Contemporary Plastic Jewellery Design: The Difference Between Current And 3D Printing (FDM) Making Processes

Zainudin Siran [1] and Alaa Al-Khulaqi [1]

[1] Centre for Innovative Systemic Design in Applications and Contents (CISDAC), Faculty of Creative Multimedia, Multimedia University, 63100, Cyberjaya, Malaysia
zainudin.siran@mmu.edu.my, alaaalkhulaqui@gmail.com

Abstract. Businesses are steered by consumer demands, and the current industry is shifting towards a paradigm of customisation with an increase in need for contemporary jewellery made with alternative or mixed materials. This shift pushes jewellery businesses to reconsider their design and manufacturing processes to meet the new demands. To explore how businesses could meet these new demands, this paper presents a comparative study between the current methods and the 3D printing method for making plastic-based contemporary jewellery with Islamic Geometric Patterns (IGPs) design. It aims to understand the different processes, the characteristics of these processes, and the different outcomes or looks of the processes. The data collection consists of a case study and data validation with experts in the jewellery industry. In the case study, earrings of the same designs were produced through two different methods: the current method (handcrafting and laser cutting) and the 3D printing method. Fused Deposition Modelling (FDM) was chosen for its accessibility as an entry level 3D printer in cost and material handling. The findings show that the 3D printing process can produce more details than laser cutting, however, laser cutting is faster, produces smooth edges, and does not require finishing (sanding, cutting, spray painting, nor buffing). The handcrafting method is unsuitable for making jewellery from acrylic sheets. The research findings provide insight on the specific criteria of the different making processes for contemporary jewellery design, inducing innovation and enhancement by utilising different methods.

Keywords: Contemporary Jewellery Design, 3D printing (FDM), Jewellery Making Process.

1 Introduction

Businesses are driven by consumer needs, garnering a competitive environment in which organisations must evolve and optimise their efficiency to maintain competitiveness [1] through new product development (NPD), on encountering the user desire [2]. Jewellery customers now pursue personalisation and uniqueness to embrace their individuality [3]. The jewellery industry garnered an increase of 38%

F. Mustaffa (ed.), *Proceedings of the 3rd International Conference on Creative Multimedia 2023 (ICCM 2023)*, Advances in Social Science, Education and Humanities Research 786,
https://doi.org/10.2991/978-2-38476-138-8_7

for custom made jewellery from 2019 to 2020 [4]. Hence, businesses need to rethink their manufacturing process and design paradigm to meet the customisation demands [5]. As customisability becomes desired, brands such as Louis Vuitton started working with clients directly to decide on the cut of the stones instead of buying them pre-cut [6]. Moreover, the range of materials designers can use expands thanks to the development of new technologies, enriching the creative potential for jewellers and designers [7]. There is potential for businesses to cater for the Muslim demographic, as they have spent $270 billion on modest fashion in 2017 alone and sales are expected to reach $402 billion in 2024 [8]. Islamic Art represents the expression of a culture deeply shaped by Islamic theology, and it is an art form found in varying media with diversity in styles and historical longevity [9] [10]. One of the forms of Islamic Art is Islamic Geometric Patterns (IGPs) commonly used to decorate doors, ceilings, minarets, walls, and domes [11]. IGPs require symmetry and accuracy in construction which demands experienced artisans or the help of machinery to achieve the designs [12]. Moreover, they found that the gap in research is in the lack of quantitative data, lack of data validation, and past research was limited in the methods used to make jewellery and limited in the materials used. Hence, to explore how businesses could meet the shifting demands in customisability and to target the growing Muslim population, this paper aims to carry a comparative study between the current methods and the 3D printing method for making plastic-based contemporary jewellery with IGPs design.

2 Literature Review

2.1 User Aspiration

Understanding the level of consumer personality and tastes change over time is critical for businesses strategy that has to ahead of trends and user behaviour [13]. In fact, the user decision is influenced from what they see and experience (interaction) with the product [14]. Zahid et al. (2023) remarks on multiple trends one being that jewellery purchasing habits is shifting into an individualistic culture, where people are relying on their own wealth. Moreover, customers increasingly seek personification and desire uniqueness and individuality in the jewellery they purchase [3]. With the advancement of new technology, another trend seen in the fashion industry is the use of 3D printing [15]. It can be used to supplement the current jewellery making process, helping in mould making and making customisability cheaper [16]. Besides, it is also be used to create the final product as done by Iris van Herpen in her Spring 2018 Couture [17]. In collaboration with the University of Technology in Delft, they were able to produce leaf-like patterns by directly 3D printing onto fabric [18]. Jewellery facilitated the spread of culture to people, and it is used to ornament the body with earrings, pendants, bracelets, and other accessories [7] [19]. Contemporary jewellery explores mixing materials and using unconventional materials to create pieces that can help people express themselves [19]. Moreover, TikTok has reintroduced materials such seashells, glass beads, macramé, felt, and leather straps [20].

