Interdisciplinary Practice in Industrial Design, Vol. 100, 2023, 87–92
https://doi.org/10.54941/ahfe1002974

Leveraging Biologically Inspired Design as an Effective Instructional Strategy

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ABSTRACT

The project(s) addressed by this paper have been undertaken by graduate students in the MID program within the School of Industrial Design at the Georgia Institute of Technology. Georgia Tech offers both two and three year graduate programs, the longer program being intended for students without undergraduate training in design. As such, they lack basic design skills or familiarity with the design process. This prerequisite "certificate year" of studies is comprised of two semesters, intended to help students develop the skills and understanding needed for the subsequent two years of study. Most of the initial semester is focused on basic design skill building – specifically form, proportions, spatial relationships, structure, problem definition, user research, basic anthropometry, 2D visualization and model fabrication to name a few. The first opportunity for students to apply these skills to a complete project has traditionally been a lighting-themed design project in which biologically-inspired design (BID) is used as a model for developing design solutions. Since 2013, this BID approach has been applied in 8 of 11 years, to projects undertaken by 72 graduate students, collaborating with professors from *Georgia Tech's Center for Biologically Inspired Design* who introduce the concept of biologically inspired design, discuss case studies where the BID process has been particularly effective, and to provide input & feedback throughout the design process to help guide the students as subject matter experts (SME) on BID. Students are given a project brief that details how students must identify a lighting-related problem and a biological inspiration that can be leveraged in solving the problem through design, along with specific project requirements. In an effort to facilitate identification of a biological inspiration, the class typically visits the local zoo or aquarium as a group with a focus on the unique characteristics of different organisms that might be utilized or emulated to innovate effective design solutions. This break from the routine has typically been both motivating and fun for the students who become very engaged in this project. While there are numerous approaches to the design process (i.e. Double Diamond, Circular Design Process, Design Thinking, Engineering Design Process etc.) using BID as a model for introducing the design process to new students has proven to be particularly effective. The final deliverables resulting from this effort frequently are outstanding – despite the fast pace of this project. This paper details how Biologically Inspired Design (BID) has been used successfully as a means of introducing the design process to graduate students.

Keywords: Biologically inspired design (BID), Industrial design, Subject matter expert (SME), Smart product, Proof-of-concept prototype

INTRODUCTION AND BACKGROUND

Biologically Inspired Design (BID) is an approach to design that involves using examples found in nature as an archetype for solving various design problems. The essence of this approach is to understand how & why biological organisms address their needs in a particular way. This approach is to be distinguished from biomimicry in which the form or appearance of a biological organism might be simply "imitated" without consideration of how/why the organism behaves or it's physical appearance is configured in a particular manner.

This paper details how a BID assignment has been utilized to introduce students to the design process and how it has proven to be a particularly effective and well-received exercise.

Biologically inspired design is an approach which uses analogies from biological systems to generate solutions in engineering and other design fields. It has become important tool for innovation and sustainable development from design practice, manufacturing, engineering and many others (Bosner 2006, Bosner and Vincent 2006, Kubota et al. 2006). Many examples can be found that use BID in teaching engineering and innovation. In this context BID has been shown to increase the novelty and variety of solutions generated by experienced students (Nelson, et al. 2009, Helms, et al 2009, Yen, et al 2011).

The contribution explored here is the use of BID as a first entry point for students with no prior design training to learning iterative, evidence-based design methodologies. BID by nature is multidisciplinary by nature that requires some understanding of systems and processes in biology and the ability to apply that within a different domain. The ability to synthesize information across different fields and identify opportunities for use between them is the kind of skill designers seek to develop and is a component in many innovations.

METHOD

Human At the outset of the project, professors from *Georgia Tech's Center for Biologically Inspired Design* introduced the principles of biologically inspired design to the students, showing examples and case studies of how various examples in nature had been effectively leveraged to create solutions to common problems. The project was then introduced to the students through a written brief that outlined the design goals & requirements of the assignment. In short, students were charged with identifying a lighting-related problem to address with their designs and a biological inspiration that could be used as a model for how to address the chosen problem.

The entire class then visited the Atlanta Zoo as a group in order to observe how animals have unique characteristics that help them address different aspects of their existence (i.e. avoiding predation, facilitating movement or feeding, attracting mates, etc.). While some students identify specific animals to leverage in engaging their chosen design problems during this visit, the intent of the zoo visit is to help students better understand how to select their bioinspirations.

