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Design Pedagogy through Biomorphic research: A digital approach to design methodology in an undergraduate architecture studio

Quratulain Asghar[1*], Fatima Javeed[1], Syed Muhammad Zille Ali Naqvi[2]

1. *University of Engineering and Technology Lahore. Architecture Department*
2. *Design Head, at Studio arch consultancy firm in Lahore*

∗ **Corresponding Author***:* Email: quratulainasghar@gmail.com

Abstract

The purpose of this research, resulting from the design studio experimentation, is to frame and explore the outcomes of a biomorphic design methodology. Also, the research observes how knowledge transfer takes place about the novice learner when exposed to such a methodology as an architectural medium. This design education literature is composed to construct a theoretical lens in digital environments as well as cognitive theories of learning, keeping in view, the challenges confronted by and achievements of the students in the studio. Assembly of design concepts from natural processes is explored as a medium of design inspiration in the research. An investigational design studio titled: 'Design through biomorphic research: the investigation of contemporary digital tools' is explained for instructing the 4th year architecture students. This framework, along with the inventive end products, is demonstrated by a sequence of stimulating research and design challenges explored in the studio. The projects presented expand upon the term 'biomorphic' by examining the animal kingdom and complex natural process as an inspiration and are focused on the understanding of a myriad of complicated and self-organized processes. Thus, these projects translate the principles from nature into design decisions with the help of digital tools available today. The paper illustrates one of the methods of investigation, bringing together architecture, science, and nature. The methodology is explained with the help of two projects resulting from an outline provided by the instructors to their 4th-year design students at the Architecture Department at the University of Engineering and Technology Lahore, during the 2017/2018 academic year.

Key Words: Bio morphism, architectural pedagogy, digital tools, Vertical landscape.

1. Introduction

The basic idea of bio morphism is to take nature and life as a model. It is by default one of the oldest and most fundamental aesthetic concepts in architecture theory. The technological advancements have now made it easier and convenient to get inspired and learn from nature. Significant scholarly attention has been paid to the areas of design education research in architecture around the globe.

Unfortunately, Pakistani architecture grounds still need to work on the intensified cognitive challenges for novice learners in a digital era and have yet to be explicitly addressed in the architectural literature. As educators, we wanted to explore how advanced and diversified software and tooling technologies impact the pedagogy of the design studio. Pakistani architectural community still has a conservative approach towards adopting digital and technological advancements. The main purpose of this experimentation conducted at the studio is to identify and exploit the aforementioned gap by addressing the cognitive and pedagogical factors that may inhibit or amplify efficient knowledge transfer for the novice learner in digital design in Pakistan.

2. Literature Review

To develop a better understanding of this study I will start by introducing the existing literature on three major components of this research in this section: The concept of biomorphic design, Research-based education, and Digital Pedagogy.

2.1 The concept of biomorphic design

Getting inspiration from nature and using it in the design are recently being understood in various terminologies like biomimicry, biomimetic, bionic, Bio design, biomorphic, bio utilization, biophilia, and bio derivation. This term biomimicry was introduced by Frosch and Gallapoulos, and they presented a special concept of resembling ecosystems by creating a balance

between nature and mankind [1]. Various investigations were performed during the last few decades to examine the evolution of biomimicry in architecture; one of these practices is to examine the development of interesting forms in architectural studios.

Biomimicry levels can be broadly classified into three stages: (1) form, (2) process and (3) ecosystem. Benyus stated that mimicking practice undergoes three levels. The first phase is to copy the attributes of an organism, namely, appearance, visual shape, components, materials, and morphological features. In other words, it means replication of an organism's design. The second phase is to look deeper into reproducing a biological entity's development and procedures within its medium to mimic the natural processes. The third phase is a more complicated set of processes: the form and processes of an ecosystem are duplicated [4]. Mimicking is applied on a large platform where the design goes beyond the entities to identify its explicit and implicit effects in the environment. Mazzoleni and Price [13] stated that biomimicry exceeds a mimicking and performs on diverse levels, such as organism, behavior, and ecosystem. Consequently, to explore this concept of biomimicry in design leads to the adaptation of *research-based studios.*

2.2 Research-Based Studios

In this paper, the semester work was not maneuvered and based on the basis of conventional design methodology rather focusses on exploring something new and original, which we believe should be the main purpose of all types of architectural studios. Novelty is emphasized as a precondition of architectural creation, as architecture is always about the new, beyond the established [14]. This studio also emphasizes the method that breeds new knowledge and experiences for novice learners. This research-based initiative leads to the growth of skills and proficiency for teachers as well. It also accentuates the situation that the teacher starts acting as the originator of new architectural knowledge and experiences rather than just being a translator. Experience-based learning and research-based learning combines on the bases of project-based transfer of knowledge in architectural pedagogy. The necessity to reconsider university education as a comprehensive process is at the center of debates in higher education since the formation of *"communities of learning, dialogue, research, and practice"* is seen as the primary mission of a modern university [10].The locus of studio education as a form of certified education at the university context asks for special consideration within the agenda of current discussions. By focusing on the inclusiveness of studio pedagogy, this experimentation investigates learning-based teaching as a search for innovation.

This studio teaching methodology boosts students to learn through questioning and critical thinking and also the act of educating outrivals only the transmission of understanding and transforms into a practice in which the teacher also unremittingly learns. Exchange of ideas and contact among the teacher and students becomes essential. Research-based teaching also aims at nurturing students with the knowledge, skills, and attitudes they need to learn. In other words, teaching becomes a new task to learn. Students, on the other hand, also take more active roles in the learning process. In research-based teaching, the emphasis is more on the process and problems engaged with, rather than the product [6].

2.3 Digital Pedagogy

Also, currently practiced models of studio education are in the process of alteration to new educational and technological environments of the digital age. This situation can be seen as akin to the manifestation of modernism as a pedagogical model during the period of the Bauhaus.

During the last decade emerging technologies have begun to influence central issues in design theory. Architectural design has become engaged with the exploration of complex geometries, 'free forms' [14] as well as related materialization processes of fabrication and manufacturing technologies [10]. These developments have begun to exert significant influence on the theoretical, conceptual and methodological contents of design.

Beyond the manipulation of digital media as tools, the relation between digital design and digital design models as a form of architectural understanding has begun to appear as a significant ideational resource for design and design education. Theoreticians have attempted to define paradigmatic approaches in architecture based on the ideational impact of digital technology [5]. This paper is an attempt to study the above mention important contemporary challenges in the context of a Pakistani architectural studio.

