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Modular Joint Using 3D Printer for Compact House in Klang Valley Area

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Abstract: The use of 3D printing technology has brought about new opportunities in designing and producing furniture. This research concentrates on creating modular furniture joints through 3D printing, with the aim of making assembly easier, reducing manufacturing time, and improving structural strength. The study explores appropriate materials for printing modular joints, along with design principles and methods for constructing joints that are both functional and adaptable. A comprehensive survey is conducted to gather information on user requirements and preferences. The results indicate that plastic materials are the preferred choice, with a focus on long-lasting durability, ease of production, and sustainability. The research aims to identify key design features, develop modular joints using 3D printing, and produce a prototype. This study is important as it contributes to our knowledge of jointing methods, additive manufacturing, and modular design principles. The results will establish guidelines and recommendations for integrating 3D printing into furniture production, benefiting manufacturers and consumers alike. Ultimately, the goal is to produce a durable and versatile modular junction for furniture that meets the specific preferences and requirements of users. The report confidently examines the promising market for products that incorporate modular joint designs and provide exceptional customer satisfaction. The study is being conducted in the Klang Valley region, with a keen focus on the area's unique environmental considerations and the specific requirements of its inhabitants.

Keywords: 3D Printing, Modular Joint, Compact House, Furniture Design, Additive Manufacturing

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1. Introduction

Technology advancements have granted people access to a vast array of furniture designs. Among the innovations that have revolutionized industries such as healthcare and design is 3D Printing Technology. This technology is capable of producing intricate and personalized items with accuracy, and its cost-effectiveness and availability have sparked an increasing interest in utilizing modular joint-use 3D printers for household purposes (Kantaros *et al.*, 2021).

Furniture joints play a critical role in the performance of interconnected pieces. They ensure continuity and provide strength and stability to the framework. Proper design is crucial to ensuring that they can safely bear loads without deforming or failing (Záborský *et al.*, 2019). When designing new products, industrial designers face various considerations. They must take into account the product's intended use, the available materials, and the manufacturing process. However, despite having numerous options at their disposal, they must also adhere to specific guidelines (Pandolfo, 2016).

Additive manufacturing (AM) is a rapidly expanding field that offers a wide range of products with adaptable technology. It is known for its versatility and flexibility (Style *et al.*, 2020). Creating a 3D object involves adding layers, regardless of the type of printer used. To reduce material usage, 3D printing often uses polymers as the main material. However, other materials like ceramics, metals, composites, and concrete are also used for specific applications. Thermoplastics like ABS, which comes from petroleum, or PLA, which comes from biobased sources, are commonly used in 3D printing, as noted by Van Wijk & Van Wijk (2015).

Modular design is a game-changer in the design industry as it introduces innovative techniques and modes of thinking. This approach enhances market adaptability and extends the lifespan of products (Wang, 2022). Studies show that mortise and tenons with rectangular ends have about 15% more strength compared to those with round ends. Rectangular-end tenons can also fit into round-end mortise joints. Additionally, joint strength increases when the tenon's width or length is increased (Kasal *et al.*, 2016). In the current competitive market, innovation is crucial for the sustainable, long-term success of businesses. By creating visually appealing, useful, and innovative goods, consumer products can meet the needs of end customers while balancing consumption and manufacturing (Aydin, 2015).

The objective is to develop a 3D-printed connector that can substitute the conventional wood connections that are bonded together. This replacement will streamline the assembly process, reduce production time, and eliminate the need for wood joint preparation and gluing operations (Nicolau *et al.*, 2022). This study centers on Sustainable Development Goal (SDG) 9, which prioritizes advancing industrial innovation and infrastructure. To create furniture designs that align with sustainable principles, a 3D model of the modular joint will be constructed using additive printing, particularly the fused deposition modeling (FDM) process (Wang, 2022). Appropriate 3D printing and modular furniture joint designs were investigated to provide optimal structural integrity and stability (Aiman *et al.*, 2020). This research will look into viable materials for 3D printing modular joints for furniture, namely plastic materials compatible with fused filament fabrication (FFF).

The purpose of this study is to investigate the use of modular joints in furniture design. To achieve this, a 3D printer will be utilized to create a modular joint. The goal is to explore the potential of advanced additive manufacturing technology to produce innovative and functional products with various design options, including shape, color, joint quantity, and size. The study will involve analyzing articles, journals, and websites to understand the standard and characteristics of modular joints. Furthermore, this research aims to examine different types, shapes, and properties of modular joints designed specifically for furniture using 3D printing technology. The joints will cater to the unique needs of users, with a focus on the B40 population living in residential areas such as apartments, flats, People's Housing Project (PPR), and squatted houses in the Klang Valley region. Selecting this location is critical to promote a conducive learning environment and academic progress.