Islamic Art is the manifestation of a culture profoundly intertwined with religious Islamic beliefs [8]. It is not a mean of self-expression, but a tool used to depict the sacred [19]. It consists of calligraphy, stylised floral, and geometric patterns [9]. Islamic Geometric Patterns (IGPs) refers to the geometrical patterns used to ornament minarets, domes, doors, and more [11]. Fig. 1 illustrates the basic levels of identification of IGPs as clarified by Embi and Abdullahi (2013).

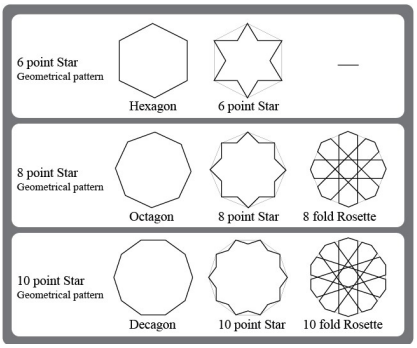

Fig. 1. First level of IGP identification adapted from Embi, & Abdullahi, (2013) [11].

2.2 New Product Development (NPD)

A new product as defined by Kim et al. (2016) is a product that requires new advertising due to the changes it has. With the increase demand for personalization, shorter product life cycles, and continuous change in customer tastes, companies need to reconsider their manufacturing design paradigm [5]. The goal of personalization is to gratify customers' needs by using their input in designing the product [5]. Thus, businesses need to always reinvent to match the continuous change in the market. In highly competitive industries, business require to make efforts in New Product Development (NPD), and there are models that aid in the first stages of NPD, such as 'Product-service system (PSS)', 'The Kano model', 'Conjoint analysis', 'The product value matrix', and 'Quality function deployment (QFD)' [24].

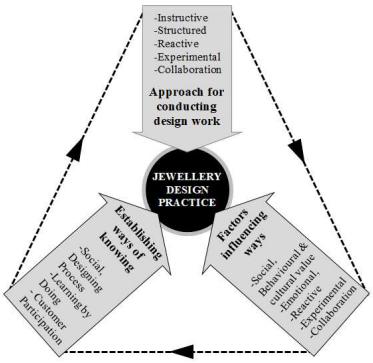

Fig.2: Different approaches of jewellery design process adapted from Rajili, et al. (2015) [23]

To make a piece of jewellery various stages are needed from finding inspiration, generating ideas, converting concepts from sketches to the final product, and more [23]. As defined by Mohd Rajili et al. (2015), There are three facets that influence a jewellery designer, and they are the role of the designer (approaches of conducting design work), the type of the jewellery (factors influencing ways of working), and the type of material used (establishing ways of knowing) (Fig. 2).

3 Methodology

Due to the dearth of research on the jewellery making processes for making jewellery with IGPs and based on the knowledge gap highlighted by Siran & Al-Khulaqi (2022), a mixed-method approach is chosen. This approach developed by Creswell (2002) consists of the Pragmatic Knowledge Claims (the theory models), Methods of data collection, and General procedure of research. This research analysis uses two theory models first is the 'domain positions' by [24] to determine the factors relevant to the jewellery making process. Then the Value Analyses by [25]. This model is used in analysing existing products to improve upon them or develop new products. In this study, it was used to analyse the jewellery making processes and uncover which areas can be improved upon. In the general procedure of research, the Design Research Methodology (DRM) developed by [26] is used to structure the research process. The third facet of the research is the methods of data collection, and they were expert interviews (qualitative), case study (quantitative & qualitative), and data validation (qualitative). The research methodology is summarised in Fig. 3. This paper only delves into the data gathered from the case study and data validation by the experts. In previous studies [12] different metals and ceramics were studied in making jewellery with IGPs, the gap was apparent in materials (TPU, acrylic sheets, and resin) and in method (3D printing). This paper adds to the body of knowledge in that area.