3. Studio Methodology

The studio commenced by introducing the concept of research in a traditional environment, where students only used to read and develop the program requirements with the help of time saver

standards[1]. Each student was probed to search for interesting phenomena or processes in nature and the term "biomorphic" was explained to them. We ensured that each student will explore their area of interest instead of getting dictated by us. After they had explored interesting phenomena and selected their areas of interest, they were introduced to the process of "***mind mapping***"[2], to narrow down their research to design a module[3] which is a three-dimensional illustrative representation of their research. The step by step process of studio instruction included:

- Research: a biomorphic process/ phenomenon.
- Mind Mapping: narrow down the research with the help of a mind map.
- Module Design: A three-dimensional module had to be designed by incorporating the gathered research.
- Architectural Project introduced: Design of a Vertical Landscape
- Site selection criteria were defined but each student selected his/her site.

Constraints Development Charts: research, site, and module constraints were to be compiled to initiate the design.

- Use of digital software: Resolving the constraints with the help of the latest digital tools available.
- Implementation of the research study to develop the design.
- Specifying individual research problems.
- Applying the findings of the research, to a design problem.

Along with these unexposed learning challenges and pedagogical implications, students were forced to establish a strong link between the biomorphic researches they conducted, the existing site and architectural problems.

[1] Time savers standards is a sourcebook for planning and designing residential and commercial buildings.

[2] Mind Mapping: a diagrammatic presentation, usually with a central idea placed in the center and linked concepts arranged around it.

[3] Modular design, is a design method that divides a system into mini components called modules that can work individually and then used in main systems.

4. Aims and Research Questions

The main drive behind this research is to enumerate the benefits and explore the biomorphic technique with the help of digital tools, keeping in view, the novice learner's exposure to digital tools as an architectural medium in an undergraduate design studio. The following are its main research questions:

• How can the biomorphic design process be assimilated into an undergraduate design studio?

• What are its fortes and flaws?

• Does the pragmatic design approach achieve its goals in generating inventive design results and help in an escalation of students' design skills?

4.1 Introduction to Digital Tools

The course consisted of 4th- year undergraduate students of architectural education and the knowledge of the students varied in terms of technical skills. Although some participants obtained skills related to the advanced 3D digital modeling, none of them had experience with Rhino and Grasshopper for parametric modeling. As a theoretical part of the studio course, they were given three different lectures on how to operate Rhino, its important plugin Grasshopper and Para Cloud Gem as designing modelers. These lectures were only basic and students were forced to practice these tools on their own. Few small assignments were given to them to produce and design a pavilion using these tools. The results of these introductory lectures and small assignments and tasks, given to the students, were amazing. Some of the students were intimidated at first and some were extremely excited and eager to learn these tools further.

The learning outcomes can be summarized as:

1. Introduction to the systems thinking and parametric tools.
2. Applying design ideas with the help of these new tools.
3. Exposure to contemporary digital media in architecture.
4. Application of research findings into a design principle by using these tools.
5. Exposure to the whole new world of design methodology.

4.2 The architectural Investigation

Students found it challenging to design a vertical landscape by narrowing and transforming their biomorphic research into an interesting program. These projects were seen as a testbed of form generation that allows for experimentation and exploration of concepts, methods, forms and digital techniques. Students were probed to select a site keeping in mind their research and project constraints and were asked to develop public and propose social spaces that can function as a complete process as it happens in nature. Natural systems were examined and findings of a selected matter or phenomenon were implemented as a design solution. Based on the outputs, it is identified that students learn from natural systems in three different ways including generation of morphological and organizational relationships, translation of properties, and processes in nature adapted to the design process**.** Students were inquired to keep the aforementioned context in cognizance during the design process and to keep it incorporated within their research. This was done to make sure that the evolution of their form passes through a laborious and attentive method.

The procedure and criteria for the design development were as followed:

- Evolution of the design process, utilizing findings from chosen research and the natural processes studied.
- Mind mapping to develop the module.
- Architectural program and design method articulated through diagrams, sketches, and 3d models.
- Production of layout, drawings, 3D examination and prototypes.
- Production of tectonic techniques and structural limitations.
- Production of detailed drawings.
- Detail of the tools and modelers used for the production of the project.

5. Exploration-I

Here I am going to discuss the work of two students who followed the schematic approach to handle the design challenges and have efficiently used the digital tools and software to transform their biomorphic research into architecture. The following projects adhere to biological adaptations of the complex nature and intricacies associated with the functioning aspects of two different organisms: Baya Weaver Bird and Sea Urchin, respectively. The research constraints were based on a series of interesting analyses which included: temperature, growth, movement, and eating and developing patterns. Aside from the technical proponents of the research, an in-depth analysis of the animal habitat was conceived in conjunction with the analysis of the animal itself through a series of technical diagrams that depict the micro and macro workings of these particular organisms.

5.1 Baya Weaver Bird Nest and Weaving Methodology

This particular student studied an interesting process of weaving and nest building of the Baya Weaver Bird. She read and understood the seven stages of the nest formation and attempted to incorporate this interesting process in her design methodology. She also studied and incorporated Baya Weaving Bird's weaving style, its location, and placement on a tree, its orbicular shape, a unique characteristic of hanging and exclusive entrances. These were some of the rare attributes that she housed while visualizing the design. This bird loves to build and live in colonies, and generally choose, on purpose, a neighborhood of a convenient tank or a terraced rice field. The bird is found in parts of South Asia and South-East Asia.

5.2 Nest building process

Baya Weaver Birds very creatively build their nest. The building material mostly is pliant grass stems and other tough fibers. They nibble a small piece from the base of the palm or other fibrous plants, reprise the notch towards the tip, by grasping strands of the margin in their beaks. Then, they shudder the head away from the leaf,

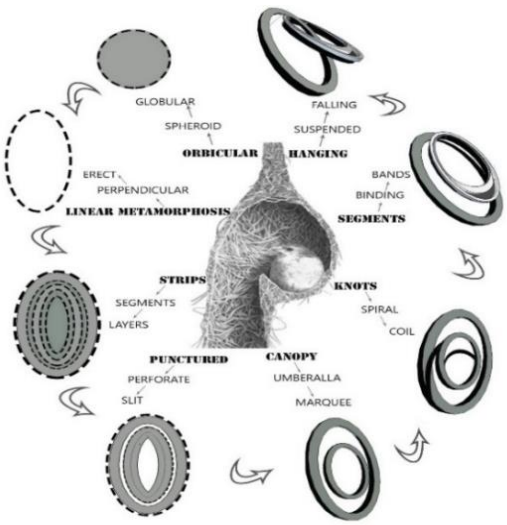

Fig. 1: Module Derivation process through mind mapping. Source: Maryam Iqbal

thus, tearing off a fine cord, perhaps a line in breadth that corresponds in length to the distance between the two incisions.

