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Biomimicry Problem-Based Approach as a Strategy for Sustainable Innovations in the Construction Industry

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Abstract

The rate of globalisation around the world and the corresponding emergence of innovative technologies daily calls for an efficient and sustainable learning strategy for professionals. It is therefore imperative for professionals to be well-equipped with requisite knowledge and skills to maintain relevance in their field of practice in tandem with the global sustainability paradigm. Nature is notably a rich source of inspiration for high performance, resource efficient, and innovative solutions due to its over 3.8 billion years of evolutionary refinement. Hence, biomimicry, a field that study and emulate nature's forms, processes and strategies to find sustainable solutions to human challenges. This paper sets out to explore the biomimicry problem-based approach as exhibited by nature, in maintaining relevance and sustainability. A quantitative research method was adopted and a structured questionnaire was used for data collection. Data analysis reveals the systematic approaches towards understanding and emulating the mechanisms behind the survival, sustenance and longevity of organisms in nature. The outcome of this study will provide professionals and other stakeholders in the construction industry with a nature-inspired approach for achieving sustainable innovative solutions.

Keywords
Biomimicry, Sustainability, Nature, Continuous Professional Training, Problem-based Approach.

1. Introduction

Globalisation with its resultant industrialisation and migration among other factors poses a lot of challenges which has resulted in the birth of innovative solutions in tackling them. Hence, an effective, efficient and time-tested learning strategies appears as a necessity to keep pace with the constantly changing career paths of professionals due to these transformations on the global scene. In the last decade, there have been records of an increasing birth of innovative technologies in response to global demands. This explosion of knowledge evident through various technological and product innovations therefore requires professionals to learn afresh at well-paced intervals of their lives (Duță & Rafailă, 2014). In this age, the knowledge, aptitudes, skills, trades, strategies and approaches acquired by professionals reaches its limits very fast (Manole & Alpopi, 2013). In addition, professionals and other stakeholders need to be kept abreast continuously of the various technologies in order to encourage their acceptability, adoption and implementation. One of the ways of filling this gap is through a robust learning path for professionals either in a formal or informal system.

Continuous Professional Training (CBT) entails the harnessing of informal and formal learning privileges, resulting in the expansion and deepening of professional expertise and capability (Stan et al., 2013). Four key features of CPT are highlighted namely: should be continuous and occurring throughout a professional's/practitioner's working life; must be organizational focused, for the execution of technical and professional duties; should be broad based, facilitating the professional's ability to improve and increase their knowledge base through critical and analytical process of novel knowledge acquisition, practice and adoption; and must be structured, entailing a personal development schedule that reflects systematic maintenance, improvement and broadening of professional capability (Mashile, 2002). However, age, status, occupation, job position, personality, and attitude to change are few among many other factors affecting the development and performance of professionals (Ionica et al., 2013). In the quest for approaches and methodologies that work for instead of against life, professionals are now heading outside the circle to learn from nature's experience from 3.8 billion years of evolution, revealing a robust system of efficiency, effectiveness and novelty (Benyus, 2011). Hence, biomimicry, the new field of discipline which studies nature's models and then emulates their forms, processes, systems, and strategies to solve human problems sustainably (Rao, 2014).

As part of a completed research study to establish the biomimicry approaches that can optimize sustainability, the results of a questionnaire survey of construction professional's perception of the problem-based approach of biomimicry is presented. The aim is to offer professionals in the South African construction industry (SACI) a much clearer and sustainable learning approach as inferred from nature's time-tested processes and strategies. While the data is based on South Africa, the findings have the potential of contributing towards the systematic and transdisciplinary understanding of nature-inspired learning strategies. A review of some related studies on biomimicry is first presented. The next section then presents the research methods adopted for the study followed by a discussion of the findings.

2. Biomimicry: Awakening the Professional Senses

With the onward march of science and technology and the continuing quest for improvement, there is a growing inquisitiveness about the natural world around us. The natural environment (biota) is found to be a rich source of novel ideas which offers robust potentials for sustainable learning if explored by professionals. Historically, early man relied solely on the natural world for existence and survival, resulting in native innovations in the medical and pharmaceutical sciences; shelter and shelter architectures; weapons and defence, including armours, sensors, and alarm systems; and agriculture and food production amongst others (Murr, 2006).

