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Original Article

Investigating DIY Sneakers for Mass Customization Business Models by using 3D Printing Technology

Agatha Dinarah Sri Rumestri [1,*], Robert Christian Subagio [2] and Ivan Eliata Kusuma [3]

[1] Department of Product Design, Faculty of Industrial Engineering and Design, Institut Teknologi Telkom Purwokerto, 53147, Central Java, Indonesia.
[2] RCS Design, 65118, East Java, Indonesia.
[3] Ivan 3D Printing & Design, 60187, East Java, Indonesia.
* Correspondence: agatha@ittelkom-pwt.ac.id (A.D.S.R)

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Abstract: Sneakers have evolved into a new fashion style popular among Generation Z, including in Indonesia. The massive use of social media has increased the sense of individualism for everyone in expressing themselves. It is one factor that supports the development of the Mass Customization Business Model. In manufacturing custom products, 3D Printing is a technology that has the advantage of producing short serial and personalized products. This study explores sneaker designs that can be customized in certain parts using 3D printing technology. We conducted existing studies and expert interviews to determine sneaker features that can be customized with 3D Printing. In this research, some experiments were also executed to determine the 3D printing material and lattice structure that are more appropriate and applicable. This research results in the application of 3D Printing on the sole and accessories that can be customized on the lace and heel. Based on consumer analysis, the more popular sneakers are unisex characters. Meanwhile, the results of observing fashion trends are the significant impact of the COVID-19 pandemic, depicted through two design concepts: Hygen (Hygienic Expression) and Radex (Radical Expression). On the basis of a series of research and experiments that have been carried out, the sneakers that Generation Z will favor are sneakers with cosmetic features that can be customized to meet individual expressions.

Keywords: Sneakers; Mass customization; 3D Printing, Generation Z; Personal style.

1. Introduction

Sneakers have evolved from basketball sports shoes to a new fashion style (Williams & Heo, 2023). Especially in the younger generation, sneakers are combined with formal suits, which have never been seen before (Keyser, 2015). Generation Z, who are also known as digital natives, are accustomed to using gadgets, the internet, and online social media. According to Beaver (2012), the massive use of online social media has resulted in an increased sense of individualism for everyone in expressing themselves.

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According to Orehek & Human (2017), the increase in individual expression in online social media supports the Mass Customization Business Model. There are technological factors, namely the development of the internet and 3D printing manufacturing, as well as economic factors, where every entrepreneur looks for a differentiation between himself and his competitors. 3D Printing is an advanced technology when manufacturing custom products compared to conventional mass production techniques. According to Cuervas-Mons et al. (2022), 3D Printing is being developed to produce finished products and is no longer just used to make prototypes. 3D Printing also has its advantages, especially in producing short-series products that are custom or personal.

On the basis of the previously stated issue, this study aims to (1) Design sneakers that can be customized in certain parts by using 3D printer manufacturing techniques according to consumer choices. (2) Explore certain features that are the advantages of using 3D Printing on sneaker designs so that it can enlarge a business opportunity. In order to make limitations in this design research that are relevant within its scope and avoid widening the topic of discussion, the authors define several problem boundaries, namely: (1) The type of sneakers that will be used in this design research is lifestyle sneakers. (2) The 3D printing materials tested for experiments are PLA, PETG, and TPU. (3) The type of 3D Printing used in this research is FDM 3D printing. (4) The target consumers in this design research are Generation Z, who are in the productive age of 18-25 years.

2. Literature Review

The authors collect data and information related to the design discussion in this section from various sources. Shoes are foot wraps, usually made of leather, rubber, cloth, etc. According to Basuki (2010), shoes were originally invented to protect the feet. In addition, the main function of shoes is to maintain and support the shape of feet while carrying out work. Marchena-Rodriguez et al. (2020) also claimed that shoes can be divided into formal and casual types. Reebok stated that lifestyle shoes are included in the casual shoes category with a balanced combination of support and flexibility designed to express one's style. Meanwhile, Michael Romeo, a lifestyle shoe designer, said that lifestyle shoes are simply shoes that are comfortable to wear daily and have a style that expresses the user (Xie & Derakhshan, 2021). Sneakers is a marketing term used in the 19th century to describe the invention of shoes with rubber soles that had quiet sounds. But now, the term sneakers is becoming popular to refer to the type of sports shoes that are starting to turn towards lifestyle shoes.