5.3 Module Derivation from Mind Mapping

To design an architectural module from this research, mind mapping is done that involves all the possible characteristics of Baya Weaver Bird's nest. The bird wraps a considerable amount of fibrous material around a chosen limb. It is often three or four feet from the top of the pendant next to the farther end of this wharf, thus fortifying a firm hold upon the tree. The small strips are not only wound around the branch but are plaited together so firmly that it is impossible with an average exertion to disperse them. This step by step study of each property and process is used to develop and design a module. Module designed through mind mapping could be applied to any section of the building and its variations and population are to be explored with the help of Para Cloud Gem. This exercise helped students to think parametrically and aesthetically as they explore this new tool which produces several interesting parametric options of how to use their designed module.

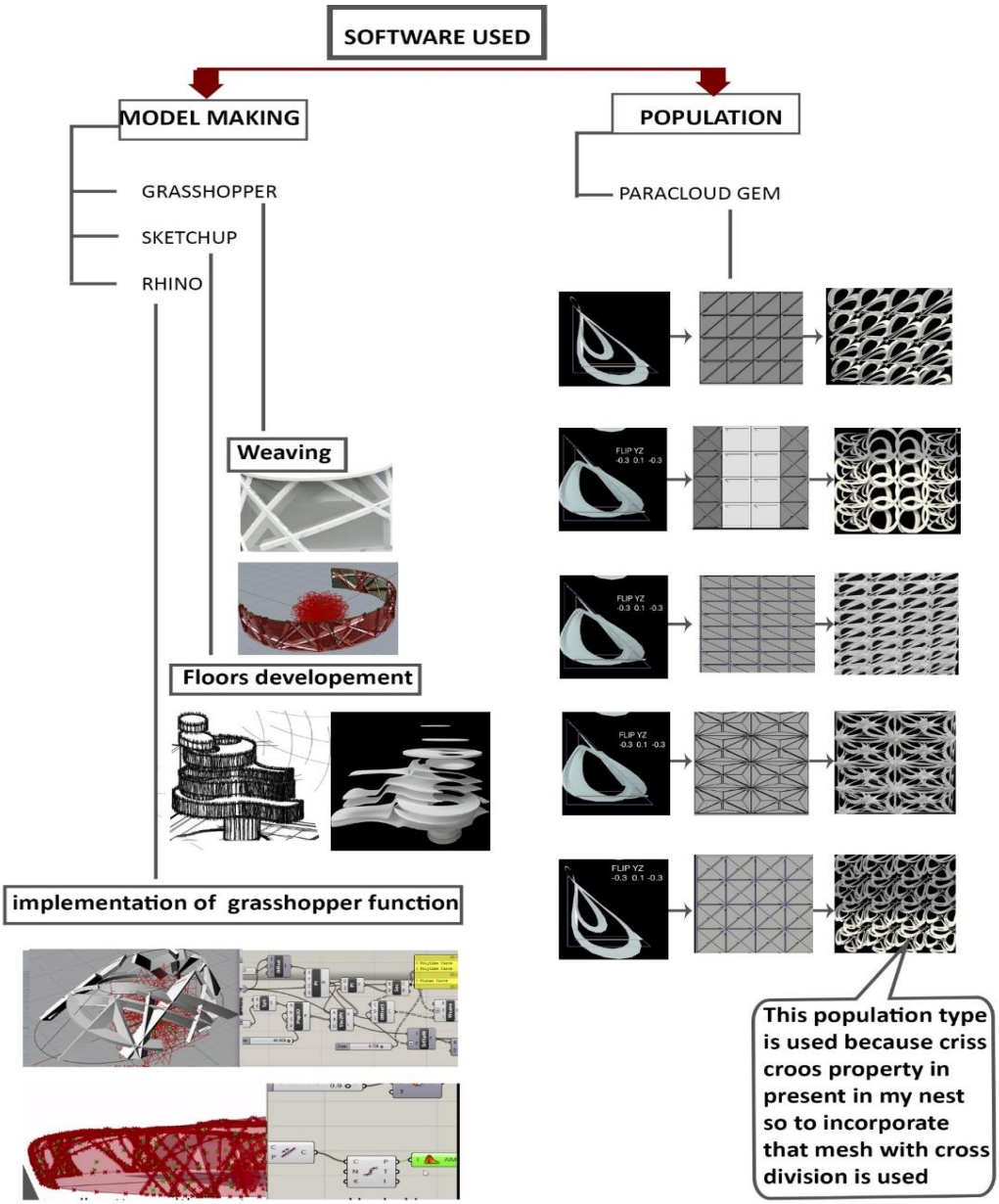

Fig. 2: Module exploration in Para Cloud Gem and Grasshopper. Source: Maryam Iqbal

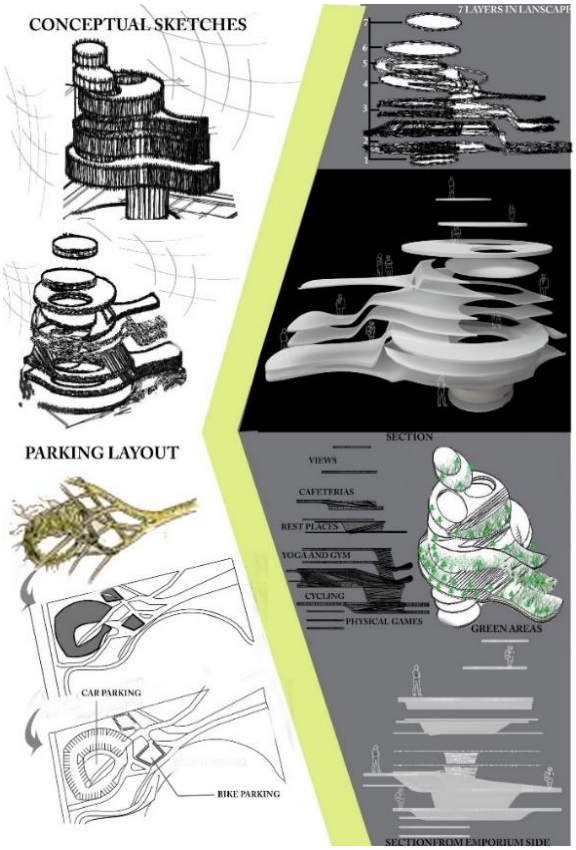

Fig. 3: Diagram showing the linkage of the research on Baya Weavers with the form-finding process. Source: Maryam Iqbal (student)