The Klang Valley region was chosen for this study because of its association with one of the most polluted rivers, the Klang River. According to Malaysia's environmental management history, squatter settlements commonly dump plastic, bottles, furniture, and other solid waste into the river (Ismail *et al.*, 2010). According to Ainoriza's study on the PPR population, there was an increase in household waste during the MCO due to the rise in the usage of packaging materials (Zulkifli, A. M., 2022). Domestic garbage is classified into three types: organic (putrescible waste), non-organic waste, and bulky waste. Paper, plastic, textiles, rubber, leather, wood, and branches are all examples of organic waste. Non-organic garbage, on the other hand, comprises glass, metal cans, and aluminium cans, while bulky waste includes electrical products, plant waste, and furniture (Abd Muin, 2018).

2. Literature Review

2.1 Modular Joint

Modular furniture joints serve as connectors that enable the creation of versatile furniture with various functionalities by linking multiple wooden pieces together. As technology has progressed, manufacturing techniques for these joints have become more refined. To ensure the efficacy of the joint in meeting functional requirements and enduring certain loads, structural analysis is employed to evaluate the design's capabilities (Aiman *et al.*, 2020). The system's modular design facilitates effortless reconfiguration of the setup in response to evolving requirements or convenient storage during periods of inactivity (Movisi, 2012).

2.2 Furniture Joinery

Throughout history, mortise and tenon connections have been a go-to method for woodworkers worldwide when joining hardwood components, particularly when they meet at a 90-degree angle. The length of the tenon has a significant effect on the joint's ability to resist the moment, while the width of the tenon has a greater impact on the stiffness of the joint (Kasal *et al.*, 2016). Research has shown that advancements can be made in the design of furniture frames featuring mortise-and-tenon joints. By implementing these improvements, it is possible to achieve a significant reduction in weight without sacrificing structural integrity and load-bearing capabilities (Hu *et al.*, 2019).

2.3 3D Printing

The process of creating physical objects through layer-by-layer material addition using geometric representation is known as digital fabrication, or additive manufacturing, commonly referred to as 3D printing. This rapidly growing field relies on Computer-Aided Design (CAD) drawings to fabricate 3D structures through the layer-by-layer construction technique. 3D printing technology has the potential to significantly improve manufacturing efficiency by reducing production time and costs. Additionally, this versatile technology offers a multi-purpose and accommodating platform for a wide range of industries (Shahrubudin *et al.*, 2019).

2.4 Main Method 3D Printing

Various technologies in additive manufacturing have been developed to meet the demand for precise manufacturing of intricate structures. The main drivers for the advancement of additive manufacturing technology are the need for rapid prototyping, the ability to print large objects, the reduction of printing defects, and the improvement of mechanical properties. Fused Deposition Modeling (FDM) is the most commonly used method for 3D printing with polymer filaments (Ngo *et al.*, 2018).

(a) Fused Deposition Modeling (FDM)

In 1989, Stratasys' co-founder Scott Crump patented Fused Deposition Modeling (FDM), which has become the most commonly used extrusion additive manufacturing (AM) method for consumer-level 3D printers. FDM is a technique that involves melting thermoplastic filament and depositing it layer by layer to create three-dimensional objects (Dizon *et al.*, 2018). Stratasys' FDM technology utilizes a heated nozzle to extrude plastic or wax material layer by layer on a mechanical stage, with the ability to produce automatic support structures and a range of materials (Ramya & Vanapalli, 2016).

(b) Powder Bed Fusion

Powder bed fusion techniques, including selective laser melting (SLM) and selective laser sintering (SLS), involve the layering and fusing of fine powders using a laser beam or binder to create 3D parts. The efficiency and size of these components are greatly influenced by factors such as the distribution of granules in the powder and how it is packed. SLM achieves improved mechanical characteristics by completely melting and fusing powders, while SLS achieves molecular-level fusion at higher temperatures. The use of a liquid binder in three-dimensional printing (3DP), however, results in greater porosity. Despite the drawbacks of lengthy processing times, high costs, and increased porosity when employing a binder, powder bed fusion offers benefits such as fine resolution and high-quality printing, making it ideal for creating complex structures in a variety of industries (Ngo *et al.*, 2018). SLS, SLM, and EBM are versatile additive manufacturing processes that are applicable to a wide range of materials, encompassing both metals and polymers (Ligon *et al.*, 2017).

(c) Stereolithography (SLA)

The SLA additive manufacturing process was developed in 1986. One method for creating solidified designs involves using either UV light or an electron beam to trigger a reaction in a layer of resin or monomer solution. This process, known as Stereolithography (SLA), can produce high-quality parts with a resolution as fine as 10 μm. However, it has some limitations, such as poor speed, high cost, restricted material options, and complex reaction kinetics and curing processes. Nonetheless, it remains a useful tool for manufacturing complex nanocomposites (Ngo *et al.*, 2018). SLA, which stands for stereolithography, is an innovative method of additive manufacturing that employs UV light to cure successive layers of photocurable resin, enabling the creation of intricate objects. The progress made in this area is impressive, but unfortunately, the high costs associated with it have prevented it from being widely adopted in the manufacturing industry (Dizon *et al.*, 2018). There are different ways to set up SLA techniques, such as vector scanning and mask projection-based approaches. The former is known for its exceptional precision (Lin *et al.*, 2015).

