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Learning from Nature: Biomimetic Design in Architectural Education

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Abstract

Biomimicry is the study of nature to emulate or be inspired by its designs or principles to solve human problems. A noteworthy example includes Velcro derived from bur hooks.
This paper describes a Basic Design Studio assignment that is informed by arthropods, a rich source of inspiration. First-year architecture students were expected to offer a solution to a common human problem through the observation of the forms and behavior of arthropods. The final work required the inclusion of a mobile structure in the design. Educational benefits include the introduction of students to alternative design methods and multidimensional thinking.

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1. Introduction

Designers draw their inspiration from multiple sources to address challenging design problems. One method is to study nature, and attempt to comprehend the ways in which it has evolved to address environmental challenges. This practice has been coined biomimetic, a term introduced in the 1950s by Otto Schmitt (Schmitt, 1969). Biomimetic has increasingly been employed in architecture and engineering. That global patents involving biomimetic or bio-inspired approaches have increased by a factor of 93 from 1985 to 2005 should be sufficient proof of the recent interest in the field (Anonymous, 2012). However, the practice is not new to engineers and designers, Leonardo da Vinci's flying machines come to mind.

Proponents of biomimetic, the study of nature's models to imitate or take inspiration from its designs and processes to solve human problems, argue that 3.85 billion years of evolution has honed designs of our natural environment and its inhabitants by necessity to allow for survival, thus we are surrounded by a world of ingeniously designed natural organisms (Benyus, 2009). Examples of such adaptive transformation observed by biologists,

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zoologists, botanists, geneticists, and biomechanics researchers (GalhaBártolo & Bártolo, 2002). What remains is to extract this information in meaningful ways.

Multiple approaches to the utilization of biomimetic as a design process are discussed in literature. These methods either: (1) identify a design problem and examine ways other organisms or ecosystems have solved it, or (2) identify a specific trait in an organism or ecosystem and translate that into a design that responds to a human problem. The former may be referred to as a top-down, problem based approach, or "design looking to biology", and the latter a solution based, bottom-up approach, or "biology influencing design" approach (El-Zeiny, 2012; Zari, 2007).

For either of the stated approaches to function, a framework for the application of bio mimicry is necessary. Varying perspectives are offered in literature. For instance: form, process, and ecosystem have been identified as different levels of mimicry (Anonymous, 2012). Other classifications with multiple dimensions are also explored: organism, behavior, and ecosystem (Zari, 2007). In essence, a design may imitate the characteristics of an individual organism, it may be inspired by how the organism behaves, or the design may draw from the entire ecosystem of an organism and its surroundings.

2. Biomimetic in Architectural Education

Schön (1985) contends that the design studio environment is a place for students to learn both about designing and about learning to design. To achieve effective learning, Schön (1988) suggests, the architecture studio becomes an environment where the "real world of practice" is replicated without the pressures associated with the professional world. Students learn by doing, as they seek to achieve competency in the field, by mastering its instruments and methods (Schön, 1988).

Biomimetics suggested by multiple authors to hold value as an inspiration to the practice of architecture (Berkebile& McLennan, 2004; El-Zeiny, 2012; Knippers& Speck, 2012; Panchuk, 2006; Stachelberger, Gruber, &Gebeshuber, 2011; Yowell, 2011; Zari, 2007). Building on Schön's contention, biomimetic should become an invaluable tool for teaching architecture.

The authors of this paper have determined that arthropods, with a 5-10 million estimated number of species (Ødegaard, 2000) and 500 million years of evolution, could serve as the ideal tool to aid in a studio project. Arthropods, from Greek "jointed leg," include arachnids, insects, millipedes, centipedes, crustaceans, as well as other invertebrate animals with jointed, external skeletons.

Students are guided through a design exercise utilizing a solution-based, bottom-up, "biology influencing design" approach (El-Zeiny, 2012). The exercise involved (1) identifying an arthropod for a solution-based approach, (2) defining the biological solution, (3) extracting biological principles, (4) reframing the solution, (5) searching for a problem, (6) defining the problem, and (7) applying the biomimetic principles to the design problem.

The Basic Design Studio exercise is outlined below.