The anatomy of shoes can be divided into two parts: the upper and the sole. Another thing that also needs to be considered is the height of the collar (cut of the upper) divided into low cut, mid cut, and high cut. In the sole, the things that need to be considered are the sole height (stack height) and the height difference of the sole at the heel and forefoot (heel drop). Huang (2020) states ergonomic aspects in sneaker design are important for optimizing performance, comfort, and health. Four things that need to be considered in ergonomic design are conforming to the shape of the foot, shock-absorbing, returning energy, and resisting bacteria, fungi, and odors. Based on Indonesian Anthropometry, foot measurements can be divided into two parts: foot length (D30) and foot width (D31). Foot length is the horizontal distance from the heel to the toe. Foot width is the distance between the two outermost sides of the foot.

According to Zhang & Ming (2023) and Salvador et al. (2020), mass customization is a marketing and manufacturing technique that combines the flexibility and personalization of custom products with the low unit cost associated with mass production. Mass Customization is a business model that manufactures and distributes custom goods to mass production standards (O'Sullivan & Sheahan, 2019). Many changes in various aspects of the business world have led to the emergence of mass customization (Radder & Louw, 1999). The first factor is consumers want more effective, varied products, features, good quality, and satisfaction. It creates competition between industries and offers customization as an effective way to find differences. The second factor is technological advances, especially Computer-Aided Design (CAD) manufacturing technology, which has removed many barriers in factory manufacturing regarding product variety and flexibility. Improved information technology has also facilitated the flow of communication between consumers and producers. The third factor is the product itself, which along with technological development, is experiencing an accelerated phase and a shortened life span. This causes a variety of increasingly diverse products.

Broekhuizen & Alsem (2000) argued four mass customization approaches: collaborative, adaptive, transparent, and cosmetic. In this research, the authors have applied mass customization with a collaborative approach. The collaborative approach involves consumers making decisions based on multi-dimensional factors. There are a lot of choices that confuse consumers to decide the best product. The solution is for the consumers and producers to decide together to determine the most suitable custom product. This approach allows consumers to participate even in the design process.

3D Printing, also known as additive manufacturing, is the process of making three-dimensional solid objects from a digital file through an additive process. Fused Deposition Modelling (FDM) is the most available and economical type of additive manufacturing. It works by depositing material continuously in horizontal layers. According to Kourentzes et al. (2020), FDM has manufacturing advantages: no setup costs, complex geometry, fast turnarounds, and an easy order process. The 3D printing material used in FDM is called filament. These filaments are made from various thermoplastic materials, namely plastic that melts rather than burns when heated and solidifies when cold (Liang et al., 2018). Based on information from McCausland (2020), the editorial team has more than 25 types of 3D printing filaments. Still, in this research, the authors only used and experimented with three filaments: PLA, PETG, and TPU.

PLA (Polylactic Acid) is a filament that is easy to print, has many color and brand variants, and is more environmentally friendly because it is made of renewable materials. Most PLA filaments are also odorless. PETG (Polyethylene Terephthalate), "G" in PETG means Glycol-modified, meaning PETG filament is clearer, not brittle, and easier to print than PET. This material is more flexible than PLA. The drawback of this material is that it is hygroscopic or absorbs moisture from the air, which results in the material being easily damaged, so it must be stored in a dry and cool place. TPU (Thermoplastic Polyurethane) is a type of TPE that is slightly stiffer, more durable, and can maintain elasticity in cold temperatures. This material is a flexible material that consists of various copolymers, which are generally soft and elastic.

3. Materials and Methods

The design research process uses two approaches: product feature analysis and midsole sneaker structure experiments with 3D printing manufacturing process. Product feature analysis is carried out in two stages. The first stage is an existing analysis through observing various sneaker brands that apply mass customization or 3D Printing. This analysis aims to determine what features are raised by the current and could be used as references for new product development. The second stage is an analysis of the results of interviews with experts in the field of footwear, fashion, and 3D printing experts. Expert interview analyses were presented as infographics and rating tables. The final features were obtained through the existing analysis and expert interviews, appointed as a sneaker design concept. This sneaker midsole structure experiment began with a midsole analysis to determine the level of specifications and functions that a midsole should have. After finishing these two stages of design research, the next process is an analysis of the best material and structure to accommodate the needs of midsoles and sneaker accessories that can be personalized.

