Innovation in Design Education:
Decoding Problem Structuring Processes of a Natural Object Driven Open-Ended Étude

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Abstract
Literature studies reveal that interpreting the problem-structuring process revolving around wicked problems needs to be explored more. To address this issue, this study aims to analyse students' problem-structuring processes through mixed methods such as quantitative, qualitative, and focus group studies. This is achieved through decoding the synthesis, and comprehension of students' processes and emergent outcomes through diverse perspectives namely, students, intra-rater and inter-raters. The nature-based exercises make small components of the whole for the Basic Design Studio of the first year of undergraduate studies in Architecture at Sathyabama Institute of Science and Technology, Chennai during the academic session from August 2023 to January 2024. Natural object-based exercises can assist in progressive learning and directions to structure open-ended tasks for academicians and give insight to students into their individual processes through reflective thinking methods. This will help design educators frame generative basic design tasks to enhance students' thinking skills, comprehension and synthesis leading to creativity with appropriate reasoning.

Keywords: Problem-Structuring, Mixed Methods Research, Basic Design, Natural Object, Design Education, Design Studio

Introduction

The term “design” is both a noun and a verb. It refers to the mental processes adopted by both individuals and groups to create outcomes with a focus on the framed problem. “Design” firmly grounds diverse domains such as architecture, industrial design, product design, graphic design, interior design, fashion design, etc. To enhance the ‘design thinking’ among the students pursuing such domains. “visual arts” or “basic design” is offered as a foundation course during the first semester. This develops thinking skills, creativity and diverse abilities such as sketching, painting, colouring, model making etc among the novices. Innovators often turn to nature to get inspiration for designs to achieve a unique product that is efficient and effective.

The design tasks framed as part of basic design or visual arts studio to develop thinking skills and creativity are ill-defined and students face numerous challenges in comprehending as well as finding solutions for the same. According to Parashar, S. (2022), the framed tasks in the foundation revolve around three strategies namely, the traditional strategy, the act of borrowing and deconstruction or decomposition. The conventional strategies focus on the progressive evolution of form while borrowing addresses the license of borrowings from paintings, sculpture and other artifacts. Finally, “deconstruction or decomposition” is about taking a unique path in comprehending something holistically or in a fragmented manner and finding new ways to combine the parts.

Figure 1: Students Working on the Task and Examples of Outcomes

Problem Structuring

Design is typically a problem-solving activity. Finding solutions to a design task is challenging. According to Restrepo and Christiaans (2004), there is less information about the problem as well as the solution and no directions to the transformation or the structuring process. Simon (1973) has posited that “problem structuring is a process of drawing upon knowledge or external information to compensate for missing information and using it to construct the problem space”. Goel and Pirolli (1992) have identified four phases in design problem-solving activity namely, an exploration and decomposition of the problem, an identification of the interconnections among the components, the solution of the subproblems in isolation and the combination of the partial solutions into the problem solution. Interpreting the framed problem, the ability of the students to focus on the problems and solutions, access to information and timing play significant roles in problem structuring (Restrepo & Christiaans, 2004).

Problem structuring in architecture education is a process that helps students understand a problem before, during and after they start collecting data, modelling, or analysing it. It is the fundamental step in the problem-solving process. Unlike some domains in education, it can not be assumed in architecture and design education that all the relevant issues constraints and goals that constitute the problem are defined in advance or are uncontroversial. In the problem structuring process of a design brief, there is no single uncontested representation of what constitutes the solution. It is against this background, that the authors have attempted to decode the problem structuring adopted by students pursuing architecture in the foundation studio. The framed tasks create a methodology for the students to explore, analyse, interpret, interrogate, induce and express the ideas while evolving, and developing conceptual ideas. (Ramaraj, 2017).

Theoretical Background

Academicians working with the first-year architecture foundation work sometimes select central themes for individual exercises. Natural objects can be selected as the theme and students are encouraged to derive, synthesize and pick from natural objects that are selected as a part of the process. The problem structuring process becomes a major part of the creative process the students undergo. The background study has been taken based on exercises that are Nature-inspired, related to student problem-structuring processes and open-ended tasks in basic design.