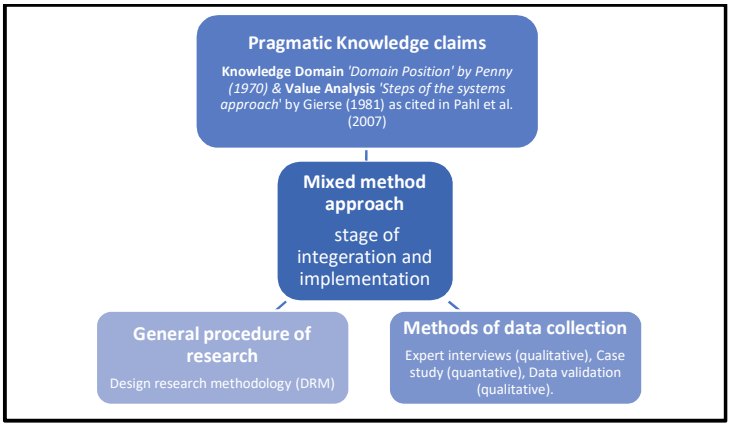

Fig. 3: Conceptual Framework of inquiry for a mixed-methods approach developed from Creswell (2002).

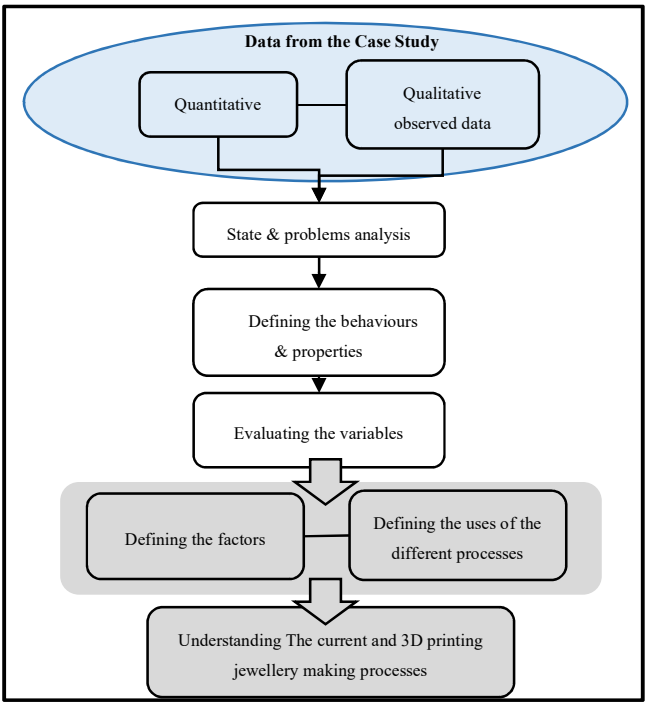

Fig. 4: The Data Analysis Process

The data collected from the case study consists of quantitative data on the time taken to perform the different tasks needed to make the jewellery products, and the

qualitative data is from observing the different characteristics or behaviours of the different processes. From these sources of data, they are analysed by defining the state and problems of the product they produced first. Then the behaviours and properties of the processes are defined. From both stages the variables are identified, and the processes are analysed based on these variables. From the data analysis, we can then define the factors and the different uses of each process, leading to understanding the current and 3D printing processes in making contemporary plastic-based jewellery (Fig. 4).

4 Findings

This paper analysed the current (handcrafting & laser cutting) and 3D printing processes in making contemporary jewellery with IGPs design. The handcrafting method failed in making a prototype, in which the laser cutting and 3D printing succeeded. The overall stages involved are similar with laser cutting being the fastest method and 3D printing the slowest method. The experts noted that 3D printing is a useful technology in making jewellery and it is used to assist in mass production.

Fig. 5: The final prototypes made for the case study through the current methods and the 3D printing method.

5 Data Collection

The case study is the source of the comparative analysis, providing the quantitative and qualitative data for the current (handcrafting & laser cutting) and 3D printing processes. The same design was used to create sets of earrings through the different processes. Earrings 01 are a design of a rosette, and earrings 02 are of a rosette in a semi-circle coloured with resin (Fig. 5). Adding coloured resin to the earrings is done by hand for all processes. A resin 3D printer was not used for this research, only a

FDM 3D printer was used, and it was chosen for its accessibility in cost and material handling.