It has been discovered that every natural organism (flora and fauna) is idiosyncratic and wholly tailored to their own environment (El-Zeiny, 2012). Invaluable information about functionality, efficiency and holistic sustainability has been gathered by early scientists and innovators by mere observation as well as in-depth study of nature. Owing to its over 3.8 billion years of evolution, nature has become an extraordinary role model for harmonious balance and proportion encompassing efficiency, collaboration, resource utilisation, and longevity (Benyus, 1997). The idea is that nature has developed highly efficient systems and processes, which have the potential to propel solutions to the waste, management and other challenges confronting humanity today (Hargroves & Smith, 2006). Hence, Biomimicry, a relatively new field of study which encourages a multidisciplinary collaboration among professionals (industrial design, medical science, material science, architecture, and interior design) to study and emulate the processes and materials in nature, and then apply those natural models to the man-made or built environment.

The term 'biomimicry' (also known as biomimetic) became popularised and widely circulated in 1997 through a book titled *Biomimicry: Innovation Inspired by Nature*, written by Janine M. Benyus (Goss, 2009). Coming from a combination of the Greek words *bios* (life) and *mīmēsis* (imitation), it literally means 'life imitation' or the 'imitation of life' (Pronk et al., 2008; De Pauw et al., 2010; Arnarson, 2016). Biomimicry is described as the quest of men and women, exploring nature's masterpieces (photosynthesis, self-assembly, natural selection, self-sustaining ecosystems, eyes and ears and skin and shells, talking neurons, and natural medicines) and then copying these designs and manufacturing processes to solve their own problems (Benyus, 1997). Despite been perceived by many to be some branch of biological science going by the sound of the term; the scientific knowledge within biomimicry only serves as a means through which nature is learnt about (Marshall, 2013). It heralds a transition from an era of exploiting and extracting from nature to learning from its forms, processes and strategies (Benyus, 2011). By aligning with the attributes exhibited by the natural world, biomimicry offers an outstanding potential in achieving its overarching goal of sustainability.

3. Biomimicry Principles

There are nine principles (attributes) of nature, which are also the basic principles underpinning the concept of biomimicry namely: nature runs on sunlight; nature uses only the energy it needs; nature fits form to function; nature recycles everything; nature rewards cooperation; nature banks on diversity; nature demands local expertise; nature curbs excesses from within; and nature taps the power of limits (Benyus, 1997; Pearce et al., 2012). However, biomimicry principles are expanded and comprehensive version of the principles of nature. They are creative common tools through which biomimetic designs, materials, and applications are evaluated for sustainability (Kennedy et al., 2015). They are important checklists to be adhered to in ensuring the application of biomimicry result in sustainable outcomes and solutions. As postulated by the Biomimicry Institute, Table 1 reveals the principles of biomimicry.

Table 1. Biomimicry principles (Biomimicry Group, 2016)

	Principles	Sub-principles
A.	Resource (Material and Energy) Efficient	Using multi-functional design; Using low energy process; Recycling all materials; and Fitting form to function.
B.	Evolve to Survive	Replicate strategies that work; Integrate the unexpected; and Reshuffle information.
C.	Adapt to Changing Conditions	Incorporate diversity; maintain integrity through self-renewal; and embody resilience through variation, redundancy, and decentralization.
D.	Be Locally Attuned and Responsive	Leverage cyclic processes; use readily available materials and energy; use feedback loops; and cultivate cooperative relationships.
E.	Integrate Development with Growth	Self-organize; build from the bottom-up; and combine modular and nested components.
F.	Use Life-friendly Chemistry	Breakdown products into benign constituents; build selectively with a small subset of elements.