(d) Direct Energy Deposition (DED)

The direct energy deposition (DED) method, also referred to as laser-engineered net shaping (LENS), is a technique utilized in the manufacturing of high-performance superalloys. Unlike selective laser melting (SLM), DED does not require the use of a powder bed. Instead, the feedstock material is melted prior to layer-by-layer deposition. This method is particularly useful for filling cracks and retrofitting pre-existing pieces. DED boasts fast speeds, expansive work envelopes, low production times and costs, and impressive mechanical properties (Ngo *et al.*, 2018).

(e) Laminated Object Manufacture (LOM)

Laminated Object Manufacture (LOM) is an additive manufacturing process that utilizes the cutting and bonding of layers of materials to create internal structures, with the aid of thermal bonding. While LOM can work with various materials, additional processing may be necessary to achieve the desired qualities. Ultrasonic Additive Manufacturing (UAM) is a subgroup of LOM that can create metal structures at low temperatures. Despite finding use in industries like paper manufacturing, foundries,

electronics, and smart structures, LOM's inferior surface quality and dimensional precision make it unsuitable for intricate geometries compared to powder-bed technologies (Ngo *et al.*, 2018). In the late 1980s, Helisys pioneered the lamination 3D-printing technique. This technique involves stacking layers of laminated materials, which are defined by cutting tools based on a CAD design. The process begins with placing a material sheet on a stage and cutting it using a laser or blade. The excess material is removed, and the process is repeated with subsequent layers until the 3D product is completed (Ambrosi & Pumera, 2016).

2.5 Materials in 3D Printing

(a) Metal

The article emphasizes the significance of using titanium, aluminum, and cobalt compounds in metal and metal composites. In addition, stainless steel powder is highly regarded for its strength in 3D printing techniques such as sintering, melting, and electron beam melting. Although it is naturally silver, stainless steel can also be coated with various compounds to produce gold or bronze effects for different purposes in the jewelry industry (Pandian & Belavek, 2017).

(b) Ceramic

Through the optimization of conditions and mechanical properties, 3D printing technology has reached a level of sophistication where it can produce crack-free 3D printed objects using ceramics and concrete. Among these materials, alumina ceramics stand out due to their strength, durability, and fire-resistant properties, making them highly suitable for a broad range of applications in the construction and high-tech industries. Additionally, bioactive glass and zirconia, which possess exceptional mechanical strength and unique properties, have demonstrated significant potential in the dental, aerospace, and nuclear power sectors (Shahrubudin *et al.*, 2019).

(c) Polymer

Nylon and ABS are prevalent plastic materials in 3D printing. Nylon is a robust, flexible, and enduring material that can be utilized in either powder or filament form. ABS, on the other hand, is another durable plastic that is available in various colors and is used in filament form. Polylactic acid (PLA) is a biodegradable resin or filament material that is not as robust as ABS. LayWood is an exceptional filament material that combines recycled wood with polymer to create realistic-looking and smelling wood-like items. It is available in light and dark wood finishes (Pandian & Belavek, 2017).

2.6 Compact House

The notion of a compact house is the same as that of a micro house or tiny house. A compact house focuses more on changing the space's function to adjust the activities carried out by the occupants. In order to maximize the limited space in a compact house, innovative storage solutions and multifunctional furniture can be utilized. Additionally, careful planning and thoughtful design can help optimize the use of utilities, ensuring efficient usage within the limited space available (Azis *et al.*, 2023).

3. Research Methodology

3.1 Questionnaire

An online survey was conducted to gather data from end users and gain insights into their preferences and needs. The focus was on the Klang Valley region in Malaysia, known for its environmental management issues and pollution of the Klang River. The study targeted B40 individuals living in specific housing types in the region and aimed to understand their behaviors related to domestic

garbage disposal, including organic, non-organic, and bulky waste. The appropriate sample size for the survey was calculated based on a 95% confidence level, an 8% margin of error, a population proportion of 50%, and a total estimated population of 12,512,951. To achieve a 95% confidence level and maintain a margin of error within ±8% of the survey results, a minimum of 151 surveys were required. The data collection process involved five sequential steps, starting with defining the research question and objectives and ending by analyzing the data and implementing the findings. The data collection approach focused on tracking interactions with end-users who completed the questionnaire. The findings were analyzed and organized to improve product design.