5.1 Making Process: Current

Two different processes were used for the current method: handcrafting and laser cutting. A jeweller experienced with alternative materials was commissioned to create the prototypes. The material used for the current method is acrylic sheets with a height of 3 mm. It wasn't possible to change the height for the current process as the material comes in a set of predetermined heights. The tools used for the handcrafting process are a hand drill (1 mm) and a cutting saw (0.4 mm). The jeweller took 15 minutes to transfer the design onto a piece of acrylic, 35 minutes for hand cutting, and 5 minutes for finishing. This process failed in making a final prototype as the edges were rough, when sanding the pieces would break, and it resulted in fragile earrings (Table 1).

Table 1. The stages and time taken to make the prototypes through the current method (handcrafting).

Jewellery	Drawing	Hand cutting	Finishing	Total Time
Earrings 02 (Acrylic Sheet)	15 min	35 min	5 min	= 55 min

Table 2. The stages and time taken to make the prototypes through the current method (laser cutting).

Jewellery	Drawing	Laser Cutting	Finishing	Total Time
Earrings 01 (Acrylic Sheet)	15 min	6 min	5 min	= 26 min
Earnings 02 (Acrylic Sheet)	25 min	7 min	1hr 37 min	= 2 hrs 9 min

The second current process is laser cutting and it succeeded in producing a prototype. The equipment used is a DSP Laser Cutter with a laser power of 70%, laser size of 0.5mm, free speed of 100 mm/s, and cutting speed of 20 mm/s (Table 2).

5.2 Making Process: 3D print (FDM)

The 3D model was modelled on Blender 3D and then sliced using Cura. The printer used is an Ender -3 (an entry level FDM 3D printer) with a nozzle heat of 220°C, nozzle size of 0.4mm, and base/bed heat of 75°C. The material used for this process is TPU and this material requires slower printing speed in comparison to PLA. The first layers were printed with a speed of 8.75 mm/s, gradually increasing to 20 mm/s. This process took the longest out of the three; however, it produced the most details. Table 3 summarises the stages and time taken to make the prototypes through this process.

Table 3. The stages and time taken to make the prototypes through the current method (laser cutting).

Jewellery	3D modelling	3D printing	Finishing	Total Time
Earrings 01	27min.	2hrs	1hrs 30min.	= 3hrs 57min.
Earnings 02	30 min.	2hrs 12min.	1hrs 28min.	= 4hrs 10min.

6 Analysis of The Making Processes

The analysis includes the data from the case study and the data from the data validation, and to build a solid conclusion, two theory models are used, and they are the 'Domain Position' theory model by [24]; [25]; [27] and the 'Steps of the systems approach' by Gierse (1981) as cited in [25].

6.1 The Procedure of Profiling the Making Process

For data the analysis, the theory models are combined as seen in Fig. 6, creating a flow for data analysis specifically to analyse the jewellery making process. The second stage 'specific factors in the jewellery making process' is not explored in this paper as it involves the data gathered from the interviews and this paper only delves into the data from the case study and data validation.

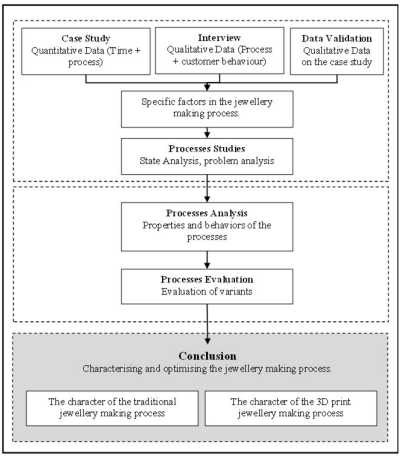

Fig. 6: The process flow of contextual and procedure analysis for analysing the jewellery making processes.

6.2 The Data Analysis Result and the Research Context

In the 'Process Studies' (Table 4) the problems with the different processes are determined based on the data collected from the case study. The problems faced with the handcrafting method is that this process failed in making a prototype, the edges of

the pieces were rough, and when sanded the pieces would break. The problems with 3D printing are that it was the slowest method out of the three, had the most steps, and due to the use of TPU it couldn't be sanded as well as it could have been if it was made using PLA. The laser cutting process was the fastest method; however, it produced less detail than the 3D printing method.

Table 4. The state and problems of the jewellery making processes.