4. Biomimicry Approaches/Design Strategies

Nature inspired approaches help redefine the levels of biomimicry and its potential as a tool for sustainability. They offer unique focal points and step-by-step paths under the larger umbrella of biomimicry to provide methodologies through which biomimicry can be incorporated into various disciplines in order to arrive at a sustainable, effective and efficient solution (Niewiarowski & Paige, 2016). Also, they furnish the context to what, why, how and why biomimicry application fits into any discipline or design scale (Planet, 2016). Biomimicry proponents believe that strict adherence to these steps constituting the approaches will result in sustainable outcomes, either in tackling human challenges or in innovative design solutions. However, one major barrier to the employability and application of biomimicry is the lack of well-defined approach (Vincent et al., 2006), especially when the goal is centered on achieving sustainability.

There are two major approaches that exist in biomimicry, with different terminologies as posited by different researchers and authors. These approaches are the dimensions through which knowledge is transferred in the application of biomimicry (Pandremenos et al., 2012). They are the *problem-based approach* and the *solution-based approach* (El-Zeiny, 2012; Bardanah & Kadri, 2015), which are also the terms adopted in this research study. The constituting steps of biomimicry approaches/design strategies in both the problem-based and the solution-based approaches are only differentiated by the path (definite and indefinite) they follow respectively. However, this study examines the potential of the problem-based approach for achieving sustainability if employed by professionals and stakeholders in the construction industry.

5. Research Methodology

The research approach adopted in the study is the quantitative approach. The combination of primary data (questionnaire survey) and secondary data (literature review) was employed in the research study. The structured questionnaire survey used in the research study targeted biomimicry and construction professionals (i.e. architects,

construction managers, construction project managers, quantity surveyors, structural engineers). The respondents adopted in the research are those registered with their various professional bodies in the SACI.

The questionnaire survey contains close-ended questions which was administered to one hundred and twenty respondents of which one hundred and four responses were received. The first part of the questionnaire sought the background information of the respondents (i.e. age, educational qualification, professional qualification, years of experience, numbers of green building projects involved in). The second part sought the respondents' assessment of the biomimicry principles that can promote sustainability. The third part dealt with the stages involved in the identified biomimicry approaches as a means of achieving sustainable outcomes. Concerning the biomimicry approaches, the respondents were asked to indicate their level of agreement to the approaches on a five-point Likert scale (strongly disagree-1, disagree-2, neutral-3, agree-4, strongly agree-5). Statistical Package for Social Sciences Version 16 (SPSS V16) software was used to analyze the data obtained. Descriptive statistics, with the aid of mean and standard deviation was employed to present the results of the analyzed data.

6. Results and Discussions

6.1 Background of respondents

The results of the study revealed that 53.8 percent are male, while females accounted 31.6 percent. For the profession of the respondents, 24 percent of the respondents were biomimicry professionals, 19.2 percent were quantity surveyors, 18.3 percent were architects, 15.4 percent were civil engineers and 11.5 percent were either project managers or construction managers. The results also showed that 54.8 percent of the respondents had master's degree, 25 percent had bachelor's degree, 11.5 percent had diploma certificates, and 8.7 percent had doctorate degree. Most of the respondents work with private organizations, representing 79.8 percent whilst the remaining 20.2 percent work with government organizations. As presented in Fig. 1, 53.8 percent of the respondents had experience that ranged from 1-5 years, 20.2 percent had experience in the range of 6-10 years, 15.4 percent had experience that ranged between 11-15 years, 5.8 percent had experience ranged from 20 years and above, and 4.8 percent represents those that had experience ranged 16-20 years.