3.2 Visual Research

The qualitative research approach of visual research is a fascinating field that has gained popularity in recent times. It employs artistic mediums to create and express knowledge, offering researchers a unique and nuanced way to capture reality. The modular joint design was investigated using the visual research method, which provided a diverse selection of interdisciplinary approaches to help designers or researchers incorporate visual literacy as part of their research practice. With visual research, researchers can gain a comprehensive understanding of the subject matter by employing observation through visual creation, such as photography, diagramming, and drawing, among others. This approach allows for a more direct understanding of people, their life experiences, and their perceptions, which helps to provide direction on how to produce an outcome of the product design. Overall, visual research is important that offers researchers a unique way to understand and explore their subject matter. Utilizing mediums such as Pinterest, and catalogues helps to gain a deeper understanding of the participant's preference based on the online survey and their life experiences, providing valuable insights that can implement the design criteria of modular joint for furniture to the development of research projects.

3.3 Thumbnail and Ideation Sketches

The thumbnail is a brief and simple sketch that provides an image that will remind and adjust the researcher's ideas when it comes to the ideation sketches later. Shape, color, size, and details serve as a framework for the subject. When creating details, the thumbnail also serves as a reference. While brainstorming new solutions is a process of ideation. It is a creative process in which designers generate as many ideas as they can in an open-minded environment in order to address a problem statement. It functions as a fresh display of complex data.

3.4 Idea Development

Creating efficient answers to challenges through hand sketching using markers and pastels is part of the idea development stage. This technique investigates ideas and results in quick prototypes that evaluate the usefulness and practicality of the design. Before moving on with the final design, this step also includes refining and making adjustments. The purpose is to guarantee that the design has been thoroughly thought through and is ready for future refinement and implementation.

3.5 Mock-up

A mockup is a scale replica of a design that displays the look and functioning of the finished item. It acts as the product's review format, layout, or content, enabling designers to find problems and make modifications before spending money on production. Additionally, mockups serve as a communication tool for stakeholders, clients, and designers, enabling them to see and comprehend the finished product. Mockups provide a successful and aesthetically pleasing final result by showcasing a variety of elements such as color schemes, textures, and user interface.

3.6 Final Design

This stage marks the completion of the design or the start of the implementation process after careful consideration of the design criteria that have been acquired through an online survey and will be required throughout the entire participatory process. It is at this point that the decision on price, method, and application of the results will be made. The finished design comprises of a thorough sketch and product specifications.

3.7 Technical Drawing

Technical drawings, sometimes called engineering drawings, are detailed representations of an object's structure that make it apparent what parts go where and what an object's dimensions and material composition are. Drawings used in this research is orthographic projection and provide a variety of views to help the viewer comprehend the product's structure, size, and shape. The top view offers a bird's-eye perspective, the side view emphasizes depth, the isometric view offers a three-dimensional depiction, and the front view depicts the object from the front. These technical drawings are crucial for manufacturing since they provide engineers, designers, and manufacturers with a plan for producing the intended product precisely. Specific data analysis procedures/methods require to be described clearly.

3.8 Prototype

A key component of the design thinking process is prototyping, which explores the real-world implications of conceptual ideas before they are put into practice. It enables designers to research consumer perceptions and feelings and assess the viability of their present designs. Prototyping, which assesses user behavior and success in the last stage, results in more changes and modifications. By focusing on the needs and expectations of the target consumers, the final product is guaranteed to be satisfactory. Additionally, prototyping reduces risks and the possibility of costly mistakes during the execution phase. Overall, prototyping is essential to the design thinking process since it allows designers to test their hypotheses and choose wisely before settling on a final solution.

4. Results and Discussion

4.1 Questionnaire Analysis

A design survey is a tool used to gather data from intended recipients to guide design procedures. It involves creating a questionnaire that gathers information on design elements, user preferences, and functionality. This study used an online platform and social media to conduct a quantitative survey to determine the target audience's design criteria and preferences. Design surveys help in making informed decisions, identifying potential issues, and validating design choices. By analyzing responses, designers can prioritize design aspects and avoid potential pitfalls, ensuring the final product aligns with users' expectations and preferences, leading to a more successful and user-friendly design. The study question was split into two parts: Section A is concerned with demographic information, specifically the background of the target user (B40), whereas Section B is concerned with comprehending and developing design standards.

Table 1 summarizes the demographic information. After analyzing the data, it was discovered that females consisted of 78 of the participants (51.7%), while males performed up 73 of the participants (48.3%). The majority of respondents, 84 in total (55.6%), were between the ages of 21 and 30, and the majority of them, 127 in total (84.1%), were employed. In terms of monthly income, the majority of respondents, 74 (49%), earned between RM1501 and RM3001. In terms of living arrangements, the majority, exactly 102 people (67.5%), currently live in apartments or flats. Due to their accessibility, affordability, and convenient positions, high-rise houses are the favored choice in urban regions. In

contrast, flat-type dwellings often offer a smaller or more confined living space, ranging from 46.5 to 60 square meters, while medium-cost apartments cover a space of between 70 and 79 square meters. Since 2000, when housing initiatives and rules were put in place to address squatter and settlement issues, the building of high-rise residences has grown in importance and momentum. This has made it easier for people from many socioeconomic groups to get houses, including those who are low-income (B40), middle-income (M40), and high-income (T20) (Mahmud, 2022). Finally, the most common problem encountered by the majority of respondents in their current housing situation was a shortage of space which accounted for 84 people (55.6%). To support the data, found that a common standard housing unit has a limited size and only essential functions, satisfying the fundamental requirements for residence. A typical low-cost house has 2-3 bedrooms, 1-2 bathrooms, a single kitchen unit, a living room, and a dining area (Safiri & Abdullah, 2020). This limited space often leads to overcrowding and lack of privacy within the household. Additionally, the shortage of space can also restrict the ability to accommodate growing families or to have separate spaces for different activities, such as work or study areas.