2.1. Exercise: Reinterpretation of Arthropods in the Context of Architectural Articulation

Research and utilization of bio mimicry has gained momentum in recent years; however, is not new to engineers and designers. Leonardo da Vinci's flying machines serve as an example.

The "Arthropods-Architectural Articulation" exercise aims to guide first-year architecture students in designing a mobile space for humans through the study of arthropods. To grasp the concept of "articulation" Basic Design Studio participants study arthropods' modes of movement that correspond to their structural peculiarities, how they have evolved to adapt to environmental factors, and the advantages of their segmented bodies.

The exercise is among a number of studio projects that aim to achieve the goals of the Basic Design 2 course; namely, to attain 3-dimensional thinking and problem solving skills, and be able to transfer these skills to the process of solving architectural design problems. Other topics covered through the semester include: transparency/light, sound, smell, adjunction, kinesthetic-space perception, time-space perception, color, biomimetic, design utopia and the city, creativity techniques, and verbal (semantic and typographic) as well as visual (digital and

printed) presentation methods. Ultimately, students are expected to improve in verbal and written communication proficiency, and excel in creative problem solving.

As utilized in the studio, the "Arthropods-Architectural Articulation" project can be described as a bio mimicry exercise. The "Arthropods-Architectural Articulation" exercise was carried out in three consecutive weeks during the 2011-2012 Spring Semester. All 48 students taking the Basic Design Studio 2 course participated in the exercise in groups of four. In the first week, concepts relating to the topic were discussed. Design work was carried out in the studio environment during the second week. The third and final week was utilized for classroom evaluation of the finalized projects.

Students were asked to pick and observe an arthropod to understand its movement, distinctive behavior and form, and to then use an analogy relating to this arthropod to design a space that is mobile, responds to various stimuli, and strives to solve a problem that the students have identified within their intimate environment.

Students actively used the Basic Design studio environment throughout the exercise, and benefited from the guidance and critique of the studio instructor, who functioned more as a coach than a teacher.

2.1.1. Step 1: Seminar

The first step of the exercise involved a seminar by the studio instructor on the concept of "articulation." The seminar was carried out by providing hints to the students and engaging in an inquisitive dialogue. Images were examined and sketches juxtaposed to provide some guidance.

Students were subsequently asked to establish groups of four. They were briefed on the content of the exercise, given a research assignment, and asked to bring materials for model making to the studio the following week. The research assignment required each group to prepare a digital presentation on arthropods; geographical, meteorological, and physical conditions within which they live; their modes of movement; and the types of behavior they engaged in to adapt to their respective environments, as well as their unique forms. Model making material was listed as chicken wire, strips of wood, fishing line, sketch paper, cardboard, white paper coated board, and one additional material to be sought on the campus premises. Each individual student was further instructed to provide printed photographs of 3 distinct arthropods, and asked to critically read Margaret C. Poloma's "Acting in the Play of Life: Dramaturgy as Theory." The article was provided with the class syllabus at the beginning of the semester.

2.1.2. Step 2: Student Presentations

Each of the 12 groups of four students presented their work on the projector fitted in the studio. Verbal presentations were supplemented with select photographs of arthropods provided by individual participants.

During and after the presentations, the studio instructor provided subtle critique by asking questions, and offering feedback. The critique focused on: (1) the originality and appropriateness of the digital presentation's conceptual and visual content to the topic at hand, (2) the expressive quality of the presentation in terms of graphic representation, and the appropriateness of the tools selected to convey the intended message, (3) the contribution of group members to the verbal presentation, and their use of body language, and (4) the sufficiency of the research carried out.

Group members were expected to critique themselves, as well as reply to questions directed by other participants. Individual participants were questioned regarding their choice of arthropods, and their respective characteristics.

Group presentations were followed by the studio exercise.

2.1.3. Step 3: Studio Exercise

Student groups were asked to review their readings and research, and reevaluate the movement, form, and adaptive capabilities to living environments of the arthropods they initially selected. Groups were further instructed to finalize their choice by selecting an arthropod that would direct them in addressing a problem in their vicinity. Some of the arthropods the students chose as inspiration were: Firefly, Rhinoceros Beetle (Orycte Nasicornis), Devil's Coach Horse Beetle (OcypusOlens), Masked Crab, Water Spider, Scorpion, Tick, Centipede, Namib Desert Beetle (Stenocara), and Antlion.