Students initially performed background research in order to identify both a lighting problem to be addressed through design and a biological inspiration that could serve as a model for how the lighting problem might be solved (Figure 1). The intent of this research is an accurate definition of the problem, the understanding of relevant design requirements and objectives, and an appreciation of how the biological inspiration solves a similar problem. As a part of this background research, students identified key stakeholders, relevant materials and technologies, competitive products as well as compensatory solutions that might exist, user needs, "pain points" inherent in the lighting problem, etc.. Students presented the results of this initial research to an audience including representatives from *Georgia Tech's Center for Biologically Inspired Design* to confirm that the choice of lighting problem is a suitable design problem and that their choice of a bio-inspiration is appropriate for their chosen problem. Typically this is a "Go/No Go" point in the process where students are advised to modify the scope of their chosen problem or alternative organisms are suggested for use as their biological inspiration.

At this point, students start their design ideation, working in both 2D "thumbnail" sketch and 3D study model formats. Morphological matrices were utilized for "mapping concepts" from the initial ideation (Figure 2). Each student developed 3 alternative concepts for addressing their chosen problem, presenting them to an audience including representatives from *Georgia Tech's Center for Biologically Inspired Design* to identify the most promising direction.

The agreed-upon design concepts are subsequently refined in terms of included features, appearance, manufacturability and usability. Students are required to detail how their designs might be ultimately be configured for production and to fabricate "proof of concept" prototypes that permit demonstration and testing of key operational aspects (partial or complete) of their proposed solutions (Figure 3). CAD models are typically used to illustrate design intent for the appearance and assembly of the final production version of their design solutions. "Proof-of-concept" prototypes can vary from simple lighting devices powered by alternative power sources to more complex systems that incorporate sensors & *Arduino* type processing to provide "smart product" functionality. Storyboards are usually prepared to communicate the sequence of use, showing how the proposed designs might be used.

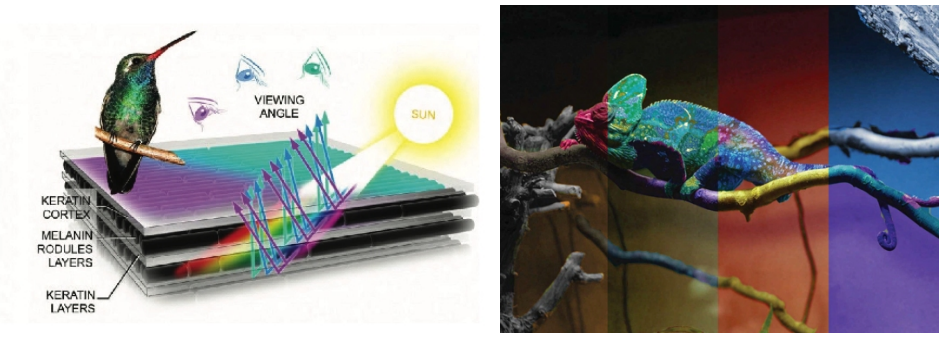

Figure 1: Supporting research infographics.

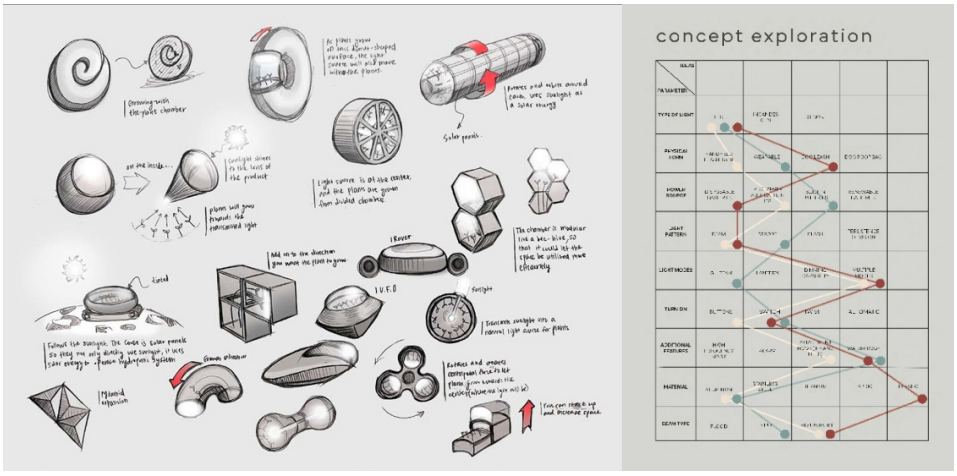

Figure 2: Example of thumbnail ideation sketches & morphological matrix used for "Concept Mapping" of results from initial ideation.