Current Methods		
Handcrafting	Laser-cutting	3D printing
Failed	Succeeded	succeeded
Roughest edges	Smoothest edges	Textured edges
Weak, breakable	Strong, solid	Flexible
Second slowest method for prototype making.	Fastest method for prototype making.	Slowest method for prototype making.
3 steps (does not include finishing)	5 steps	6 steps
detailed	detailed	Most detailed

In the 'Process Analysis' stage (Table 5), properties of the different methods used in the case study are analysed. The handcrafting and 3D printing methods were able to make products in 3-axis, but the laser cutting process works only on flat designs.

Table 5. The properties and behaviours of the jewellery making processes.

Handcrafting	Laser-cutting	3D printing
Second slowest method for prototype making.	Fastest method for prototype making.	Slowest method for prototype making.
It can make products in 3-axis	It can only do flat designs	It can make products in 3-axis
Produced the most waste	Produced waste	Did not produce waste
Hand-cutting duration 35 min	Cutting speed 20mm/s	Printing speed: First layers 8.75 mm/s, and then gradual increase to 20 mm/s
Needs experience	Basic training	Basic training

The cutting speed of the laser cutter was 20 mm/s making it the fastest method. The handcrafting method took 35 minute, and the 3D printing method required adjusting the speed depending on the stage of the printing. The process starts with a speed of 8.75 mm/s for the first few layers and then it was gradually increased to 20 mm/s and remained at this speed till the end of the printing process.

In the 'Process Evaluation' variables or pros from the previous stages are highlighted and summarised as seen in Table 6. These variables are 'Least Time Taken', 'Most details', 'mass-production', 'custom orders', 'least material waste', and '3-axis'. Handcrafting and Laser cutting fulfils two of these pros while 3D printing fulfils four. The area in which 3D printing can be used in mass production is in the mould making process. Handcrafting is the process suitable for custom orders but unsuitable for mass production.

Table 6. Evaluation of variables in the jewellery making process.

Variables	Jewellery making processes		
	Handcrafting	Laser-cutting	3D printing
Least Time Taken		X	
Most Details			X
Mass-production		X	X
Custom orders	X		X
Least Material Waste			X
3-axis	X		X

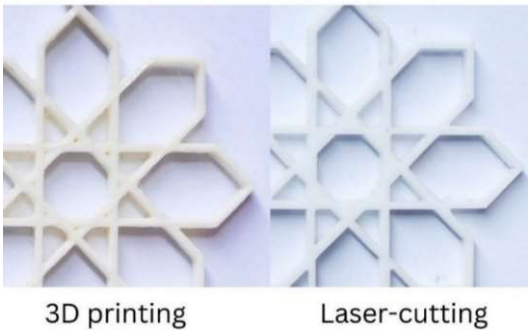

Fig. 7. The difference in details between 3D printing and laser cutting.

6.3 Prototype Validation by Experts

Data validation adds a calibre of scientific validation and credibility to a case study [28]. The experts agreed that 3D printing produced the better results, due to the 3D printed product having the most details and due to the flexibility of the material. It is to note that Expert 2 and 3 disagreed on one aspect which is the texture of the 3D printed product. Expert 2 prefers the smooth finish of the laser cut product; on the other hand Expert 3 prefers the textured finish of the 3D printed product (Fig. 7) as it reminded them of the texture of brushed gold jewellery.

The design of earrings 02 had resin added to them by hand for both processes (Fig. 6), and expert 3 preferred the look of the resin on the laser cut prototype and recommended to fill the 3D printed prototype with less resin (Table 7). It is to note, because of the smoothness of the laser cut prototype, it was more difficult to get the resin to securely attach to the walls in comparison to the 3D printed walls. Moreover, adding resin to the 3D printed prototype makes it lose the flexibility of the TPU.

Table 7. Summary of the data validation from the Jewellery experts.

Expert	The better method	The reasoning behind the answer	Recommendations for improving the methods

1	3D print	1. Flexible. 2. Suitable for a young audience. 3. More economical and detailed.	1. How to set stones to plastic. 2. Improve on how much details Laser cutters can produce.
2	Laser cutter	Smooth edges	To sand/buff the edges for the 3D printed jewellery
3	3D print (earrings 01) Laser cutter (earrings 02)	3D print 1. Because the finishing has texture. 2. The material is flexible. 3. More detailed. Laser cut (earrings 02) 1. The finish of the resin looks cleaner and is not too thick.	3D print (earrings 02) 1. Fill with less resin. Laser cut 1. Change the material. 2. Improve how much detail the machine can produce.

Fig. 8. Close up on the texture of the 3D printed earrings.

