INTRODUCING NATURE ANALOGIES AT THE FRAMING STAGE OF DESIGN PROJECTS

Mithra ZAHEDI and Manon GUITÉ
University of Montreal, Canada

ABSTRACT
This paper reports on the effects of introducing biologically-inspired approaches at the framing stage of design projects. Biologically-inspired approaches involve application of analogies with biological systems to develop design solutions. In design education, this offers particular added benefits in terms of potential to encourage collaboration among teams of students, exposing them to interdisciplinary approaches, bringing their attention to functionality, sustainability, and user experience, and fostering development of holistic views of projects. Literature on biologically-inspired design, collaboration, and reflective practice were used to prepare students for a project-based design activity: Sixteen teams of four students were each asked to work on possible services to offer at Montreal's next cultural *Nuit blanche* (*Sleepless night*). The teams were asked to start framing by reflecting collaboratively on the context and criteria of the project. Each team created a mind map to tackle a design problem and define elements for further development. Biologically-inspired approaches were then introduced, and the teams were asked to re-examine and reframe their design problems. Each team created a new mind map and developed new design solutions based on biologically-inspired approaches. Findings of the workshop support both the application of biologically-inspired approaches at the framing stage of design projects and the use of mind maps as creative collaborative design tools.

Keywords: Design education, biologically-inspired design, interdisciplinary, framing, collaboration, reflective practice, mind map

1 INTRODUCTION

The overall goal of the project-based workshop was to explore the effects of biologically-inspired approaches on problem-setting [1] when introduced early in the design process. Biologically-inspired design uses analogies to biological systems to develop design solutions [2], [3], [4]. Interest in biology as inspiration for design issues has gained momentum [3], most notably as a means for generating innovative ideas and sustainable development. As well, understanding of biological systems and making of analogies between functions of nature and design problems is a promising trend in design education that helps to prepare students for richer design practice. Biologically-inspired approaches offer design students a number of new learning potentials:

- encouragement of collaboration
- exposure to interdisciplinary attitudes
- focus on functionality, sustainability, and usage
- promotion of holistic and systemic views
- generation of innovative ideas

These learning outcomes are possible because biologically-inspired design brings together into a team different disciplines that need to collaborate and develop understanding of each other's language and methods. By working together to assess structures and functions of design, an interdisciplinary team is encouraged to build new interpretations of design problems and to seek innovative solutions.

2 FRAMEWORK

Central conceptual elements of the workshop, in addition to "biologically-inspired design," were "collaboration" and "problem-setting." Collaboration involves the developing of awareness of a project as a whole and the sharing of all information related to the project [5], [6]. As Achten [6], explains (p. 7), "… collaborative design is a process in which the participants work together in a meaningful way; not just working together efficiently, but stimulating each other to contribute to the design task. They act towards mutual understanding and maximizing outcomes that satisfy not only their respective goals, but also those of other participants." Collaboration within a team at the beginning of the design process is especially important, based on a fundamental belief that the initial phase of design projects is puzzling and uncertain [1], [7], and that for optimizing of a design project a number of disciplines need to engage and collaborate at the outset to frame and define it [8], [9]. In the initial phase, a team needs to go through processes of framing, naming, and deciding [1], [7], [10]. As Schön [1] suggests (p. 40), "Problem-setting is a process in which, interactively, we *name* the things to which we will attend and *frame* the context in which we will attend to them."

Inspiration from the way elements in nature are constructed and shaped and how they function and interact with each other is not new. Leonardo Da Vinci's flying machines are well-known examples. Today many designers, architects, and engineers focus on function to learn from nature and solve complex design problems [11], [12]. And researchers in biology, design, and computation work together to develop new tools and new methods for applying the framework of biologically-inspired processes. A variety of terms are used to refer to this process—for example, biomimicry, biomimetics, bionics, biologically-inspired design. For this research, biologically-inspired design (BID), used among others by researchers of Georgia Institute of Technology, was chosen. At Georgia Tech, it is believed that biology is an important guide to developing new ways of thinking and that BID is an innovative tool utilizing design strategies observed in natural systems to stimulate creation of novel inventions. Helms et al. [4] highlight a number of characteristics that make BID especially appealing: First, BID is interdisciplinary, based on analogies requiring expertise across at least two distinct domains—biology and industrial design, architecture, and/or engineering. Second, BID is collaborative and fosters development of a common language, necessary for communications, relations, and processes across disciplines. Third, BID offers advantages of multiple perspectives: those of biologists who seek to understand functions of nature, and those of designers (industrial, architectural, and/or engineering) who seek to improve situations through design for humans; these two groups apply different methods of investigation and have different perspectives on design.