4. Results and Discussion

4.1. Design Features Identification

Existing studies are conducted by differentiating existing into two types based on the brand scale: big brands such as Nike, Adidas, New Balance, Reebok, Under Armor, and small brands such as Unis Footwear, Fick, and Fused Footwear. The output of this existing study is to determine the part of sneakers that are possibly manufactured using 3D Printing and the implementation of customization, and these two things would be a benchmark for how new the design is. Following are the results of the existing studies:

Table 1. Analysis of Big Brands

Big Brands Categories		Nike	Adidas	New Balance	Reebok	Under Armour
3D Printing	Upper/ Accessories	V		V		
	Sole		V	V	V	V
Mass Customization	Upper	V	V			
	Sole	V	V			
	Personalization	V	V			

Table 2. Analysis of Small Brands

Small Brands Categories		Unis	Fick	Fused Footwear
3D Printing	Upper/ Accessories			V
	Sole	V	V	V

Small Brands Categories		Unis	Fick	Fused Footwear
Mass Customization	Upper		V	
	Sole		V	
	Personalization			

Tables 1 and 3 capture that 3 out of 8 shoe brands apply 3D Printing to the upper or as accessories. Two of them, Nike and Fused Footwear, make a complete upper from 3D Printing, while New Balance uses 3D Printing to make an accessory on the upper. According to the results, this study decided to make upper accessories using 3D Printing instead of the upper ones with 3D Printing. Then, it was found that 7 out of 8 shoe brands applied 3D Printing to the soles. 5 out of 7 shoe brands that apply 3D Printing to the soles apply a lattice structure that cushions the shoes. Because of that, the authors decided to apply 3D Printing to the sole and provide a lattice structure to the midsole as cushioning. Finally, it is known that 3 out of 8 shoe brands offer customization when customers purchase shoe products. After carrying out the existing study, the authors conducted interviews with experts. They are three footwear experts, two fashion experts and a 3D printing expert. After conducting interviews with experts, the authors summarize and conclude that five main features are the advantages of sneakers manufactured with 3D Printing, namely:

4.2. Shapes Exploration

3D Printing opens opportunities for designers to produce new, different, and innovative shapes compared to the usual forms of sneakers, which are bound by factory regulations and restrictions. It allows designers to be "wilder" in designing.

- **Complex Design Outline** - A complex shape means a formation that cannot be produced from a conventional production process, so it becomes a value creation. An example is the lattice structure, which several shoe brands also apply.
- **Customization** - 3D Printing also presents a customization trend regarding material, color, texture, and shape. Experts also recommended customization that emphasizes personalization features such as writing names.
- **Cosmetics** - Consumers can add parts to the upper that is cosmetic or embellishment. The presence or absence of this part does not affect function but acts as an additional value for aesthetics and beauty.
- **Fastener Part** - Possibility of maximizing 3D Printing to create a part that also functions in a shoe's lacing system. An example is a buckle, strap, and so on. Its function is as a binder or lock.

4.3. Consumer Analysis

In this section, the authors examine the characteristics of Generation Z and fashion trends to determine the sneakers concept. According to Afandi & Marsasi (2023), Generation Z is the successor to the Millennial Generation, which has a significant presence in society. They are starting to enter the professional working environment, have ideas, and produce new trends, and their large number has the potential to become a new economic and social power. Individualism and self-expression have become megatrends among Generation Z. Roche (2021) also claimed that individual expression arises through the massive use of social media. It is rise to the desire to have individual expression, be treated individually, and get offers personally. Individual and personal things will continue to grow during the younger generation. Amed et al. (2018) discuss that younger consumers are concerned about social and environmental issues. It greatly affects their shopping habits. Generation Z supports brands whose values align with their beliefs and avoid incompatible ones. In response to this condition, many fashion brands have started integrating social and environmental issues into their products and services. Nine of ten Generation Z consumers believe companies or sellers are responsible for environmental and social issues.

Ren et al. (2020) explained that fashion products are increasingly in demand, simultaneously increasing the amount of waste, carbon emissions, and the number of overworked workers. The COVID-19 pandemic has changed and even almost reset the production cycle of the fashion industry. One of the long-term impacts is sustainability-related issues. Through the pandemic, many people are starting to be aware of the importance of protecting the environment, and because of this, many fashion brands will develop more sustainable materials. 3D Printing is one of the options because the material is developed for recycling. Several brands, such as Unis and Fused Footwear, have also implemented this concept. These two brands also offer that shoes that are not used can be returned to the factory for recycling, and consumers will get a discount for their next purchase, so in principle, we only have a pair of shoes that are continuously recycled.