7 Recommendations

Recommendations for future research is to explore how to set stone to plastic, test laser cutter's ability to cut through materials similar to TPU, to explore more complex IGPs in jewellery designs, and to test different types of rapid prototyping other than FDM. Moreover, since the processes explored in this study have different characteristics, different results, and they vary in which areas they excel, this could prompt for future researchers to explore how to combine these processes together to extract the best from each.

8 Conclusion

As drawn from the data analysis, laser-cutting and 3D printing processes stand at an equal footing. Each process is suitable to make different kinds of products; Laser cutting is fit for mass producing flat designs while 3D printing is suitable for customisability (if used to make the final product) and fit for mass production if used to aid in the mould making process. The handcrafting process failed in making a prototype, and this could be due to the material used rather than a fault of the process. Finally, Table 8 summarises the data from all the stages, highlighting in red the negatives of the process and highlighting in green where the process does well within the context of making contemporary plastic-based jewellery with IGPs designs.

Table 8. The character of the jewellery making processes.

The Criteria	Handcrafting	Laser-cutting	3D printing
Did it Produce a Prototype?	Failed	Succeeded	succeeded
Prototype texture	Roughest edges	Smoothest edges	Textured edges
Prototype State	Weak, breakable	Strong, solid	Flexible
Process Pace	Second slowest method for prototype making.	Fastest method for prototype making.	Slowest method for prototype making.
Number of Steps Taken	3 steps (does not include finishing)	5 steps	6 steps
Level of Detail	detailed	detailed	Most detailed
Process Axis Ability	It can make products in 3-axis	It can only do flat designs	It can make products in 3-axis
Level of Waste Produces	Produced waste	Produced waste	Did not produce waste
Process Speed	Hand-cutting duration 35 mins	Cutting speed 20mm/s	Printing speed: First layers 8.75 mm/s, and then gradual increase to 20 mm/s
Training requirement	Needs experience	Basic training	Basic training
Product Type	For custom or exclusive designs	For custom or mass-production	For custom or mass-production

Authors' Contributions. Alaa Al-Khulaqi researched the information from literature, then the data findings were reviewed and analysed by them with the guidance of Dr. Zainudin Siran; they guided in drafting the manuscript and approved the final version.

Acknowledgements. We would like to acknowledge and appreciate the division of Human Resource Development Fund (HRDF), Multimedia University (MMU) for the financial support to perform this research and participation in the conference.

References

1. Rocha, H. T., Ferreira, L. P., & Silva, F. J. G. (2018). Analysis and Improvement of Processes in the Jewelry Industry. 28th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2018), 17, 640-646. Elsevier. https://doi.org/doi:10.1016/j.promfg.2018.10.110
2. Siran, Z., Abidin, S. Z., & Anwar, R. (2020). The Influence of Reference Material for Sketching Strategies and Form Establishment at the Embodiment Design Level. *Environment-Behaviour Proceedings Journal*, *5*(SI3), 135-140.
3. Zahid, R., Jaleel, J., Mehmood, M. A., & Janjua, Q. R. (2022). Factors Influencing Purchase Intentions towards Fashion Jewellery: An Exploratory Study. Pakistan Journal of Humanities and Social Sciences, 10(1), 135-148. https://doi.org/10.52131/pjhss.2022.1001.0181
4. McCain, A. (2023, March 5). 20+ Dazzling Jewelry Industry Statistics [2023]: Facts, Data, Trends and More. Zippia. https://www.zippia.com/advice/jewelry-industry-statistics/
5. Ogunsakin, R., Marin, C. A., & Mehandjiev, N. (2021). Towards engineering manufacturing systems for mass personalisation: a stigmergic approach. International Journal of Computer Integrated Manufacturing, 34(4), 341-369. https://doi.org/10.1080/0951192x.2020.1858508
6. MOF Team. (n.d.). The Future of the Jewellery Industry: Trends & Insights. Matter of Form. Retrieved November 11, 2021, from https://www.matterofform.com/news/articles/jewellery-industry-trends
7. Gerasimova, A. A., Kagan-Rosenzweig, B. L., & Gavritskov, S. A. (2021). Design of modern jewelry using unconventional materials. IOP Conference Series. Materials Science and Engineering, 1079(2). IOP Publishing. https://doi.org/10.1088/1757-899x/1079/2/022049
8. Abdullah, T. (2021, July 6). The Rise of Halal Fashion. Halal Watch World. https://www.halalwatchworld.org/the-rise-of-halal-fashion
9. Madden, E. H. (1975). Some characteristics of Islamic art. The Journal of Aesthetics and Art Criticism, 33(4), 423-430. https://doi.org/10.2307/429655
10. Bonner, J. (2017). Islamic geometric patterns: their historical development and traditional methods of construction. Springer. https://doi.org/10.1007/978-1-4419-0217-7
11. Embi, M. R., & Abdullahi, Y. (2013). Evolution of Islamic Geometrical Patterns. Global Journal Al-Thaqafah (GJAT), 2(2), 243-251. https://doi.org/10.1016/j.foar.2013.03.002
12. Siran, Z., & Al-Khulaqi, A. (2022). The Criteria of Islamic Geometric Patterns Design for the Contemporary Jewellery Making Process. In 2nd International Conference on Creative Multimedia 2022 (ICCM 2022), 245-256. Atlantis Press. https://doi.org/10.2991/978-2-494069-57-2_26.
13. Ignatius, C. (2022, October 20). Consumers Demand Brands Get Personal as They Reject Labels and Stereotypes. Business Today. https://www.businesstoday.com.my/2022/10/20/consumers-demand-brands-get-personal-as-they-reject-labels-and-stereotypes/

