION OF THE RESULTS FOR THE DEFINITION OF A BIOMIMETIC “MEDIATOR” PROFILE

We remind that despite the increasing development of tools for interdisciplinary cooperation in biomimetics [7], few are used in practice [26], [27]. Moreover, the increasing number of tools classically leads to an unclear path that makes the design team unclear which one to use and when [7], [11]. This

leads us to believe that most tools are relevant but are not sufficient to overcome the challenges of biomimetics.
The scientific literature encourages another way to complement the creation of these tools: the integration of a "mediator" profile that would facilitate interdisciplinary cooperation to generate and develop innovative biomimetic concepts [28]. This proposal is corroborated by Chirazi et al. who stressed the need to work with profiles having strong interdisciplinary capabilities, thus raising the issue of teaching and training of profiles involved in the biomimetic approach [9].
To define the knowledge and skills of this new "mediator" profile, the competences present in biomimetic projects are currently being studied [11], [12], [29]. Graeff et al investigated the biological expertise and engineering knowledge to be combined through this new profile [10].
Our study allowed us to identify new essential skills, from those of the designer, especially the skill “materialize and contextualize ideas and knowledges through artefacts, representations or use cases” [18]–[21], to be integrated in the training of this "mediator" profile and of the biomimetic practitioners. these skills are shown here to promote the generation of original and contextualized biomimetic concepts.

6 DISCUSSION & CONCLUSIONS

This research proposes to focus on the impact of designers from artistic and industrial backgrounds on the generation of biomimetic concepts. Initially, we identified in the literature seven skills of interest acquired by designers. In a second step, thanks to a student experiment, it was demonstrated that the integration of designers in a design team had a significant positive impact on the contextualization and originality of the generated biomimetic concepts. Moreover, despite the absence of significant results in terms of the number of concepts developed, it is noted that groups with designers proposed 5 more concepts than groups composed solely of engineers. The time of the experiment being limited, we can suppose that this criterion could have been significantly positive if the students had had more time to generate biomimetic concepts.
These first results allow us to complete the skills of interest to be trained to future biomimetic practitioners, in particular the new "mediator" profile recommended by the literature [28]. These skills can be integrated thanks to the implementation of targeted modules resulting from the training of designers. As our study shows us, these skills can promote the generation of original and contextualised biomimetic concepts. These two criteria seem to be elements facilitating the biomimetic process because they illustrate the good understanding of the initial problem and the presence of a good hybridization of contextual knowledge with biological knowledge, hybridization necessary to generate efficient biomimetic concepts.
This paper is a basis for future work to define the knowledge, skills, and role of a new biomimetic expert "mediator" profile. It should be noted that these results are the first of a more complete analysis of the contribution of designers to the deployment of biomimetics in design practices. Our future work will aim to test in more detail the impact of the skills developed by designers on all steps of the biomimetic process. Indeed, to further support the results obtained in this first experiment, we will carry out additional analyses based on industrial projects carried out and supervised by Ceebios (the French network of biomimicry expertise). Indeed, we were able to observe empirically that when one or more designers were integrated into the project team, interdisciplinary cooperation seemed to improve. We will develop this research in a future article.
To conclude, we identify two main research axes in terms of education to train future biomimetic practitioners:

- Collect more information on the impact of designers in biomimetic design reasoning to complete and identify the teaching modules to be included in the training of the "mediator" profile. As this profile is currently being formalized, we propose to integrate, in future research, designers in biomimetic design teams to deepen their contributions.
- To continue the research concerning the profiles currently present in biomimetic projects (engineers, sociologists, ergonomists, researchers ...) to complete the training required to become a "mediator" profile expert in biomimetics. For example, in our experience, we have found that the production of biomimetic concepts is more efficient when engineers and designers know each other previously, which reinforces the idea of combining interdisciplinary skills in the training of a "mediator" profile, expert in biomimetic.

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