Table 1: Summary of demographic and personal information

Question	Description	Response	Percentage (%)
Gender	Female	78	51.7
Age	21-30 years old	84	55.6
What is your current professional status?	Employed	127	84.1
Range of monthly income	RM1,501-RM3,001	74	49.0
What is the type of your house?	Apartment / flat	102	67.5
Do you face any issues with your current housing?	Lack of space	84	55.6

According to the data analysis provided in Table 2, the majority of respondents (33.8%) had never heard of modular joint design in furniture, and the most common opinion (72.2%) on the appropriate application for 3D printed modular joint design was coffee tables. Furthermore, plastic was deemed the most appropriate material (73.5%) for 3D-printed modular joints, and the home setting (85.4%) was deemed the most appropriate for this design. Respondents were more likely (58.9%) to utilize a 3D-printed modular joint design, and the top benefits mentioned were increased flexibility in furniture arrangement (53.6%), improved aesthetic appeal (45.7%), improved functionality (49%), and easier customization (47%). When examining a modular joint design manufactured by 3D printing, respondents prioritized durability (79.5%), simplicity of assembly/disassembly (60.9%), and affordability (53%). Material qualities (60.9%), joint shape (60.3%), and connection method (68.2%) were the most significant aspects to consider when constructing modular joints for mechanical systems. A sizable proportion of respondents (75.5%) stated that 3D printed modular joint design improves the utility and longevity of the furniture, and sustainability was regarded as highly essential in furniture design (73.5%). Option 1 (43.7%) and Option 3 (55.6%) were the recommended design solutions for modular joints in terms of strength and durability. Almost half of the respondents (47%) would be willing to pay more for a product that uses modular joint design, and the majority (64.9%) would likely recommend such a product to others. When asked if they had previously used furniture with the modular joint design, 52.3% indicated no, whereas nearly half (47.7%) said yes. 53.4% of respondents who had used such furniture were satisfied with its functionality.

Based on the extensive survey questionnaire, the expected outcome is to utilize a 3D printer to produce a modular joint of furniture for a compact house, taking into account the tastes and expectations of the intended users. The modular joint design requirements should prioritize durability, simplicity of assembly/disassembly, flexibility in furniture arrangement, better utility, and sustainability. The

majority of respondents favor plastic as the material for 3D-printed modular joints, with a focus on strength and longevity. The modular joint design should be suitable for coffee tables, with the house being the optimum venue for its implementation. Material properties, joint shape, and joining method should all be considered while designing mechanical structures. The study also suggests that modular joint design goods have a potential market, as a high majority of respondents are willing to pay more for such products, and satisfaction ratings among those who have used modular joint design furniture are positive.

Table 2: Summary on the understanding and design criteria

Question	Description	Response	Percentage (%)
How familiar are you with the concept of 3D printed modular joint design for furniture?	Unfamiliar	50	33.1
In your opinion, what would be the ideal application for 3D printed modular joint design in furniture?	Coffee table	109	72.2
Which material do you think the most suitable for 3D-printed modular joints for furniture that you preferred?	Polymer	111	73.5
In which setting do you think modular joint design made by 3D printing would be suitable for?	Home	129	85.4
How likely would you be to use a modular joint design made by 3D printing in the setting you selected?	Likely	89	58.9
What benefits do you think a modular joint design made by 3D printing could provide in the setting you selected?	Increased flexibility of arrangement	81	53.6
	Enhanced aesthetic appeal	69	45.7
	Improved functionality	74	49.0
	Easy customization	71	47.0
If you were to use a modular joint design made by 3D printing, what features would be the most important to you?	Durability	120	79.5
	Easy of assembly	92	60.9
	Affordable	80	53.0
In your opinion, what are the most important factors to consider when designing modular joints for mechanical structures?	Material properties	92	60.9
	Joint shape	91	60.3
	Connection method	103	68.2
Do you think 3D printed modular joint design enhances the functionality and durability of furniture?	Yes	114	75.5
How important is the sustainability factor in furniture design for you?	Very important	111	73.5
In your opinion, what is the ideal design for a modular joint in terms of strength and durability do you prefer?	Option 1	66	43.7
	Option 2	64	42.4
	Option 3	84	55.6
Would you be willing to pay more for a product that utilizes modular joint design?	Yes	71	47.0
	Depend on product	79	52.3
How likely are you to recommend a product that utilized modular joint design to others?	Likely	98	64.9
Have you used furniture with modular joint design before?	Yes	72	47.7
	No	79	52.3
If your answered ‘yes’ to question above, how satisfied were you with its functionality?	Satisfied	39	53.4

4.2 Visual Research

In order to provide some perspective on how to design the product in accordance with the design requirements that respondents need, Figure 1 depicts three pieces of visual research with various concepts as an early design brainstorming phase.