Meanwhile, the production process using 3D Printing can also reduce carbon dioxide emissions because it does not rely on heavy vehicles for logistics. It is enough to provide design files and local printers. The next impact is production restrictions, where previously fashion products were produced according to season and trend. It could lead to overproduction and overstocking. The pandemic has changed consumer habits, so consumers buy only the needed products, so many brands produce fashion products according to consumer demand to limit production. Referring to the seasonless Fashion Trend and Indonesia Trend Forecast (Chan & Astari, 2017), these two fashion trend references raise the same issue: the impact of the COVID-19 pandemic. Based on information from Meilianna (2020), current and future fashion trends or consumer clothing styles can be seen from their reactions to the Covid-19 pandemic. The first group is people who are increasingly aware of the importance of health and personal hygiene. Through the pandemic, they know they must take better care of their health, exercise, comply with health protocols, etc. The second group is the reaction of some people who want to be free because they feel bored with being isolated at home. They want to return to "appearing" and express themselves publicly. On the other hand, one of Z Generation's characteristics is upholding gender equality. It can be seen from the many fashion products that are created without referring to certain gender style tendencies. Many fashion products are made to be used by both men and women; in the fashion world, they are considered unisex. Here, the authors have made an image chart to illustrate sneakers with a unisex - complex impression.

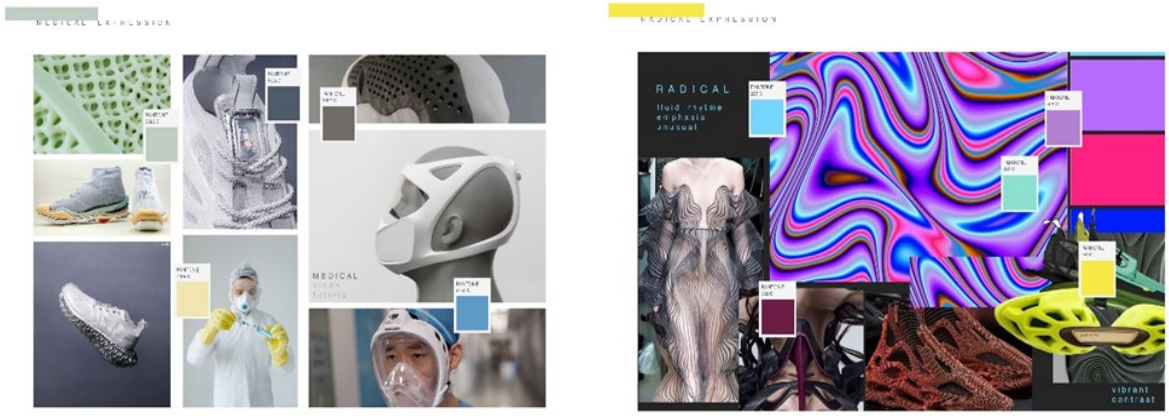
(a)

Features Character of Complex-Unisex Form	Features Character of Complex-Unisex Color
1. The sole and upper components are made of 3D printing. 2. Many layers. 3. Several identical or similar repeated forms. 4. A lot of details. 5. The overall shape and structure is dynamic and unique/unusual.	1. Mostly use neutral base colors. 2. The use of contrasting colors as highlights. 3. Some designs apply monochromatic. 4. The use of dark and brigth color compositions. 5. The overall color tends to be bright.
Features Character of Complex-Unisex Material	**Features Character of Complex-Unisex Elements**
1. 3D Printed materials. 2. Custom Knitting. 3. Custom Mesh. 4. TPU & TPR. 5. Special engineered sole.	1. Continuous design between sole and upper. 2. Focus on exploration and form innovation on components: counter heel, mudguard, quarter. 3. Unique and innovative lace system.

(b)

Figure 1. (a) Sneakers image chart with unisex – complex impression; (b) Analysis of sneakers image chart with unisex – complex impression

According to the tendencies and preferences of Generation Z consumers, the authors decided to create two design concepts based on consumer reactions to the COVID-19 pandemic, which were expressed in the sneaker's design styling.