Figure 3: CAD model of proposed design & proof-of-concept prototypes.

RESULTS

Student design solutions developed and submitted as a part of this BID Assignment over past years were assessed following a common three-point rubric.

Each proposed design solution was evaluated in terms of (1) whether the design solution successfully addresses the chosen problem; (2) whether the design solution makes appropriate use of the chosen bio-inspiration; and (3) whether the design solution was convincingly demonstrated by the proof-of-concept prototype? Each question was answered on a scale of 1–5 with "1" indicating "not at all" and "5" indicating "yes/effective/complete", which was used to derive an assessed value for the overall level of completeness for the design (Table 1).

Table 1. Comparison of results from Project over 8 semesters it has been assigned.

Academic Semester:	Number of Student Projects:	Average Assessment (% Complete):	
Fall 2013	11	4.18	84%
Fall 2014	7	3.95	79%
Fall 2015	14	4.04	80.9%
Fall 2019	7	3.67	73.3%
Spr 2019	10	4.3	86%
Fall 2020	7	3.8	76.2%
Fall 2021	13	4.0	80.5%
Fall 2022	9	4.22	84.4%

DISCUSSION

Using BID as a model of an effective problem solving process has been observed to be an interesting and enjoyable break from the heavy workload and routine skill building exercises that comprise the rest of the semester and traditional design projects that are typically assigned over the following year of studies. By having supporting details regarding how an organism solves a problem (and the "tangible" example itself), it seems to be easier for students who lack prior experience with the design process, to address their chosen design problems than if no such example could be followed.

Students tend to be highly motivated over the course of this project, often incorporating "smart features" into their designs and creating more sophisticated and complex solutions to their chosen problem than actually assigned in the project. The familiarity with the design process and application of basic design skills learned over the course of this project seem to benefit students as demonstrated in their approach to subsequent projects in the following semester of study. While subsequent projects follow a more traditional design process (i.e. *Double Diamond*), there does not seem to be any confusion or hesitation on the part of students that have participated in this project in making this transition.

As demonstrated in Table 1, designs developed by students over the course of this project are typically fairly complete solutions to their chosen problems. Considering this is their first attempt at developing a design from concept to prototype, it is the opinion of these authors that following the example of BID helps students remain more engaged in their projects. (It has been observed that student at this level can easily become discouraged during the process or can tend to "over focus" on specific details and lose sight of the end-goals of the overall development process. Clearly it would be helpful to perform a similar assessment of the solutions developed using more traditional development processes. Comparison of the resulting scores could be more a more objective validation of the educational value of integrating BID during the introduction of the design process.

CONCLUSION AND RECOMMENDATIONS

This assignment has been a particularly effective method to introduce students to the design process. The focus on a bio-inspiration as a part of this introductory process removes the stress to students of developing totally new solutions and has motivated and encouraged students in developing their solutions, utilizing skills & techniques only recently introduced.

It is recommended that future iterations of this project be more tightly defined so as to narrow the range of problems pursued by students, making it easier to compare the resulting designs in a meaningful manner. Perhaps a specific design problem could be posed to the class so that students must identify a suitable bio-inspiration and focus more directly on their design solutions that leverage their particular choice of inspiration. It is also recommended that a pre/post project survey be developed in order to more accurately assess student's familiarity with Biologically Inspired Design (BID) before and after engaging in this project. Finally, it is suggested that a similar analysis & assessment of student designs developed as the result of a more traditional design processes be undertaken in order to permit a more objective evaluation of the effectiveness of using BID as an introduction to the design process.

ACKNOWLEDGMENT

The authors would like to acknowledge the ongoing assistance and guidance of *Georgia Tech's Center for Biologically Inspired Design*, contributing heavily to the relevance and effectiveness of this project since 2013.

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