3 CONTEXT

The study was conducted within the context of a project-based design workshop entitled "Experience and Interaction" that was conducted three days a week for two weeks. The objective was to stimulate creativity of students and provide tools and methods to help develop innovative solutions that optimize user experience. The workshop was offered to sixty-four students in the final year of the Bachelors in Industrial Design program at University of Montreal. Students were grouped into sixteen teams of four members, and the teams were asked to work independently on possible services to offer at Montreal's next cultural *Nuit blanche* (*Sleepless night*). The teams each went through two exercises of problem-setting (Activity A and Activity B below) as the initial steps to help in understanding of the context of the project. (Note: Subsequent steps of design and development are not explained in this paper.)

3.1 Activity A

On the first day of the workshop, the design project was presented. The teams were given two hours to reflect collaboratively on the project applying their usual tools—brainstorming, discussion, sharing of experiences, critical thinking—and come up with a global understanding of the context of the project related to the service they chose to offer. The teams were asked to synthesize their reflections by hand on a poster (a tabloid page). The teams were encouraged to use knowledge representation tools such as mind maps and concept maps to present their understanding of the project in non-linear ways. This was in keeping with accepted beliefs that by presenting concepts and ideas visually, learners are more likely to understand the complexity as well as the relations between concepts of a situation [13], [14], [15].

3.2 Activity B

On the second day of the workshop, a lecture introducing biologically-inspired design approaches was given. The first part of the lecture focused on complexity of design projects and on uncertainty and "fuzziness" of initial phases of design processes [1], [7], [10]; special attention was placed on the significance of "problem-setting" versus "problem-solving" [1]. The second part of the lecture centred on explanation of biologically-inspired design approaches; examples of how nature's functions and structures influence design and architecture were presented, and supporting reading materials and research tools were provided. The third part of the lecture was dedicated to the particular design process of the workshop—which was emphasized as non-linear and iterative.

Teams were then asked to reflect collaboratively again on the project. They were invited to apply their new knowledge about biologically-inspired design, to explore the context of the project holistically, iteratively, and reflexively, and to frame/reframe the project in ways that would allow for decisions on innovative solutions. The process was detailed as follows:

- Reflect in a holistic way allowing for discovery of elements and interactions between elements.
- Reframe and select a few elements or strategies on which to proceed (due to time limitations of the workshop).
- Perform functional/structural analyses of chosen elements or strategies.
- Research nature for similar functions/structures/strategies; unfolding functionality of elements individually and systemically, and extracting principles related to biological solutions.
- Schematize functions/structures/strategies of biological solutions; using analogies to translate schemas into the design domain and develop solutions.

Once again the teams were asked to synthesize their reflections by hand on a poster. As before, they were encouraged to apply knowledge representation tools. The study undertaken was to compare results of pre-intervention and post-intervention of biologically-inspired design approaches.

4 STUDY

Each of the sixteen teams submitted posters of results of reflections for Activity A and Activity B. Six teams presented results of reflections for Activity A (pre-intervention) in the form of linear lists that included key concepts and sub-items; since there was no interaction shown among ideas, these posters were eliminated for the purposes of the study. Several teams used mind maps for both activities.

Note: The terms “concept maps” and “mind maps” are often used interchangeably, and it is important to clarify the distinction between them. Concept maps “show the specific label (usually a word or two) for one concept in a node or box, with lines showing linking words that create a meaningful statement” [13], [15]. Concepts are arranged hierarchically, typically with the most general and inclusive positioned at the top and the most specific positioned at the bottom. Mind maps are non-linear general interpretations that “comprise a network of connected and related concepts … any idea can be connected to any other” [16]; their purpose is to stimulate associations among ideas, and their making requires free-form and spontaneous thinking. A mind map is loosely structured and not hierarchical from top to bottom [15], [16]; ideas start at the centre and grow outward organically in all directions. In representing ideas and associations, a variety of different line thicknesses, colours, arrows, pictures, and diagrams may be used to aid in knowledge recollection [16].