(a) (b)

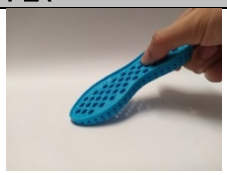
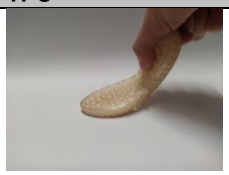
Figure 2. (a) Moodboard Hygen; (b) Moodboard

The first concept is called "Hygen," taken from the hygienic expression, describing the first group of consumers paying attention to personal hygiene. The design style is a bit futuristic and clean. The colors chosen to describe Hygen tend to be bright but are calming and gentle. The second concept is called "Radex," taken from radical expression. It describes the second group of consumers, who want to "appear" and express themselves in their social environment and are driven to produce radical styles. The design styles displayed are fluid rhythm, emphasis, and unusual. The authors have made mood boards to describe the concept (see Figure 2).

4.4. 3D Printing Experiments

This study conduct some trials in this section, from the experimental process and analysis to the design. Experiments were carried out on the sneakers part that will be manufactured using 3D Printing, namely on the soles and upper accessories. The sole is the bottom part of the shoe that is in direct contact with the ground. Therefore, the sole must be elastic and flexible for walking. To determine which 3D Printing material is most appropriate for making soles, the authors conducted trials between PLA, PETG, and TPU. The sole experimental results are shown in Table 3.

Table 3. Sole Experimental

Bending Test - Sole Material Trials			
Material	**PLA**	**PETG**	**TPU**
Figure			
Result	Too stiff, unable to be bent.	Too stiff, unable to be bent.	Able to be bent, but still a bit stiff.

On the basis of the results, the authors decided to use TPU material because it is more flexible than PLA or PETG. However, the sole is still too heavy and stiff, so the experiment continues with trials of applying the sole structure.

Table 4. Experiment of Sole Structure Types

Bending Test – Sole Structure Types			
Structure Type	**Unsimilar**	**Similar**	**Shell**
Figure			
Result	Stiff on the solid section and flexible on the loose section.	Very flexible but too stiff and painful when stepped on.	Not flexible but supple enough.

Table 4 shows that the shell type is the suitable structure application for soles. This type is a combination of similar types on the inside, but it is given a shell structure on the outside part, so it doesn't hurt the feet when stepped on. The next experiment was a trial of the lattice structure for the midsole. In the first stage, the authors applied 4 types of structures, namely BCC (Body Centered Cubic), Diamond, Fluorites, and Gyroids, to the cube, as well as carried out pressure tests and simulations to test the damping power of each structure type applied to the midsole. The lattice structure experimental results are shown in Table 5.

Table 5. Experiment of Lattice Structure for Midsole - Stage 1 (Cuboidal)

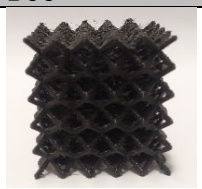
Pressure Test: MidSole Lattice Structure - Stage 1 (Cuboidal)				
Structure Type	**BCC**	**Diamond**	**Fluorite**	**Gyroid**
Figure				
Result	The structure is too weak. Too tenuous and the beam thickness is too thin. The structure shortens to 90% of its original height.	Weak structure. Too tenuous and the beam thickness is too thin. The structure shortens to 70% of its original height.	Strong structure. Less tenuous. The structure shortens only 5% of its original height.	The structure is too strong. Less tenuous. The structure has not changed of its original height.

Table 5 found that cross and geometric structures responded more to compressive forces. When giving pressure, deformation of the structure occurred, and it caused compaction. This is a cushioning effect in the midsole of sneakers. However, the authors needed to conduct several trials to find a structure with ideal spacing and beam thickness. The results of the second experiment on lattice structure are shown in Table 6.

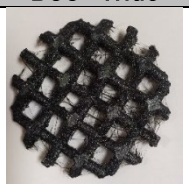
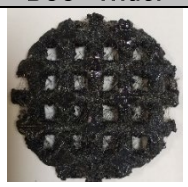
Table 6. Experiment of Lattice Structure for Midsole - Stage 2 (Cuboidal)

Pressure Test: MidSole Lattice Structure – Stage 2 (Cuboidal)				
Structure Type	**BCC**	**Diamond**	**Fluorite**	**Gyroid**
Figure				
Result	Ideal structure. The structure shortens to 20% of its original height.	Ideal structure. The structure shortens to 30% of its original height.	The structure is too tenuous and weak. The structure shortens to 90% of its original height.	The structure is too strong. The structure has not changed of its original height.