Nature-inspired designs help form the basis of design education which subsequently helps in learning about forms and masses in architecture in later semesters (Jebakumar Clifford, 2021). Lin and Liu (2023) argue how nature-inspired design can help students tackle changes in educational cognition, knowledge categories, way of thinking, logic of design, and value of design caused due to technological advancements and artificial intelligence. According to Stevens et al. (2020) research conducted during the Spring semester of Design at The Hague University of Applied Sciences in 2019 showed that students tended to use biomimicry principles more as a hollow concept rather than going through a rigorous in-depth process of understanding and applying the concepts in their design. This meant correct imitation or adaptation of biological strategies and mechanisms into an individual design idea that needed improvement. Journal-keeping steers students toward reflection that leads to the restructuring of their knowledge base which in turn promotes an increasingly theoretical understanding of their metacognitive knowledge (Hargrove, 2012). The open-ended task that was introduced to students started with a journal-keeping process on the individual natural objects. Student psychology plays an important role in tasks. Open-ended tasks show that they help students in various systematic investigations such as “research”, “problem”, “exploration” and “solution” spaces (Ramaraj, 2024).

Methodology

According to Creswell et al. (2004) the logic of mixing both quantitative and qualitative data results in visualizing the big picture of a situation through an in-depth analysis. Mixed method research incorporates multiple methods in a systematic manner which revolve around collecting, analyzing, interpreting and reporting both qualitative and quantitative data (Bryman, 2012; Creswell, 2021; Creswell & Plano Clark, 2011). The purpose of mixed-method research is “to expand and strengthen a study’s conclusions” (Schoonenboom & Johnson, 2017). By employing a mixed-methods design, researchers can combine and harmonize diverse data sources, which aids in the exploration of intricate problems that have not yet been studied (Poth & Munce, 2020). In this study, emergent mixed methods as posited by Morse (2009) are adopted sequentially during the study phase to decode the problem structuring processes adopted by novices.

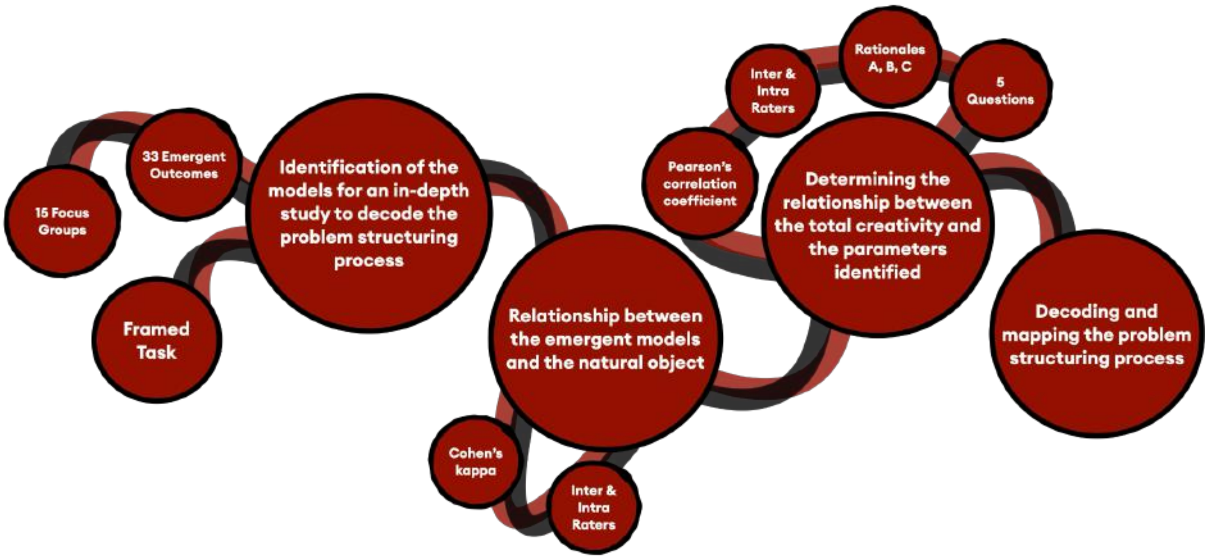


Figure 2: Research Methodology

Participants

As part of the basic design studio (Design studio I, SARA9102), the task was framed. Thirty-three students (17 girls and 16 boys; average age 18.3 years) pursuing architecture at the Department of Architecture, Sathyabama Institute of Science and Technology, Chennai during the academic session, August to December 2024 participated voluntarily. For the evaluation process, five skilled assessors (1 male and four females; average age, 35.4 years) with an average experience of 9.4 years in teaching participated voluntarily. Among these skilled assessors, two members planned, organized, conducted and successfully conducted the basic design studio.