Figure 1: Visual Research

4.3 Thumbnail and Ideation Sketches

Thumbnails are two-dimensional sketches of various forms randomly created on paper that serve as a starting point for further research and refinement of concepts. Thumbnails are used to develop several concepts and iterate on them until they find the best solution for the customer's needs. This iterative process encourages creativity and innovation, yielding a final design that effectively satisfies the needs of the consumer.

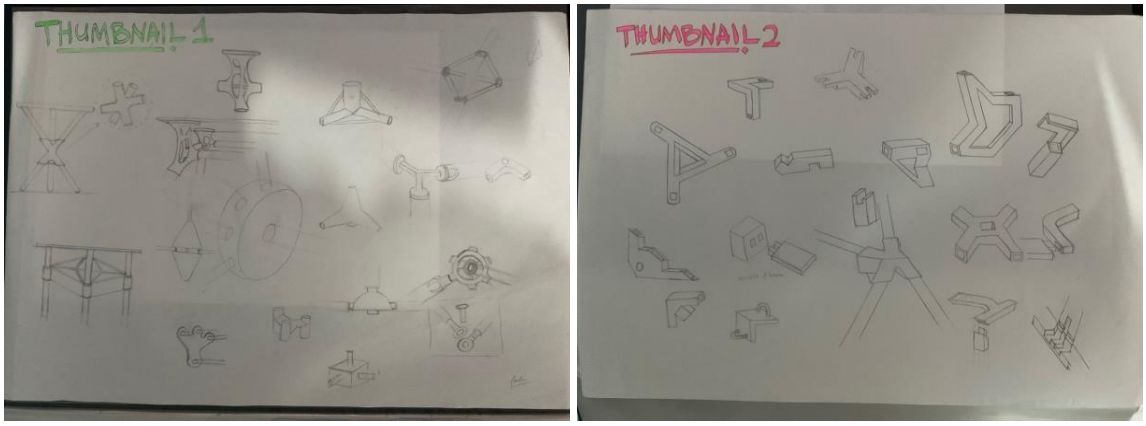

Figure 2: Thumbnail

The sketching process included a detailed design demonstrating the application and several aspects of the design. This strategy helps to see the finished product, detect potential defects or adjustments, and facilitate efficient communication. This method ensures that the design concept is agreed upon, providing for a more comprehensive understanding of the finished product before committing time and resources in manufacturing.