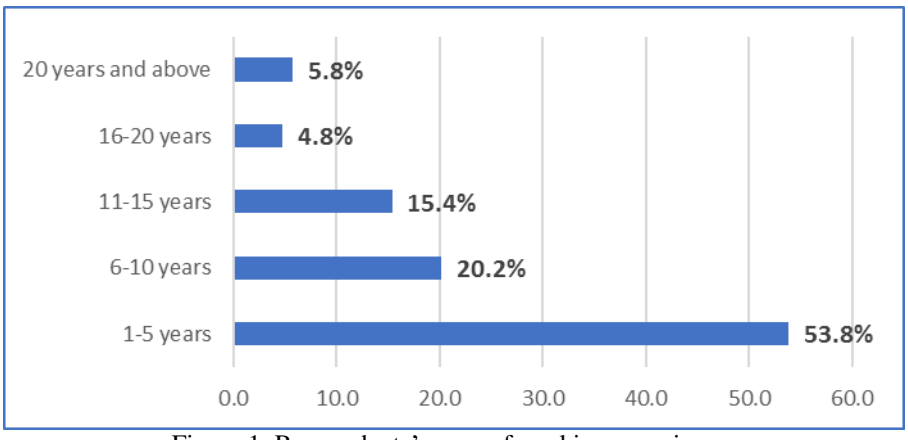

Figure 1. Respondents' years of working experience.

6.2 Application of biomimetic problem-based approach

On the level of agreement of respondents to the application of biomimicry problem-based approach, the results as presented in Table 2 reveals that all the eight (8) stages assessed have mean values above 2.5 (Field, 2013). This implies that all the stages involved in the problem-based approach of biomimicry are considered very significant learning and application path for sustainable outcomes in the industry. However, the respondents considered 'emulate design principles', 'brainstorm bio-inspired ideas', 'identify function', 'discover natural models', and 'abstract biological principles' as the top five important stages of biomimicry problem-based approach. Other important stages are 'measure using life's principles', integrate life's principles', and 'define context'. The results agree with the studies of several researchers on the stages involved in the biomimicry problem-based approach, though in an indefinite form (Zari, 2007; Helms, et al., 2009; Knippers, 2009; El-Zeiny, 2012; Pandremenos et al., 2012; Buck, 2015; Biomimicry Group, 2016;). It also agrees with the studies of McDonough and Braungart (2010),

and El-Zeiny (2012), which reported that this approach will transmit the built environment from an unsustainable state to an effective and resilient one, by its potential to proffer sustainable solutions to identified existing challenges.

Table 2. Ranking of Stages in Problem-based Approach of Biomimicry

Stages	Mean	Standard Deviation	Rank
Emulate design principles	3.24	1.867	1
Brainstorm bio-inspired ideas	3.23	1.860	2
Identify function	3.20	1.840	3
Discover natural models	3.20	1.840	4
Abstract biological principles	3.16	1.812	5
Measure using life's principles	3.15	1.805	6
Integrate life's principles	3.12	1.775	7
Define context	3.11	1.784	8

7. Conclusion and Recommendation

The study has shown the existence of a gap in the learning path of professionals in keeping abreast with the consistent changing and advancing technological terrain. In keeping to date with these changes in maintaining relevance, professionals are now heading outside the box and consulting with the natural environment proven to be of high performance. However, one major hindrance to this effort identified in literature is the lack of a comprehensive and well-defined approach for adopting, applying and incorporating nature's blueprint that have made them to become *models*, *measures*, and *mentors* of sustainability. However, the study showed that professionals agreed that the application of the stages involved in the problem-based approach of biomimicry would offer sustainable learning process. Though, the pattern of this approach follows a progression of different steps. It is an approach effectively spearheaded by engineers, innovators, and designers identifying preliminary design objectives and frameworks (El Ahmar, 2011). Here, the professionals look to the living world for solutions by first identifying the challenges with biologists needed to correspond these to organisms that have resolved similar cases (Zari, 2007). Hence, the need for multidisciplinary collaboration among the professionals in order to maximize the in-depth knowledge and learning pattern that nature has to offer through biomimicry. Awareness, training, and education of professionals on this significant biomimicry approach should also be encouraged for its adoption and application to be widely embraced. Integration of biomimicry into the university curricula and likewise the continuous professional development activities of professional bodies is therefore highly recommended. It is also recommended that government and other authorities, with the full support and partnership of professional bodies, should put in place policies and frameworks that will be encourage the adoption and application of biomimicry. This is believed will result in the birth of innovative and novel technological solutions with sustainable characteristics to human challenges.

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