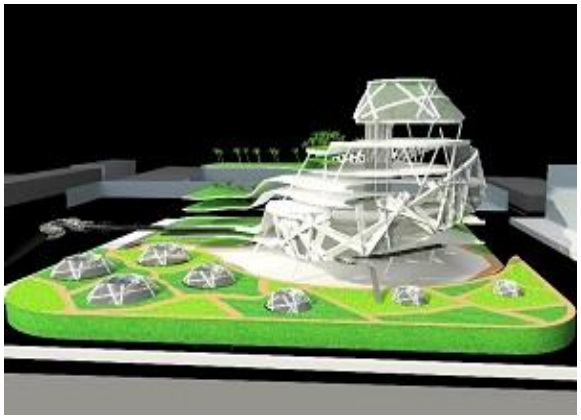

Fig. 4: 3D visualization of the building on the site. Source: Maryam Iqbal (student)

5.4 Vertical Landscape

At this stage, an architectural project was introduced to the students which were a design of a vertical landscape. They were asked to design a dedicated vertical building that provides space to grow plants and trees in city centers. Vertical landscapes seek to invite nature back into our cities on a broader scale. Lahore is exceeding its boundaries and construction is growing day by day, a practice that has diminished green areas and parks in the city. Hence, it has now become a necessity to make Lahore greener through vertical structures, which can create park-like activities whilst consuming less space. In the age of increasing population and pollution, there is an urgent need for such structures around. The real challenge now was to come up with the form that explains the bird morphology as well as tackle the site and architectural challenges associated with the project. Contrariwise the Baya Weaver's structure methodology teaches the student that the birds wrap a considerable amount of fibrous material around its limb. It is often three or four feet from the top of the pendant next to the farther end of this wharf. This process promises a firm hold upon the tree. The small strips are not only wound around the branch but are plaited together so securely that it is impossible with an ordinary effort to separate them. To adapt this for the inspiration of the form, the weaving technique is used as the skin around the building by using Grasshopper's weaving plugin. The building has less floor area at the bottom. The central part becomes orbicular and upper gets contracted again. Seven stages are incorporated in defining levels in the landscape. The levels are divided into different floors showing division of chambers in the bird's nest. Bridges are formed with neighboring buildings to interpret the colonization of the Weaver Bird's nest. This bird uses around 500 strips as well as 3500 strands of grass to build a complete nest in 18 days. The final pattern comprises woven knots and the lower bottom is kept less dense. There is a clear division of chambers in the nest which has been used in form development by keeping different floors in the building. It is usually suspended from the tree with various openings, each having a diameter of around 10 cm. The diameter of the complete bulb ranges from 5 or 6 inches on the bigger side and 4 inches on the smaller. After shaped this upper chamber and having located the future egg chain bet, the birds then build a strong, compactly woven transverse band or bridge that divides the lower part of the space into two unequal chambers. By studying this phenomenon, our student has derived the basic shape of the plan. The two voids that act as a buffer or atrium space, prominently show the entrances, as defined in the nest. Moreover, as we move upward the plans get contracted like the 3D shape of the nest that acts like an oval tube-like form. During the development of the 3D model of this building, the orbicular verticality of the weaver nest was kept in mind. Like the nest, the upper part of the building

is less dense as compared to the lower part. To give a proper structural strength to the building, a weaving network is circulated, which reflects the closure we have seen in a nest. This weaving network is formed by aluminum steel strips that only act as a skin around the building. Proper internal support is given by the inclined columns. In the front elevation, the wireframe structure, which has been populated and designed on Para Cloud Gem, fulfills the structural purpose.

5.5 Digital Software Used

Grasshopper4 - a plugin for Rhinoceros, Grasshopper was used in the process as a parametric modeling tool to create virtual simulations of the concepts. It is worth mentioning that Grasshopper should be treated as a tool in the design process; it can be an extension of the process which enables architects to create innovative new possibilities and to test a variety of new ideas quickly and easily.