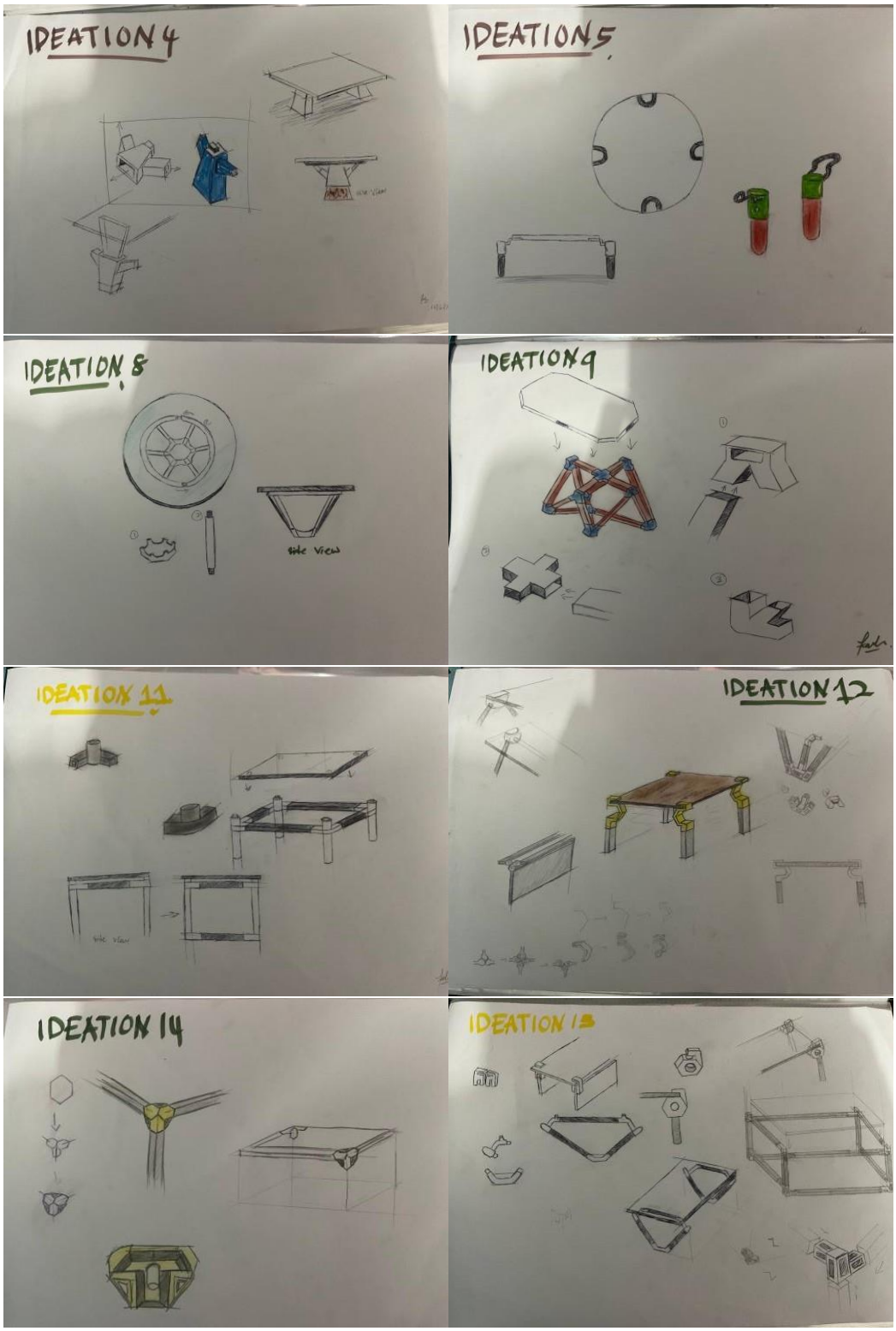

Figure 3: Ideation sketches

4.4 Idea Development

The design was created utilizing the AutoCAD 3D program from Ideation 14, and two designs were developed. The second design was chosen for its greater aesthetics and utility. AutoCAD was used to achieve precise measurements and correct depictions, resulting in a high-quality end product. Figure 4's design lacks durability due to its lack of a wood locking mechanism. A new design, depicted in the fifth diagram, addresses this issue by incorporating a locking mechanism for wood stability. This simpler and more solid construction significantly enhances durability compared to the initial concept presented in Figure 4. The design's simplicity and solid construction make it a more effective solution for enhancing wood durability.

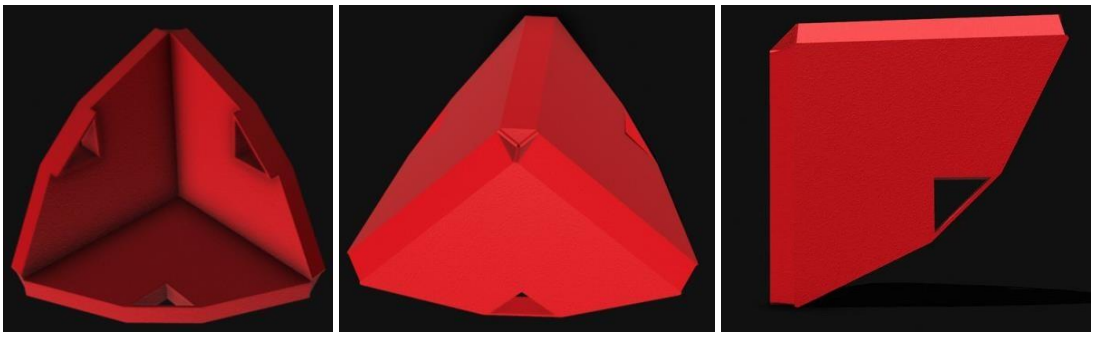

Figure 4: Idea development 1

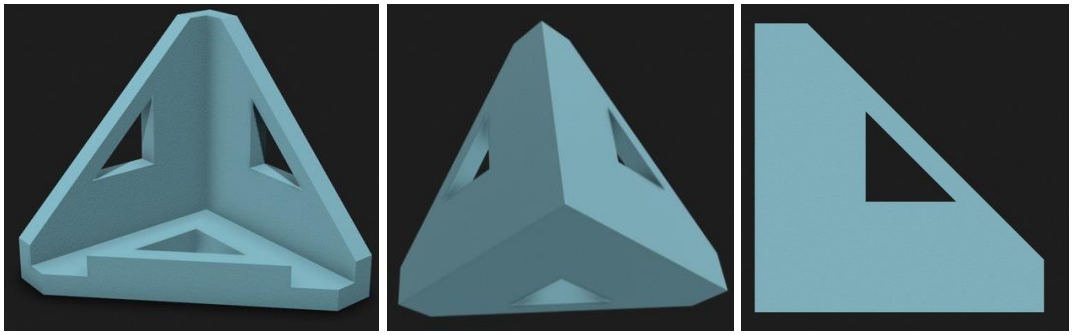

Figure 5: Idea development 2

4.5 Mock-up

An AutoCAD or comparable type of software was required in order to 3D print a mockup of a modular joint in three-dimensional. The mockup was put to the test in its actual size in order to find problems like sharp edges and poor locking mechanisms. The design could be altered by chamfering the edges and lengthening the locking mechanism for a stronger grip to enhance safety in kid-friendly households. These changes will improve the mockup's usability and usefulness for the purpose for which it is designed.