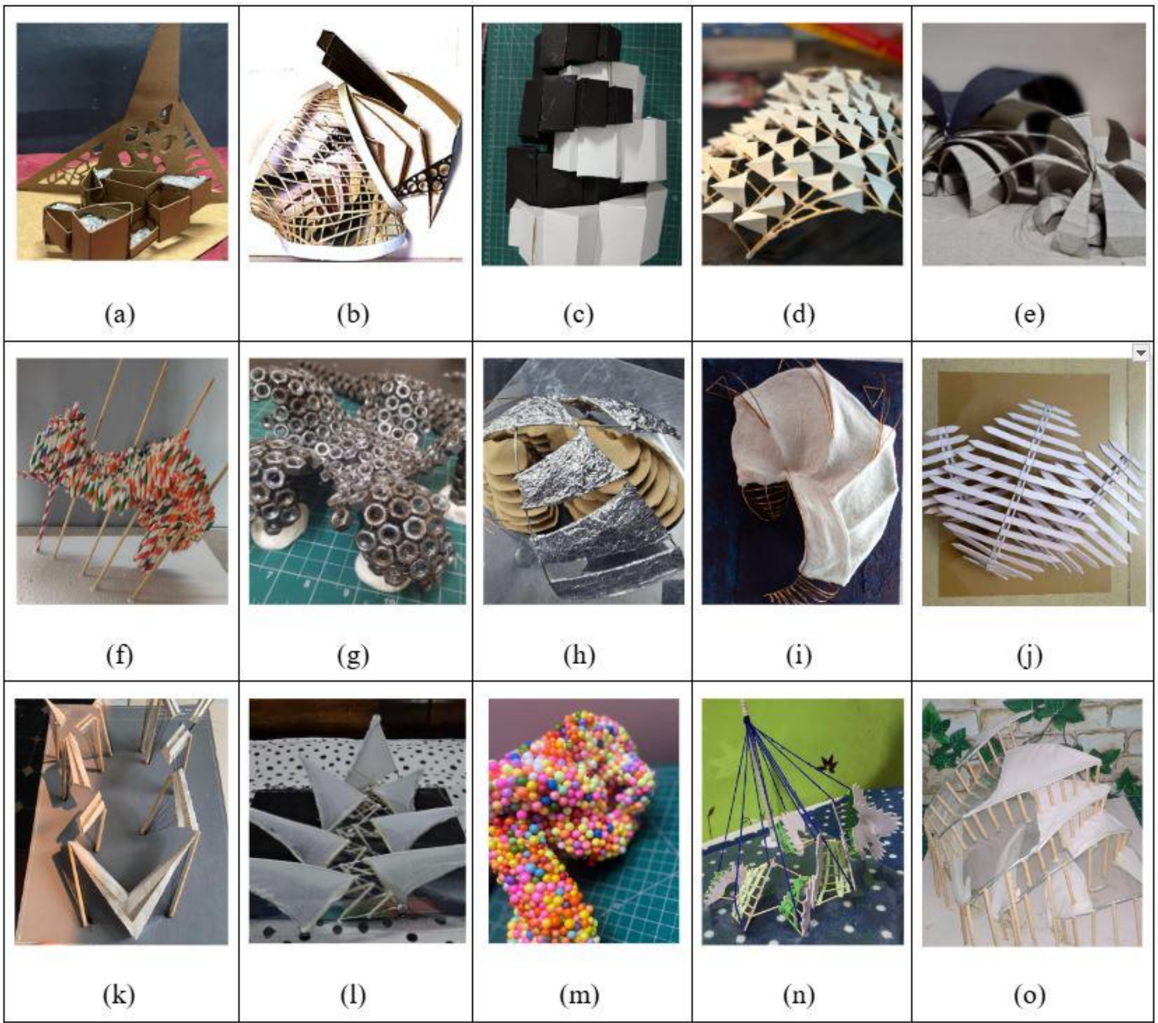
Data Collection and Analysis

The study is conducted in four phases as shown in Table 1. The first phase revolved around the identification of unique outcomes based on the shared views of the design studio team. Among the thirty-three emergent outcomes, fifteen models as shown in Figure 1 were selected for an in-depth study. The second phase revolves around the design processes and the outcomes of a basic design task that revolves around generating a 3D model with inspirations drawn from a natural object. During this phase, two intra-raters (2 females; average age, 35.5 years) shortlisted fifteen models for further study. According to Viera and Garrett (2005), the value of Cohen’s kappa more than 0.61 depicts substantial agreement. The relationship between the emergent models as well as the natural object was observed by two intra-raters (2 females; average age, 35.5 years) and an inter-rater (1 female, 35 years) on a dichotomous scale to determine Cohen's kappa.