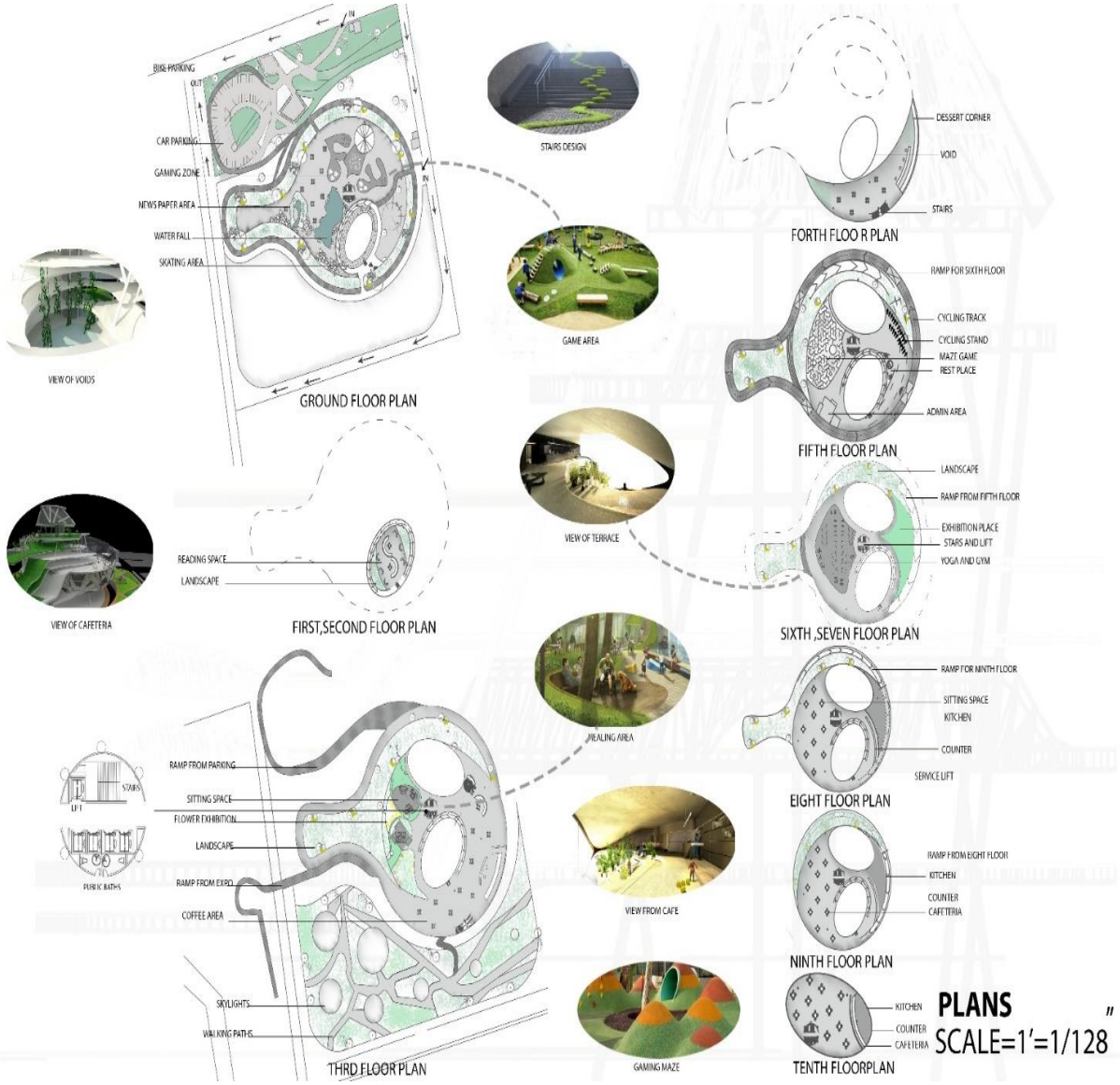

Fig. 5: Figure showing transformation of Bea weaver bird into plans and masterplan. Source: Maryam Iqbal

[4] The plugin is mainly an algorithmic modeling tool for Rhinoceros which provides a visual scripting interface, allowing users to build their 3D models without prior knowledge of complex programming languages or scripting experience.

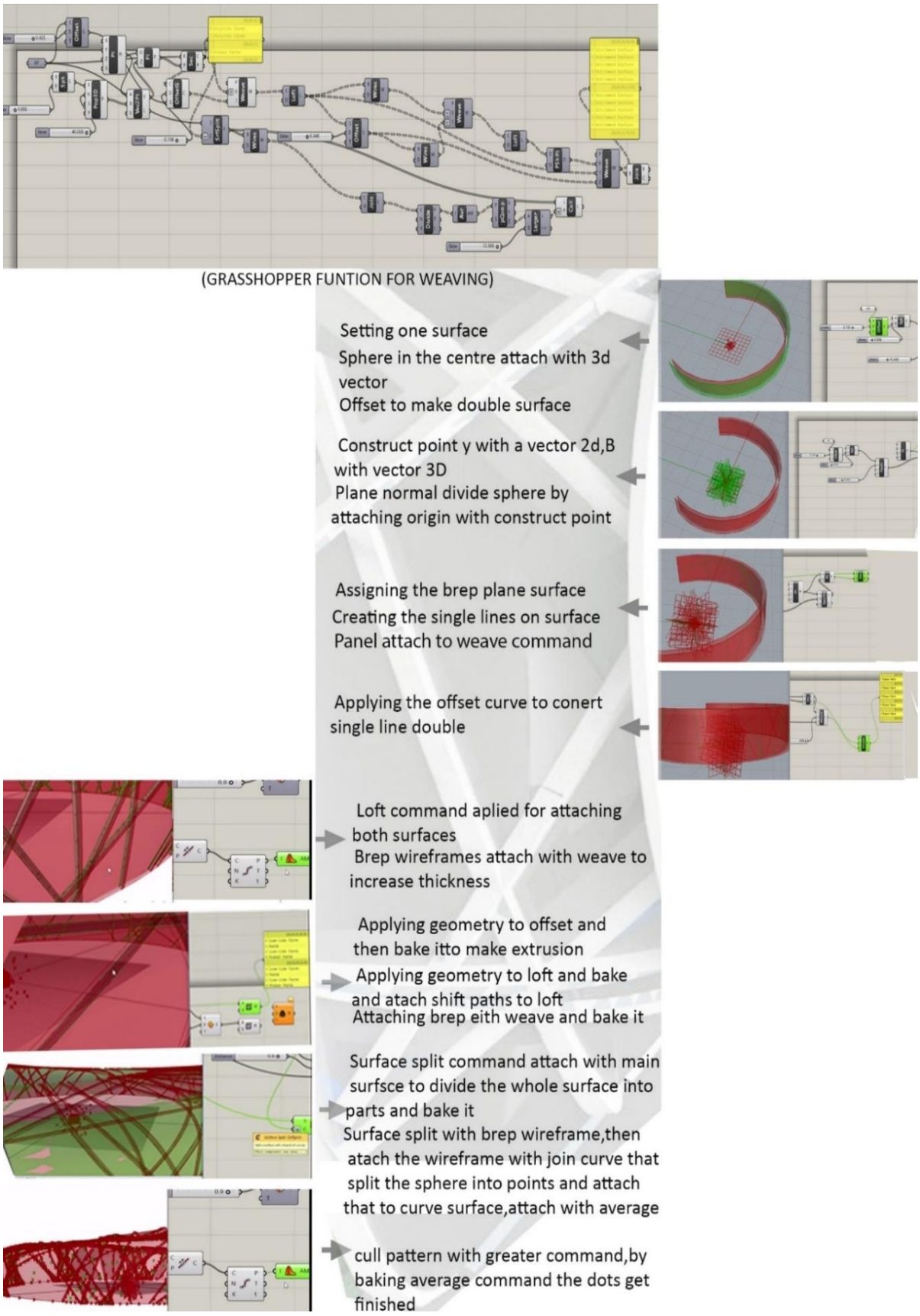

Fig. 6: Use of Grasshopper to derive the weaving pattern on the facade. Source: Maryam Iqbal (student)

6. Exploration II

The second project is inspired by the interesting processes and morphology of the Sea Urchin. These interesting organisms inhabit the littoral region of the Atlantic Ocean. They are shallow-water echinoderms having soft bodies enclosed in a thin spiny globular shell. Lives in the rocky bottom or close to Coral reefs, thick, blunt, radially arranged spines. The Sea Urchin has been defining as one of the threatened species on earth. First of all, this student came up with a comprehensive mind map by studying the morphology of the Sea Urchin in detail.