After the students determined their choice, they were asked to conceive a scenario based on their arthropod's behavior, form, and movement for a space that would address the previously stated problem, and would respond to external stimuli with movement. Groups that agreed on a specific scenario were allowed 30 minutes to locate one additional material on campus for their model. Once the model materials were collected, groups commenced to develop their designs through sketches and working models within the studio environment. During the studio exercise, the instructor inquired and provided critique regarding students' scenarios, their choice of arthropods, and the nature of the problem they were addressing, their working models, and their spatial designs.

Students were asked to complete their scenarios and designs by the following week. For the final presentation student groups were asked to: (1) build a model of their design that could be encapsulated in a 1 X 1 X 1 meter cube, (2) prepare an A1 sized presentation board that included the arthropod and its influential characteristic, the design process, and the final design of the mobile space, (3) stage a 20-second creative drama that conveyed the design problem the students were addressing, the arthropod's behavior that influenced the final product, and the form characteristics of the arthropod of choice, (4) prepare a digital video presentation that described the scenario, movement, as well as reaction to external stimuli of the final space the students created, (5) summarize the purpose, content, and process of the exercise; identify the potential skills they may have acquired; and describe the benefits of the exercise to them.

Students were asked to communicate the report on an A4 sized page. An example of student work is further described below.

Student Work: Rhinoceros Beetle / Fighting Cage Project

The Rhinoceros Beetle (Oryctes Nasicornis) is protected from environmental impacts by a very thick chitin layer. Its wings, tucked under its shell allow it to flee in case of danger. The students used the arthropod's concealed ability to fly and its protective armor as an analogy as they developed their scenarios.

According to the scenario, the Rhinoceros Beetle has gone under Morphosis and houses an arena within itself. This arena has a stage for fights, as well as observation decks for spectators. The wings of the arthropod allow the arena to be moved to various locations for successive fights. The moveable horn and wings have influenced the final design.

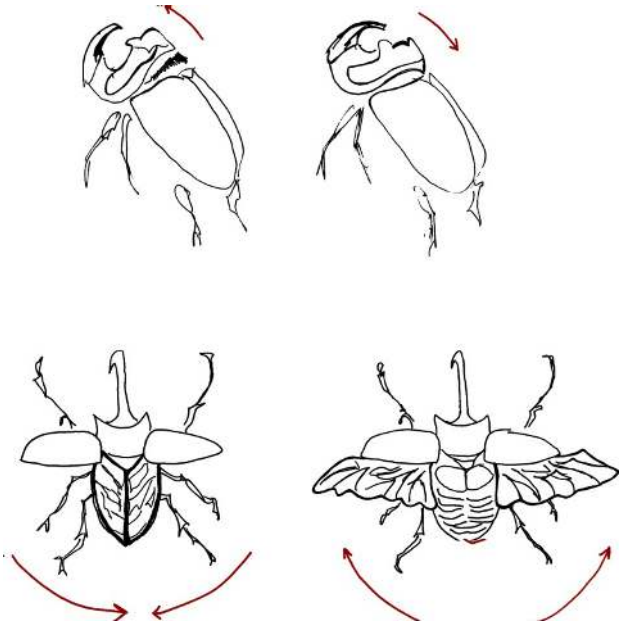

Figure 1. Sketches of the Rhinoceros Beetle and the movement of its horn and wings.

Student sketches exhibit the defensive movement of the arthropod's horned head (Figure 1). The head is reflected in the final design as an organically shaped shell that folds onto itself. During an attack, the shell encompasses the entire building. The fighting cage's design inspired by the opening motion of the beetle's wings (Figure 2).