Tables 5 and 6 show the results of experiment stage 1 and stage 2. The authors concluded that the Gyroid structure is too stiff, so it cannot cushion on sneakers. Thus, this type of structure was eliminated for further experiments. The fluorite type had an extreme level of shape deformation when its tenuous structure modified it, so it was also eliminated. The ideal structure is BCC and Diamond. However, after conducting discussions with experts, it was found that the BCC structure is easier to manufacture using an FDM 3D printer, so the authors decided to use the BCC structure in this design. In practice, the structure would not be cuboidal. Still, it would be shorter and dynamically shaped, so a test of the BCC structure was carried out on a short cylindrical shape to simulate its application to the midsole. Another problem encountered was that the beam thickness was too thin, resulting in manufacturing constraints, so the next trial was to increase the beam thickness and add a shell. The results of the third experiment on lattice structure are shown in Table 7.

Table 7 indicates that the BCC-wide and BCC-wide-shell structures are ideal. However, because the BCC-wide structure causes foot pain, the authors decided to use a BCC-wide structure with shells to achieve a midsole comfort factor. After completing the third stage experiment of the midsole lattice structure, the authors conducted trials on the stack height (sole height). The higher it is, the more comfortable it will be because it provides more cushioning. Conversely, the shorter it will be, the easier it is to move your feet while wearing sneakers.

Table 7. Experiment of Lattice Structure for Midsole - Stage 3 (Cylindrical)

Pressure Test: MidSole Lattice Structure – Stage 3 (Cylindrical)				
Structure Type	BCC - Wide	BCC – Wide - Shell	BCC - Wider	BCC – Wider - Shell
Figure				
Result	Ideal structure. The structure shortens to 20% of its original height. Looks untidy and causes pain to the feet when stepped on.	Ideal structure. The structure shortens to 20% of its original height. Less flexible because it is a bit stiff when bent.	The structure is too strong. The structure does not deform when given a compressive force.	The structure is too strong. The structure does not deform when given a compressive force.

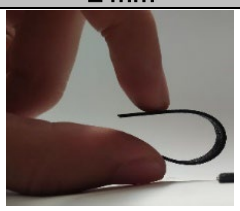
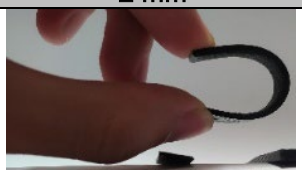
There are three sole height types: minimal, medium, and maximum. The application depends on the desired impact on the sneakers.

Table 8. Experiment with Stack Height

Bending Test: Stack Height Experiment			
Stack Height	Low (5 mm)	Medium (10 mm)	High (15 mm)
Figure			
Result	The sole can be bent.	The sole is a bit stiffer, but still able to be bent.	The sole is difficult to be bent.

Table 8 found that the higher the stack height, the more difficult it is to be bent, while the shorter the stack height, the more uncomfortable it is because the cushion or structure in the midsole is thinner; this is a trade-off. Therefore, the authors decided to use a medium height. Next is an experiment regarding the lace cap. The lace cap is an accessory part that functions as a lace hold on the lacing system. This accessory is located on the top of the sneaker's tongue, where most shoelaces are located. The author uses TPU material for the lace cap because this accessory is located on the instep, which requires flexibility. First, the authors conducted a bending test of thickness level to prove the material's effectiveness. Three thickness sizes have been tested, namely 1mm, 2mm, and 3mm. The results of the lace cap experiment are shown in Table 9.

Table 9. Experiment with Lace Cap Thickness

Bending Test: Lace Cap Thickness			
Thickness	1 mm	2 mm	3 mm
Figure			
Result	Very flexible, but easily	Very flexible but can be	Flexible and strong enough.

Bending Test: Lace Cap Thickness			
Thickness	1 mm	2 mm	3 mm
	deformed and prone to tearing.	deformed if it is pulled too strong.	

Table 9 shows a thickness of 3mm for the lace cap. Although it is a bit stiff, it is strong enough.

Table 10. Experiment of Lace Cap Forming

Forming Test: Lace Cap		
Shape	Cross Unit	Separate Unit
Figure		
Result	Works well and attractive appearance.	Less binding strength. Less attractive appearance and untidy.