6.1 Module Derivation

The linking diagrams below, explain how the properties of the Sea Urchin have helped this student to design an architectural module. Firstly, the five-fold symmetry is the major character because of which the module is kept self-similar and symmetrical. Spherical, and round shape was chosen, which represents the globe form. The module shape can be explained as a depth going up with its underside being slightly flat. The upper side follows a domical shape. The focus is made in the center of the whole shape to show the centralized tube feet system of the Sea Urchin. Variations in the module shape are also studied. It has been strongly linked to the specimen's movement. Circulation, symmetry, fertilization, cell division, and development of the organism have been studied in detail, to develop the mind map.

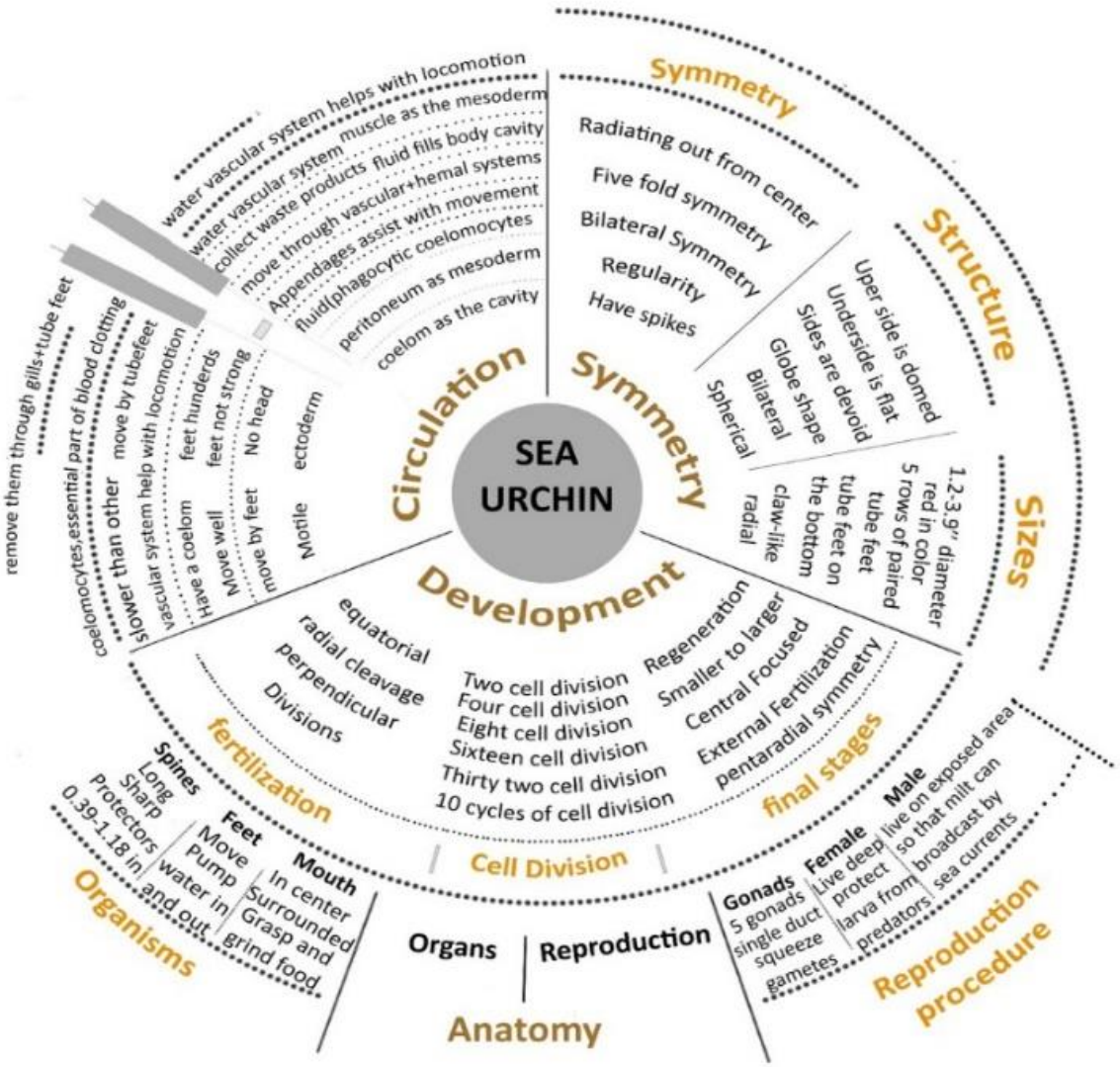

Fig. 7: Mind mapping for module derivation with the help of Sea Urchin Morphology. Source: Syeda Rida