14. Siran, Z., Abidin, S. Z., & Anwar, R. (2020). The Influence of Reference Material for Sketching Strategies and Form Establishment at the Embodiment Design Level. *Environment-Behaviour Proceedings Journal*, *5*(SI3), 135-140.

15. Elmelegy, N. A. (2017). 3D Printing; The Future of Innovative Shapes and Materials in Women Fashion Design. Eurasian Journal of Analytical Chemistry, 13(3), 151-173. https://eurasianjournals.com/abstract.php?id=451

16. Formlabs. (2019, July 3). How 3D Printing is Disrupting the Jewellery Industry. https://formlabs.com/asia/blog/3d-printed-jewelry/

17. Verner, A. (2018, January 22). Iris van Herpen Spring 2018 Couture. Vogue. https://www.vogue.com/fashion-shows/spring-2018-couture/iris-van-herpen

18. Jordahn, S. (2020, May 7). Architectural knowledge is "very useful for material development" in fashion says Iris van Herpen. Dezeen. https://www.dezeen.com/2020/05/07/iris-van-herpen-video-interview-architecture-fashion-design-vdf/

19. Wang, X., Wang, X., & Zhang, K. (2010). Forms and Material of Modern Jewelry. IEEE 11th International Conference on Computer-Aided Industrial Design & Conceptual Design 1, 1468-1470. https://doi.org/10.1109/CAIDCD.2010.5681933

20. Lischke, H. (2022, May 11). The Rise Of Craftcore Jewellery And Why You Need A Seashell Necklace This Summer. Vogue. https://www.vogue.co.uk/fashion/article/craft-jewellery-trend

21. Safavi, H. (2020). The Study of The Principles of Philosophy of Islamic Art. RUDN Journal of Philosophy, 24(1), 23-38. https://doi.org/10.22363/2313-2302-2020-24-1-23-38

22. Gurbuz, E. (2018). Theory of New Product Development and Its Applications. In (Ed.), Marketing. IntechOpen. http://dx.doi.org/10.5772/intechopen.7452

23. Mohd Rajili, N. A., Liem, A., Olander, E., & Warell, A. (2015). Processes, Methods and Knowledge Creation in Jewellery Design Practice. In ICoRD'15, International Conference of Research into Design Indian Institute of Science, Bangalore.

24. Penny, R. K. (1970). Principles of engineering design. Postgraduate Medical Journal, 46(3), 44-349. https://doi.org/10.1136/pgmj.46.536.344

25. Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2004). Engineering Design A Systematic Approach (3rd ed.) [E-book]. Springer.

26. Blessing, L. T.M. & Chakrabarti, A. (2009). DRM, a Design Research Methodology. Springer, London, 13-42. https://doi.org/10.1007/978-1-84882-587-1_2

27. Siran, Z., & Anwar, R. (2020, December). The Theoretical Framework of Design Thinking Behavior Model. In International Conference of Innovation in Media and Visual Design (IMDES 2020). 242-247

28. Widdowson, M. D. J. (2011). Case study research methodology. International Journal of Transactional Analysis Research, 2(1), 25-34. http://dx.doi.org/10.29044/v2i1p25