Use of C-K Theory Templates for Engineering Design Innovation

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Abstract

The Concept-Knowledge (C-K) theory is a well-established approach for integrating multiple domains of information and facilitating innovation through connection building. For the purposes of evaluating the benefits of using C-K theory and their application to design innovation, students in sophomore engineering are assigned a design project using C-K theory template. This paper discusses the adoption of Concept-Knowledge (C-K) theory template for student's use in sophomore design course for design innovation in undergraduate engineering curriculum. Analysis of student's work using the C-K theory template will be discussed. Multiple examples of C-K templates will be reviewed in order to demonstrate its capability for use in design courses.

Keywords

Bio-Inspired Design, C-K Theory, Multi-Disciplinary Design, Innovation

Introduction

The economic leadership of an industry in the market is determined by its ability to produce new, better and improved products through innovative design solution. Training 21st century engineers to solve complex design engineering problems for the innovative solutions require them to be competent in multidisciplinary domains and to involve them to collaborate across technical and non-technical boundaries. One of the approaches suggested by engineering education researchers to adopt multidisciplinary approach in design engineering course is the biomimicry-based design engineering course[1-4]. Biomimicry or bioinspired design is a discipline of getting innovative solution for the improvement product performance or the development of new products with novel features and performance characteristics using nature as inspiration or the knowledge resource.

Nowadays, researches focusing the development of methods for the effective translation of biological knowledge into innovative design solutions is growing exponentially and the recent investigations revealed the possibilities for the evolution an effective methodology for integrating biological and scientific knowledge through C-K theory [4]. In this approach, design solutions were obtained through the activation of biological knowledge by the blockage of traditional design path, expansion of biological and traditional knowledge, exploration of the traditional knowledge and concepts portioning. It explains more precisely about the method of connecting, exploring and expanding concept and knowledge space to get an innovative solution. It was also found by the researchers through the qualitative analysis of biomimicry-based students' project that the C-K theory based bioinspired design process resulted in significant learning and engagement[5]. In our investigation, we used quantitative analysis techniques to address the research gap in

demonstrating the capability of C-K theory-based templates used in bioinspired design process to produce innovative design solutions.

Research Methodology

The C-K theory based bioinspired design course was introduced to sophomore design students at James Madison University (JMU) and University of Georgia (UGA). As a part of their course work, the students were asked to complete a C-K theory-based biomimicry design project and about 53 and 48 students from JMU and UGA were participated in this project work. They were instructed to record their bioinspired design process in the C-K template with the connections between biological and engineering knowledge spaces as shown in Fig. 1. The students' performance on this design project work was evaluated based on their performance on design engineering attributes listed in table1 following the evaluation scheme described in the table 2.

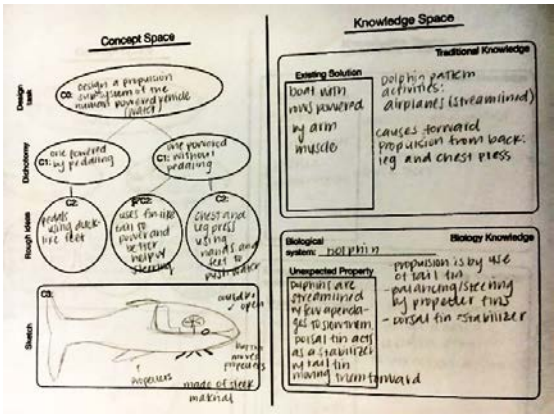

Figure 1. C-K template used for analysis

Designation of Design Engineering Attributes of UGA and JMU data
Innovation (U_DE1 & J_DEl)
Imagination (U_DE2 & J_DE2)
Decision making (U_DE3 & J_DE3)
Active participation (U_DE4 & J_DE4)
Redesign and Improvement (U_DE5 & J_DE5)

Table 1. Design Engineering Attributes

Table 2. Criteria for Assignment of Score Value to Each Attribute

Scale Value	Criteria
4	For well-defined / described concepts with higher order of creativity and with well-defined design path
3	For moderate explanation of concepts with moderately defined design path
2	For lower level explanation of concepts with roughly defined design path
1	For the poor explanation of concepts with unclear design path

The students' performance score data on each design attributes was prepared and by using MATLAB function fitdist(), the normal distribution functions were fitted for each attribute's data for the 95% confident intervals. The probability distribution plot was generated for each design attribute using the normal distribution functions computed using MATLAB for the performance score values ranging from 1 to 6 and had been studied to understand the capability of CK theory based bioinspired design process to produce innovative solutions.

Results and Discussion

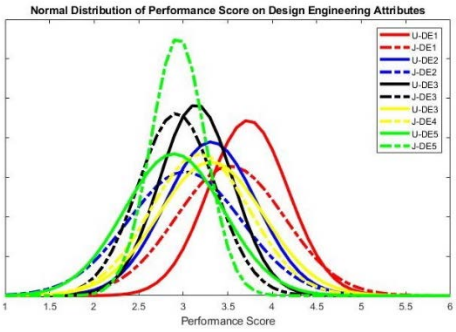

Figure 2. UGA and JMU students' performance score normal distribution on design attributes

The probability distribution function for each design attributes of UGA and JMU data were plotted as shown in figure 2. The resulting plot showed that the design engineering attributes Innovation (U_DE1 & J_DE1) and Imagination (U_DE2 and J_DE2) had wide distribution. The peak value of normal distribution function for the all attributes were occurred on the right side of the performance score value 2.5. Further it was observed that the peak values of design attributes of UGA and JMU data, U_DE1, U_DE2, J_DE1 and J_DE2 were close to maximum design performance score value of 4. This revealed that the mapping of bio inspired design process on CK map has significant capability to produce innovative solutions.

Summary and Future Work

In this study, the bioinspired design solution mapped in concept – knowledge (C-K) space was analyzed using statistical methods to find its capability to produce innovative design solutions from student's project work. The statistical analysis of the students' data from UGA and JMU revealed that the C-K theory based bioinspired design process had significant capability to produce innovative design solutions and could be integrated into the engineering curriculum to train the engineering students. Future research will be aimed to find relationship biomimicry and design engineering attributed of C-K theory-based bioinspired design process model using statistical tool.

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