Posters for Activity A and Activity B of five teams were deemed the most complete and significant, and were chosen for detailed study. Figure 1 and figure 2 are examples of mind maps of both activities of a team. Comparative analysis of pre-intervention and post-intervention posters of the selected teams surfaced findings about the effects of analogies with nature on:

- reframing of the project (criteria explained below)
- changes in focus on elements and introduction of new elements

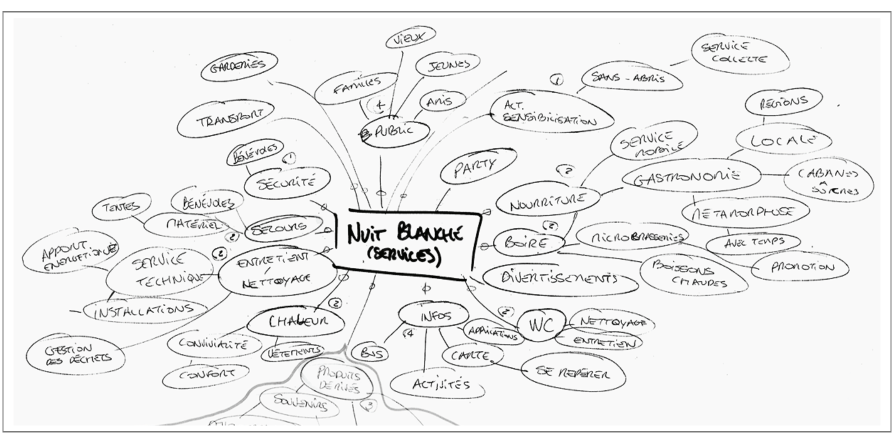

Figure 1. Example of pre-intervention mind map

4.1 Examination of pre-intervention and post-intervention team posters

Examination of pre-intervention (Activity A, Figure 1), and post-intervention (Activity B, Figure 2) team posters was based on complexity and structure [15], [16]. All mind maps were presented in a web-type structure—a central idea (highlighted or presented in colour), a set of key ideas—an activity, a need or a desire—centred around the main idea, and many other related concepts—which, according to Peters et al. [17], signifies a higher complexity than structures constructed with rays or links.