Table 1: An Insight into the Four Phases Adopted for Data Collection and Analysis

Phase I	Identification of the models for an in-depth study to decode the problem structuring process
Phase II	Relationship between the emergent models as well as the natural object using Cohen's kappa
Phase III	Pearson's correlation coefficient to determining the relationship between the total creativity and the parameters identified for decoding the problem structuring process
Phase IV	Decoding and mapping the problem structuring process

The shortlisted models were evaluated with a focus on profiles, experimentation with ideas and materials, and inherent quality with a thrust on the natural object identified by the students on a five-point Likert scale by five inter-raters. For the assessors, the image with both the outcome and the source inspiration was shown twice, firstly to rate and secondly to confirm the rating. Besides, total creativity was measured on a twelve-point scale, primarily to overcome the degree of biased evaluation. The total creativity was evaluated by an inter-rater (1 female, 35 years) who has ten years of experience in teaching as well as in conducting a basic design studio. The scores obtained on the twelve-point scale were converted into a five-point scale from one to five representing 'strongly disagree', 'disagree', 'neutral', 'agree' and 'strongly agree'. Pearson's coefficient was determined between the calculated fifteen mean values and the respective overall impression scores to examine the type of correlation. These parameters were mapped hierarchically to decode how the students had drawn inspiration from the natural object to evolve ideas for the 3D models.



Source of inspirations (a) Pomegranate (b) Peepal leaf (c) Fern (d) Acorn (e) Mangosteen (f) Bamboo (g) Jackfruit (h) Walnut (i) Conch (j) Feather (k) Antler (l) Dragon fruit (m) Pepper (n) Cactus (o) Dahlia

Table 2: Identified Outcomes and the Source of Inspiration

Findings

Cohen’s kappa is calculated from five questions on the aspects such as experimentation with materials, ideas, inherent quality, modules and layers collected from both intra-rater and inter-rater is 0.71. This value shows a substantial agreement among the raters which indicates that the identified aspects for decoding the problem structuring process are appropriate. Pearson’s coefficient was calculated for the identified aspects in two ways. Firstly, between the total creativity and the mean score of the four intra-raters and secondly between the inter-rater and total creativity. The calculated coefficients are shown in Table 3. The values obtained to check the degree of agreement between the total creativity and the intra-rater depict moderate relationships for all the identified aspects. Concerning total creativity and inter-rater, the values depict a strong relationship for inherent quality, experimentation with ideas and modules; and moderate concerning the experimentation with ideas. However, the value obtained for the aspect ‘layers’ depicts a weak relationship.

Table 3: Pearson's Correlation Coefficients

Aspects		Intra-rater (5 nos.)		Inter-rater (1 no.)	
		Coefficient	**Relationship**	**Coefficient**	**Relationship**
Experimentation	Materials	0.55	Moderate	0.58	Moderate
	Ideas	0.54		0.68	Strong
Inherent quality		0.57		0.79	
Modules		0.58		0.68	
Layers		0.53		0.46	Weak

The process adopted in all the thirty-three emergent outcomes was decoded in association with the source of inspiration by the two intra-raters who handled the design studio. The processes were decoded and interpreted as 'rationales'. Three rationales were interpreted as shown in Table 4 and the students had predominantly adopted a 'metaphoric approach' and classified as tangible as well as combined metaphors as posited by (Antoniades, 1992). Three rationales such as A, B and C were interpreted. Rationally A focuses on the overall profile to generate modules that were either scaled up or scaled down to create a form. When the cross-sectional or longitudinal profiles serve as the source of inspiration to create a form, it is identified as Rationale B. Rationale C revolves around deriving a profile from a part of the natural element to create modules and forms incorporating an inherent quality.