Figure 6: Mock-up

4.6 Final Design

Figure 7 shows a 3D-printed product designed to replace a failed furniture joint, making assembly easy and extending the life of the furniture. The joint is durable and sturdy, ensuring long-lasting support. The innovative design saves time and effort by allowing users to locate the jointing rather than discarding the furniture, ensuring a more efficient and sustainable solution.

Figure 7: Final design

4.7 Technical Drawing

Product measurements are informed by technical drawings, which also offer a variety of viewpoints on the products' structure and design. They make it possible for manufacturers to clearly convey ideas and offer details on assembly, materials, and manufacturing procedures. This guarantees smooth production and effective communication among project stakeholders. This makes sure that everyone is on the same page and can collaborate successfully to accomplish the project's objective.

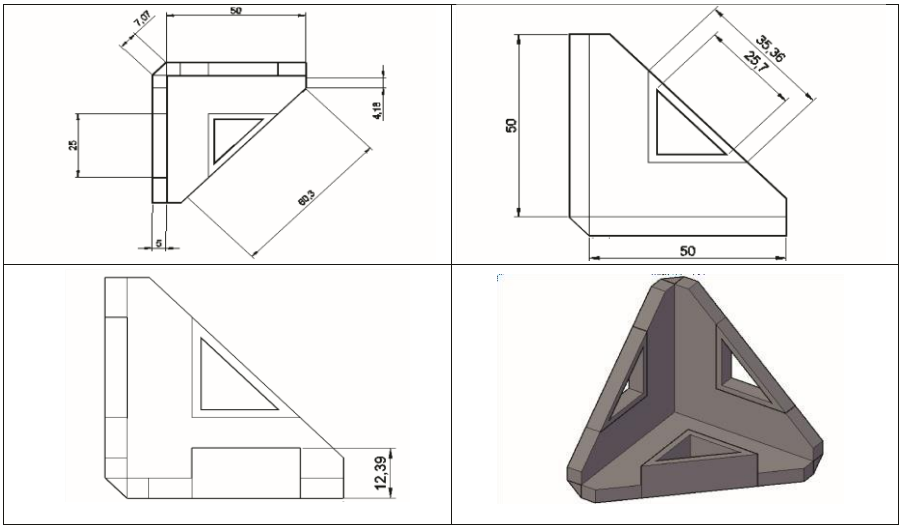

Figure 8: Technical drawing

4.8 Prototype

Figure 9 demonstrates the usage of modular joints in the assembly of furniture, showing their critical function in the creation of small-scale home furnishings. This system makes it simple to customize and versatile when creating layouts that respond to certain needs and preferences, making it an effective and adaptable solution for furniture design.

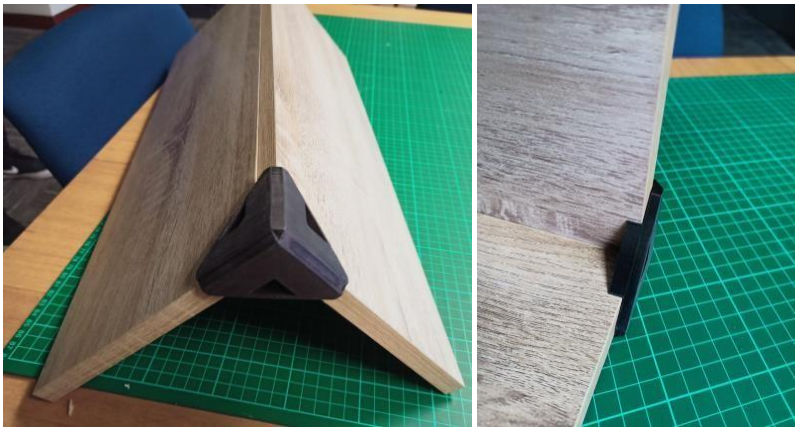

Figure 8: Prototype

5. Conclusion

In conclusion, this study explores the use of modular joint design and 3D printing technologies to improve furniture manufacturing in compact houses in the Klang Valley. Plastic materials are chosen due to their durability, simplicity, and sustainability. The ultimate design aims to simplify assembly procedures, increase furniture longevity, and meet unique requirements for small living spaces. Sophisticated manufacturing processes, such as additive manufacturing, are recommended to achieve these goals. A prototype can be created for testing and refinement in real-world situations, and user feedback can be used to refine and expand the design across various furniture types. This study advances furniture design and additive manufacturing, offering a feasible method for creating environmentally friendly furniture components.

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