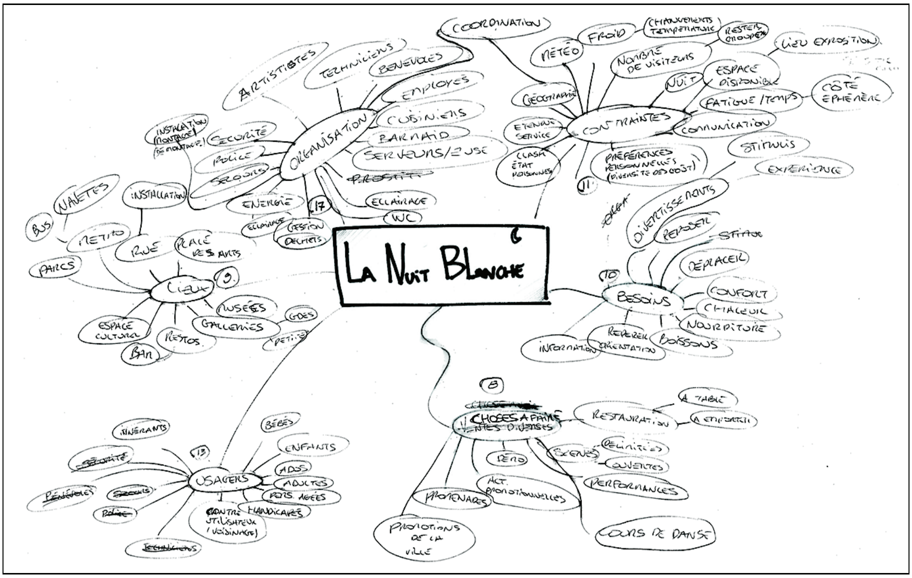

Figure 2. Example of post-intervention mind map

Figure 3 below is adapted from the work of Hay et al. [18] and Davies [15] p. 291 who maintain that meaningful learning occurs when “new concepts are linked to the retained knowledge structure and new links are made between those parts of the prior knowledge structure that are retained.” Davies [15], referring to Hay et al., contends that “non-learning occurs when no detectable change in knowledge occurs before and after the presentation of new material. Rote learning occurs when new information is added (or rejected) in a students’ knowledge store, but there is no new integration made between the new or substituted information…. Meaningful learning, by contrast, occurs when new perspectives are integrated into the knowledge structure and prior concepts of the student.”

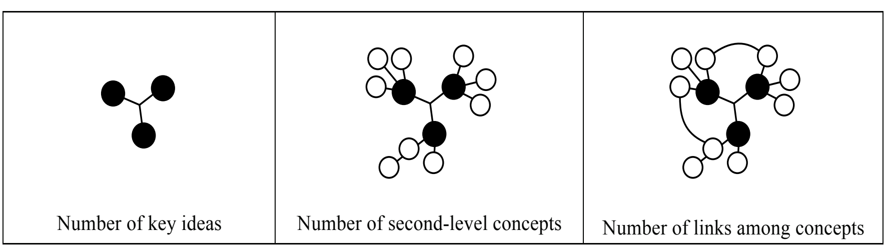

Figure 3. Illustration of criteria used for examining mind maps

Table 1 below presents results of comparisons between pre-intervention and post-intervention posters of the five selected teams according to number of key ideas, number of second-level concepts, and number of links among concepts.

Table 1. Comparisons between pre-intervention and post-intervention team posters

	Number of key ideas		Number of second-level concepts		Number of links among concepts	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Project/Team A	14	6	25	68	0	2
Project/Team B	8	9	38	53	1	3
Project/Team C	6	6	62	23	0	0
Project/Team D	5	3	3	11	0	0
Project/Team E	16	12	30	47	0	1

5 DISCUSSION AND CONCLUSION

The results of the study suggest the conclusion that by using biologically-inspired design approaches, teams of students were able to frame/reframe projects more systemically; they presented a greater number of concepts interacting with key ideas, and they became much more significantly focused on users. Intervention of nature analogies helped students to enrich their knowledge construction at the framing stage of the design project. Students recognized nature and related concepts as models at the outset and were reminded to look holistically at problems and solutions. Creation of mind maps seemed to be a successful tool for reflective practice among teams, with students showing openness toward using them as structuring tools for framing/reframing ideas. Mind maps played a considerable role in team reflective practice and teamwork, providing opportunities to discuss, exchange, and modify ideas.

Three overall category-type of results were evident:

1. Change in structure of problem-setting—creation of Activity 2 mind map with fewer key ideas and more second-level concepts than Activity 1 mind map. Key ideas tended to be grouped into more general categories. With some teams, the number of second-level concepts rose dramatically—for example, from 25 to 68 for Project/Team A. Other observations included grouping of elements related to infrastructure (policies, organizational support, etc.) and greater focus on activities, environment, and user needs.
2. Evolution in structure of problem-setting—creation of Activity 2 mind map using Activity 1 mind map as baseline. These teams added both new key ideas and new second-level concepts. Greater attention was given to activities, environment, and user needs.
3. Change in structure of problem-setting—creation of Activity 2 mind map with similar number of key ideas as and greater number of second-level concepts than Activity 1 mind map. Only one team was considered Type 3: with this team, a complete reframing occurred.

The workshop study serves as an interesting pilot, with findings that merit further investigation for relevance both to design education and design practice. Parameters planned for envisioned future research include a greater number of case-study samples, a more controlled setting conducive to collaborative learning and teamwork, and obligatory use of mind maps as tools. A template for organizing a mind map and instructions to write a narrative on the process of its creation would be provided.

6 IMPLICATIONS

In general terms, the workshop results encourage education in design to:

- emphasize analogies with nature as tools to gain better understanding of complex situations;
- promote creation of mind maps as tools for reflective practice and framing/reframing at the beginning of design projects.

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