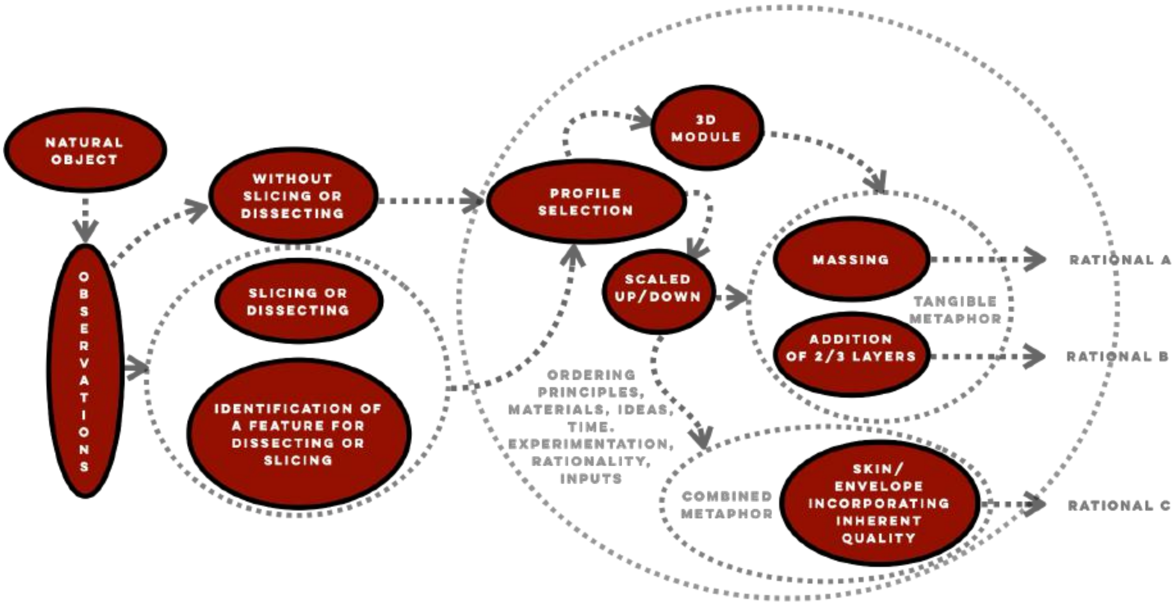


Figure 3: Mapping the Problem Structuring Process

Among the thirty-three outcomes, around eighty per cent of the outcomes fall under tangible metaphors. Concerning the outcomes identified for an in-depth study to decode the problem structuring process around 40% were classified as combined metaphors.

Table 4: Interpreted Rationales and Classification of the Emergent Outcomes

Rationales Interpreted After Decoding the 33 Emergent Outcomes	**Metaphoric Approach**	**Number of Emergent Outcomes**			
		33		15	
		Nos.	**%**	**Nos.**	**%**
Rationale A: Overall profile (positive / negative) + Module+ scaled up/scaled down + Massing	Tangible Metaphor	Fourteen	42.42	Four	26.66
Rationale B: Profile derived from cross section or longitudinal section + Scale up/Scale down to generate modules + Massing + layers		Twelve	36.37	Five	33.34
Rationale C: Profile derived from the cross section or longitudinal section of a part derived from the natural element + Scale up/Scale down to generate modules + Massing + layers + Inherent quality	Combined metaphor (Tangible & intangible)	Seven	21.21	Six	40

Conclusion

The processes decoded to interpret the problem structuring process were mapped as shown in Figure 2 to construct the different processes adopted by the novices to create a model drawing inspirations from the natural element selected. It was observed that the models incorporating two or three layers incorporating inherent quality were unique. Such outcomes displayed that the problem structuring process adopted by respective novices was firmly rooted in the natural elements from which they had drawn inspiration. Besides, the nature journal which was introduced at the beginning of this task facilitated them to comprehend and interpret the diverse properties visually as was sensorially. The students were able to incorporate the ordering principles, and continuous experiments with ideas and materials along with the suggestions and comments were given by the design faculty enabling them to think out of the box to create metaphoric three-dimensional forms.

Future Directions

Exploring the problem structuring process will also help faculty members frame tasks that are challenging and unique in nature. A longitudinal study of the problem structuring process for an open-ended task will give an insight into how creativity and thinking processes change concerning time. Besides, taking inspiration from natural elements in architectural design studios offered in higher semesters can also be explored to comprehend the principles of 'bios' in architecture with a thrust on biomorphism, biomimetics, biophilic etc.

The methodology adopted in this study can be extended to other open-ended tasks in basic design studios or foundation studios which are offered in diverse domains such as fashion design, product design, interior design, visual communication, animation etc. A comparison of the problem-structuring process of students to an AI-generated algorithm is a possible pathway to a future of education in design.

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