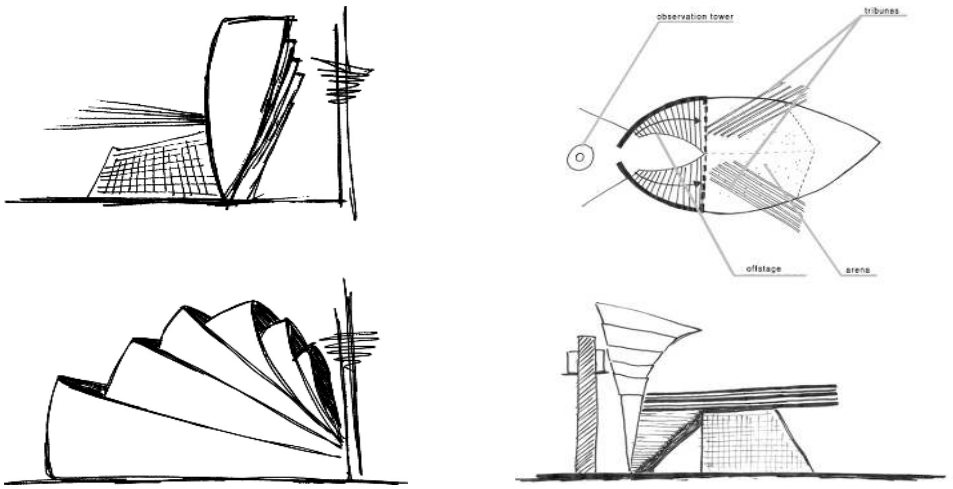

Figure 2. Student Sketches. Cage for fights inspired by the movement of the Rhinoceros Beetle's wings.

The student work presented in this article demonstrates that the arthropod's form and environmental response behavior is reflected in the scenario. The example further substantiates that the students succeeded in (1) selecting and observing an arthropod to understand its movement, distinctive behavior, and form, (2) subsequently using an analogy to design a mobile space that relates to the arthropod, and (3) creating a space that responds to various stimuli, and strives to solve a problem that the students have identified within their intimate environment. The students' work is presented in a moveable model (Figure 3), and A1-sized, digitally produced poster explaining the design process and illustrating the final product (Figure 4).

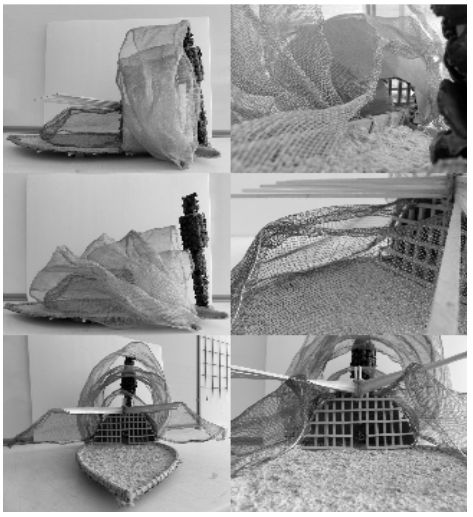

Figure 3. Photographs of the model for The Rhinoceros Beetle / Fighting Cage Project.

2.1.4. Step 4: Jury Evaluation

Jury evaluation for this particular exercise took into account each of the five assignments summarized above under Step 3: Studio Exercise. In addition, student groups were evaluated on group harmony during studio exercises, participation, curiosity, etc. Students were given leeway to supplement their presentations with particularized costumes, gestures, and vocal tones.

The final evaluation took into account: (1) the description of the reason the arthropod was selected, (2) appropriateness of the arthropod's stated characteristic to augment the design, (3) the use and transformation of the analogy, (4) the scenario, as well as the arthropod's contribution to the scenario, (5) the appropriateness of the final product (space) to the stated function and user group, (6) the expressive quality of the presentation and legibility of its message.

3. Findings & Conclusion

The 'Reinterpretation of Arthropods in the Context of Architectural Articulation' exercise had a number of objectives relating to basic design education. The exercise in bio mimicry (1) functioned as a catalyzer for creating a vibrant yet relaxing studio environment for design education, (2) helped the students in understanding the process of creative thinking and creative problem solving, (3) aided the process of learning from nature / bio mimicry, (4) allowed the students to gain an awareness of nature acting as a design mentor, (5) allowed the students to get accustomed to work in groups, and (6) helped students gain an understanding of an architect's leadership role.

Based on the exercise documented above, the researchers contend that the aim and objectives of the exercise were met. The students described their experience as interesting, informative, and enjoyable. This evaluation may suggest that bio mimicry as a tool for fostering creativity may be a viable instrument in architecture schools, and possibly in other levels of education from kindergarten to primary school science classes, provided the intensity, scope, and difficulty of the exercise is varied.

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