Table 10 shows the results of the lace cap formation. The form with a compact unit was much more effective, comfortable, and attractive. Thus, the authors concluded that the lace cap must be compact in one unit, not a separate one. Next is the counterheel experiment. A counter-heel is an accessory located on the heel that is static and does not require a lot of flexibility, so both PLA and TPU are an option. In the following, the authors conducted experiments to recognize the differences between PLA and TPU for counter-heel design.

Table 11. The experiment of Counter Heel Material

Materials Test: Counter Heel		
Material	PLA	TPU
Figure		
Result	More "holding". PLA provides optimal support and protection to the heel.	More following the form and volume of sneakers counter heel.

Table 11 displays the results of material testing on the counter heel. It was found that a stiff material such as PLA can provide more support and protection to the heel and can be an accessory. Meanwhile, a flexible material such as TPU provides looseness and is adaptive to the changes of form or volume when stepped on.

4.5.Customized Sneakers Design Series

This section describes the design process for the appearance and the 3D printing application of sneakers. We start from the initial sketch process, development sketches, and the final design. Initial sketching is the process of expressing ideas by finding many design alternatives. The authors created 20 initial sketches of each series, so there were 20 initial sketches of the Hygen series and 20 initial sketches of the Radex series. Initial sketches are made digitally based on previously formulated design concepts.

(a) (b)

Figure 3. (a) Initial sketches of Hygen series; (b) Initial sketches of Radex series

The next process is design development, and the authors developed designs from initial sketches in each series. There are 5 Hygen series design developments and 5 Radex series design developments. Designs were developed by emphasizing forms, coloring, material selection, and describing details for a clearer design visualization.

(a) (b)

Figure 4. (a) Development design of Hygen series; (b) Development design of Radex series

After carrying out the design development process, the authors held discussions to agree to determine one final design from each series. The final design discussion was carried out by creating an assessment matrix for design development. The matrix criteria used in the Hygen series are futuristic, clean, and composition of design elements. Among the 5 design development alternatives, the one with the highest value was chosen as the final design. The results of the assessment are shown in Table 12.

Table 12. Assessment Matrix of Hygen Design Series

Alternatives	Futurist	Clean	Design Elements Composition	Total
Hygen 1	3	3	4	10
Hygen 2	2	4	3	9
Hygen 3	3	2	2	7
Hygen 4	4	3	4	11
Hygen 5	2	3	2	7

The matrix criteria used in the Radex series are liquid rhythm, unusual, and composition of design elements. Among the 5 design development alternatives, the one with the highest value was chosen as the final design. The results of the assessment are shown in Table 13.

Table 13. Assessment Matrix of Radex Design Series

Alternatives	Liquid Rhythm	Unsual	Design Elements Composition	Total
Radex 1	2	3	2	7
Radex 2	2	4	3	9
Radex 3	4	3	4	11
Radex 4	4	2	4	10
Radex 5	3	4	3	10

After reaching an agreement on the final design selection through the assessment matrix, the authors visualized the final design of each series in rendered 3D modeling.

(a) (b)

Figure 5. (a) Final design of Hygen series; (b) Final design of Radex series

5. Conclusions

After researching sneaker design, the authors concluded that (1) Sneakers designed for the mass customization business model are must-have accessories that consumers can customize in shape and color at purchase. It also has personalized features such as providing motivational quotes, names, or personal symbols. The point is design that expresses the personality of its users. (2) Sneaker designs using FDM 3D printing technology have the following features: exploration of complex forms, custom-made items, cosmetic components, and fastener development. It is hoped that this research will give readers an overview of the sneaker design process through the Mass Customization Business Model using 3D Printing. The data and analysis the authors collected and processed can be used for further research and motivate footwear design practitioners to innovate. The authors realized that both the research and design process were still imperfect. Several things must be studied deeply to obtain relevant and applicable designs for businesses and industries. In order to achieve better results, the authors provided suggestions to further researchers and designers regarding this topic, namely: (1) Focus on designing one part of sneakers, between the sole or upper, so that the study can be deeper and more focused. (2) Expand and deepen 3D printing material experiments. More specifically, the brand, type of 3D printing filament, and price are to a certain specification. (3) Compare FDM 3D printing with other types of 3D printing manufacturers such as SLA.

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