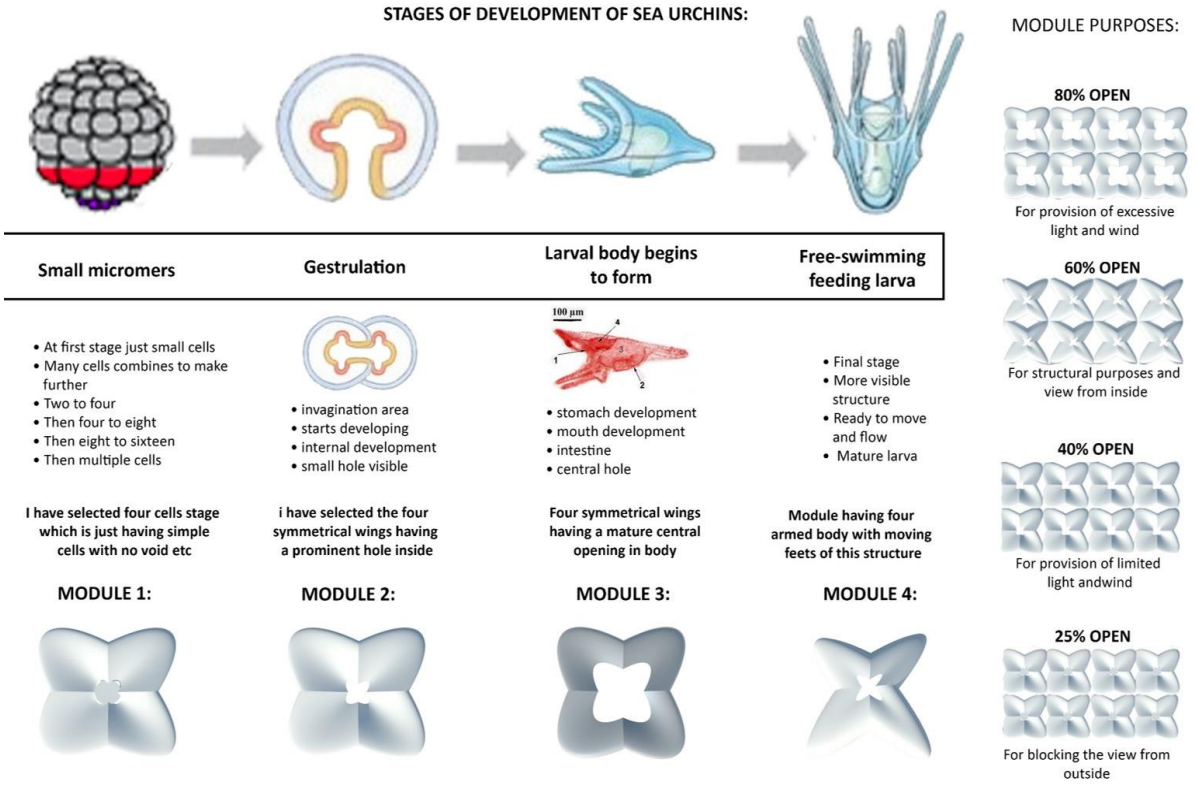

Fig. 8: Diagrammatic representation of Sea Urchin's research leading to Module variations. Source: Syeda Rida

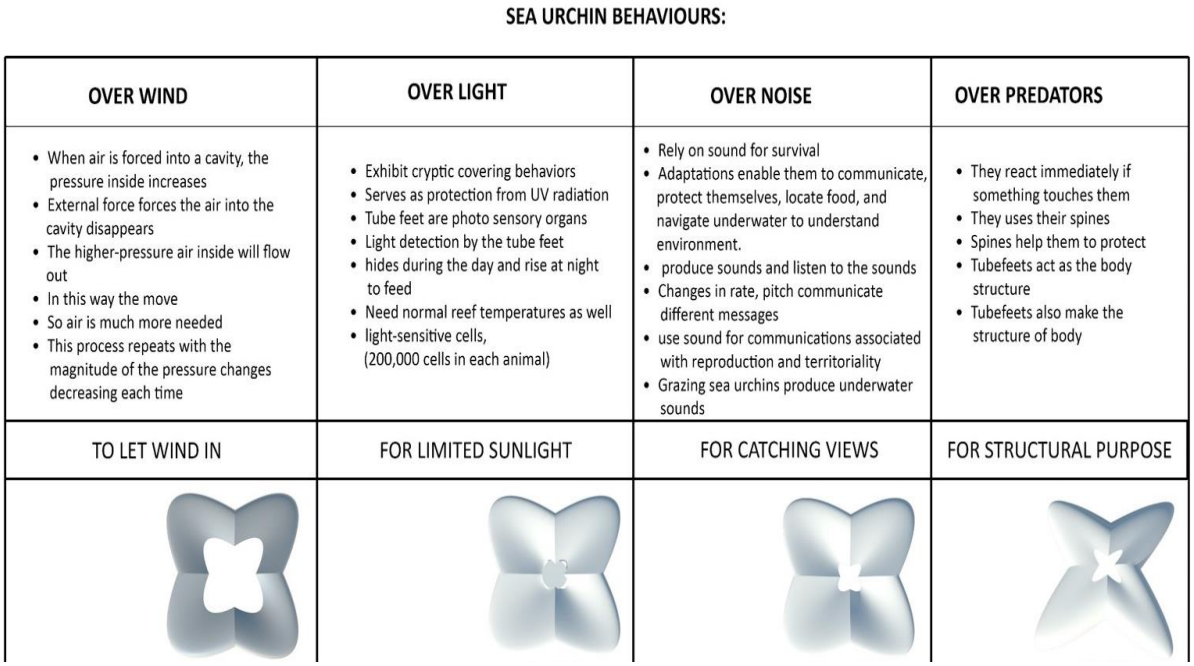

Fig. 9: Diagrammatic representation of Sea Urchin's research leading to Mind Map. Source: Syeda Rida (students)

6.2 Site Contraints

This student visited, explored and understood the functional and operational issues of the selected site to study its impact on the existing environment. Research on the Sea Urchin behavior helped the student to resolve some major issues on the site. Site analysis diagrams are drawn carefully.

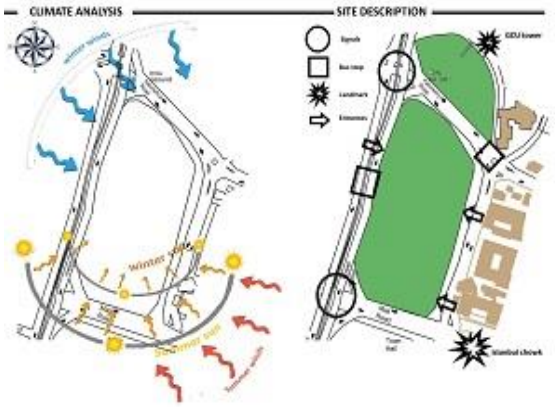

Fig. 10: Study of the site and its constraints. Source: Syeda Rida

In this case, the site was in the Nasir Bagh area in Lahore and its major problems are explored with the help of a questionnaire, public response and recordings of user-demand were recorded. After that, further site constraints were studied and later incorporated in project development. Parking was introduced to meet the challenge of contextual problems.

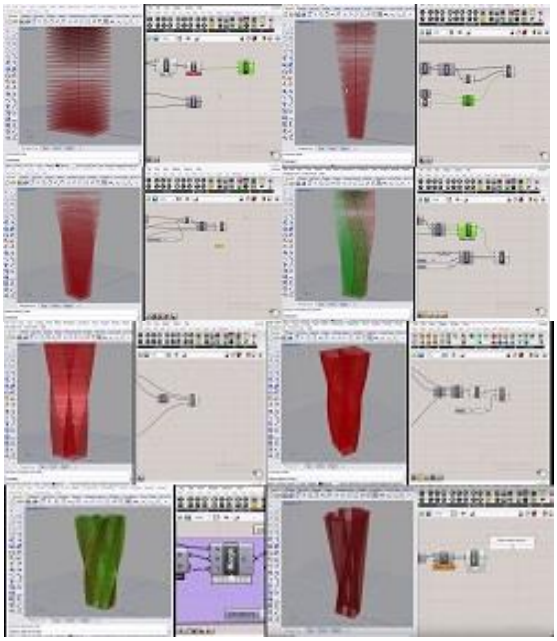

Fig. 11: Stages of development of tower in Grasshop per. Source: Syeda Rida

Two major soft wares were used to develop the 3D image of the project; Rhino (Grasshopper) and Para Cloud Gem (for mesh and module population) to incorporate the major research constraints. Variations of a module in the design are used in the Gem population for different purposes like to catch the view or to block it, to let the wind in or block it, to let the sun in or prevent it as well as for structural purposes, etc. Different types of selected plants (indoor and outdoor) and trees which would grow on upper floors with lesser demand for water and less expansion of roots are used. They will be environmentally efficient because these specified plants are known to be highly efficient pollutant absorbents.

Research data was also collected through a survey at the area and public response indicated that people are facing a lot of problems in terms of parking, which was one of the major issues.

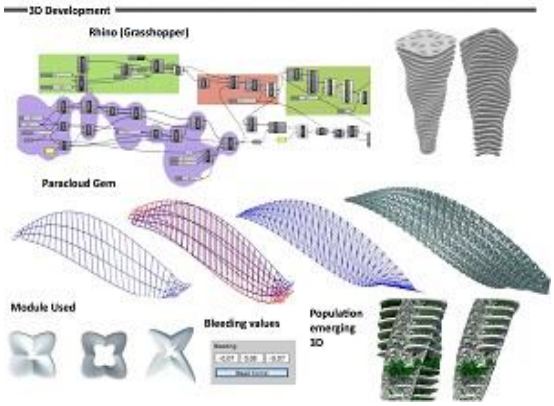

Fig. 12: Process of tower and skin development on Grasshopper and Para Cloud Gem respectively. Source: Syeda Rida

The major design decisions were based on the data derived from the Sea Urchin morphology and the survey conducted. This exercise helped the student to derive a 3D from research and examine how to use conceptual thinking throughout the project. In contrast, the module design helped them to use Para Cloud Gem for various parametric options on the mesh. Using module constraints, research constraints and site constraints simultaneously, resulting in surprising outcomes that helped in resolving the problems of the site.

Fig. 13: Proposed Vertical landscape at Nasir Bagh. Source: Syeda Rida

7. Discussion and Analysis

Instigating biomorphic design in architectural studios has different directions and taxonomies. It mostly depends on the outcome obtained from research. Garcia-Holguera et al [8] stated that architects and researchers addressed biomimicry in architectural design based on three directions: (1) through the development of architectural courses and experimental designs (2) advancement of design tools and methods to establish systematic and organized research and (3) the development of actual design models by architectural firms and research groups.

Various types of biomimetic methods were being practiced since the last two decades however, their reliability for application is still questionable in architecture. The major difficulty is the lack of a clear selective design procedure and the practical application of a design methodology that remains indefinable. Cohen et al [4] mentioned that simulating organisms and processes into methodological structures need to be based on a solid policy and concise framework.

Although this studio methodology establishes that design like this offers many opportunities for innovative building forms. However, at the same time, such explorations face several challenges, particularly when transforming ecological concepts into procedural architectural systems. Many of these proposals only depend on individual parts rather than the whole system. Moreover, this current studio experimentation has established that applying biomorphic concepts in architecture is still in its initial stages and this needs to delve further by the academicians as well as practitioners. Rivka Oxman [10] stated: beyond any doubt, digital design appears to be a mainstream phenomenon, and the theory of digital design appears to be one of the most active and significant subjects of theoretical discourse today. Our approach to fitting the digital and the theoretical has dealt with the problem of any new pedagogy: beginning with a new taxonomy for digital architectural theory. This has occurred to create the theoretical foundations of new processes of design that, in turn, are transforming our accepted traditional models and logic of design.

8. Conclusions

The visions outlined above can provide a sufficient general overview of the punitive characteristics of architectural design that has been most significantly transformed by technologies in the last few decades. However, it is still unclear whether the depth and breadth that this radical shift of focus anticipated twenty years ago, has been successfully implemented in design education. Whereas a cumulative number of graduate and postgraduate programs have adopted a coherent and consistent pedagogic framework that integrates the exactitudes and proficiencies of the digital world, this job has proven to be much more challenging in the case of undergraduate studies. The main research intentions achieved in this studio can be summarized as:

- Professional knowledge with creativity as the highest professional value.
- Critical thinking that challenges the limits of each discipline though analysis and research
- An ethical judgment that stresses the importance of community and sustainability
- Technological expertise in the most advanced technologies available

Many younger Architecture students struggle to develop their design processes in a manner that guarantees a sufficient degree of spatial and functional sophistication. Hence, they often become frustrated by the shallowness of their design arguments. Conversely, undergraduate students also tend to be inexperienced in the use of digital tools, which, to make matters worse, are often understood as simple representational skills to be acquired rather than as design tools. Because of this, the incorporation of digital thinking into the learning experience has often led to bringing out undesired effects of hampering the already problematic development of the students' design process rather than leveraging it. One of the reasons for this state of affairs is that the instructors often stress the importance of digital skills for architectural production, but rarely

outline a methodological model that facilitates a consistent approximation to the design process while being digital. Thinking parametrically and using parametric software has been very useful in this methodology as conveyed by the participants. Participants in the studio cherish this way of proceedings to be accustomed to the environment of the architectural studio; a process that is very cyclic with constant alteration in design. Correspondingly, building facades serve numerous roles, as interfaces between its users and environmental components (e.g., water, air, sound, light, and temperature). Resulting architectural building skins respond; they take into inspection pulsating local environmental circumstances, augmenting and integrating them rather than influencing them and hence, introducing a more sustainable way of designing. Here, the suggestion would be that we should start improvising our conventional pedagogical techniques and schools should work for the time evolution of studio education and its integration with digital media to enhance the knowledge of maneuvering digital tools that are facilitating the design of sustainable and contextually profound buildings. The query which should be addressed after this research is: *what are the impacts of the digitalization of the design process in Architecture and how can we devise a framework based on this methodology in architecture studios?*

9. Acknowledgment

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