Harmonising Traditional and Technology: 3D Printing's Role in Modernising Rebab Melayu

Mhd Sany Mhd Hanif[1], Mohammad Kamal Sabran[2], & Hasnul Azwan Azizan[3]
Universiti Sains Malaysia[1,2] Universiti Teknologi Mara, Malaysia[3]
e-mail: mhdsany_mhdhanif@yahoo.com[1]

Article received: June 10, 2024
Article revised: June 15, 2024
Article accepted: June 20, 2024
Article published: June 30, 2024

Cite this article (APA): Mhd Hanif, M. S., Sabran, M. K., & Azizan, H. A. (2024). Harmonising traditional and technology: 3D printing's role in modernising Rebab Melayu. *Jurai Sembah*, *5*(1), 23-36. https://doi.org/10.37134/juraisembah.vol5.1.3.2024

Abstract

The Rebab Melayu, a traditional string instrument deeply rooted in Malay culture, symbolizes the rich cultural heritage of Southeast Asia. However, the continuity of this iconic instrument is increasingly threatened by the decline in skilled craftsmanship and the rising costs associated with traditional manufacturing techniques. This study investigates the potential of 3D printing technology as a modern solution to these challenges. By integrating 3D printing with traditional craftsmanship, the research aims to preserve the cultural essence of the Rebab Melayu while enhancing production efficiency in terms of cost, time, and space. The study also explores whether 3D printing can replicate the intricate design that defines the Rebab Melayu. Through a comparative analysis of traditional and 3D-printed Rebab Melayu, this research highlights the potential of 3D printing to revitalize interest in the instrument, particularly among younger generations. The findings suggest that a balanced approach, combining modern technology with traditional methods, can ensure the continued relevance and preservation of the Rebab Melayu as a vital part of Malay cultural heritage.

Keywords: 3D printing, cultural preservation, modernisation, Rebab Melayu, traditional craftsmanship

Introduction

The Rebab Melayu, a traditional bowed lute integral to Malay cultural and musical heritage, traces its origins to the Arab world and arrived in Southeast Asia via 13th-century trade routes (Matusky & Tan, 2017). Over time, it has evolved into a symbol of Malay identity, characterized by its distinctive oval or round body, long neck, and construction from wood, animal skin, and strings made from gut, nylon, or silk (Kechot et al., 2015). The meticulous craftsmanship of the Rebab, passed down through generations, reflects the cultural values and artistic sensibilities of its makers. Historically, it has been the lead melodic instrument in traditional Malay ensembles, particularly in Mak Yong, a dance-drama recognized by UNESCO as an Intangible Cultural Heritage.

In the context of preserving traditional instruments like the Rebab Melayu, the decline in skilled artisans and the rising costs of traditional manufacturing present significant challenges. Similar to the modernization efforts seen in other traditional instruments such as the flute and violin, which have successfully integrated additive manufacturing (AM) technology, 3D printing offers a promising solution (Kantaros & Diegel, 2018). This technology not only replicates the visual and acoustic properties of these instruments but also allows for customization, making the instruments more accessible and appealing to modern audiences.

3D printing enables precise replication of intricate designs and introduces innovative possibilities in material selection, ensuring the Rebab Melayu remains relevant for future generations. By integrating modern technology with traditional craftsmanship, this research aims to preserve the cultural essence of the Rebab while adapting it to contemporary manufacturing processes. This study addresses the balance between maintaining traditional artisanal methods and embracing technological advancements, contributing to the ongoing dialogue on cultural preservation in a rapidly changing world.

This study aims to investigate the following research questions: (a) How does 3D printing compare to traditional methods regarding cost, time, space, process and material efficiency? (b) Can 3D printing preserve the cultural integrity of the Rebab Melayu? The research explores the potential of 3D printing as an alternative to traditional techniques in the production of the Rebab Melayu, a culturally significant Malay musical instrument. It focuses on comparing the two methods in terms of cost, time, space, material, and process efficiency, while also evaluating whether 3D printing can uphold the cultural essence of the Rebab Melayu.

The study examines whether 3D printing, using materials like PETG, can provide a more cost-effective and time-efficient alternative to the traditional, labour-intensive process, which typically relies on materials such as jackfruit wood and cow stomach skin. Additionally, the research explores whether 3D printing requires less space and minimizes material waste compared to traditional crafting methods, which often demand large workshop areas and result in significant material loss. A key aspect of this study is to determine whether 3D printing can replicate the intricate craftsmanship and cultural significance of the Rebab Melayu. The research investigates if a 3D-printed Rebab can maintain the instrument's traditional sound and aesthetic, ensuring it continues to hold its place as a meaningful element of Malay heritage. Ultimately, this study seeks to establish whether 3D printing can modernize the production of the Rebab Melayu without compromising its cultural and acoustic qualities, providing valuable insights into how traditional crafts can be preserved and revitalized through technological advancements.

Traditional Craftsmanship and Cultural Significance

The Rebab Melayu is more than just a musical instrument; it is a vital embodiment of Malay cultural identity, deeply interwoven with the traditions, ceremonies, and daily lives of the Malay people. Its integral role in various ceremonial and cultural performances underscores its significance as a cultural symbol, bridging past and present, and connecting generations through its melodic expression (Jusoh, 2011). The Rebab's enduring presence in Malay culture highlights its importance in preserving and transmitting cultural values (Nasuruddin, 2018).

Crafting a Rebab Melayu is an intricate process that requires not only artisanal skill but also a deep understanding of the instrument's cultural significance. The Rebab comprises thirteen distinct parts, including the *Kepala Rebab* (head), *Batang Serunai* (reed stem), *Pemulas* (tuning pegs), and *Muka Rebab* (face), among others, each contributing to its unique sound and durability (Zapri, 2015). Traditionally, these components are crafted from materials like jackfruit wood, valued for its strength and acoustic qualities, and cow's stomach skin, which provides the necessary tension and texture for the Rebab's distinctive sound (Jusoh & Bidin, 2017). The meticulous craftsmanship involved in creating the Rebab Melayu is a testament to the skill and dedication of its artisans, preserving cultural knowledge and practices passed down through generations (Nik Salleh, 1995). However, the preservation of these traditional skills is increasingly threatened. The number of artisans capable of crafting the Rebab Melayu is dwindling, with younger generations showing less interest in learning these methods (Zapri, 2015).

The Rebab Melayu, with its deep-rooted cultural significance and intricate craftsmanship, stands as a testament to the rich heritage of the Malay people. However, the sustainability of these traditional methods is increasingly challenged by modern realities. As the number of skilled artisans declines and the cost of traditional materials rises, there is a growing need to explore alternative methods that can preserve the Rebab's cultural essence while adapting to contemporary demands. This is where modern technology, particularly 3D printing, presents a compelling opportunity. While the traditional crafting of the Rebab Melayu is steeped in cultural significance, integrating 3D printing into its production process offers a potential solution to the challenges of preservation and accessibility. The transition to 3D printing raises critical questions about maintaining the Rebab's cultural and acoustic integrity, which this study aims to explore in depth. As we move from discussing the traditional craftsmanship to examining the possibilities of 3D printing, it is essential to consider both the benefits and potential cultural implications of adopting this modern technology.

3D Printing: A Modern Approach to Preservation

3D printing has offered innovative approaches in the preservation and creation of musical instruments, impacting cultural preservation significantly. This technology allows for the precise replication of rare or historical instruments (Dabin et al., 2016; Cottrell & Howell, 2019), ensuring cultural heritage is maintained and accessible for future generations. Specifically, for the Rebab Melayu 3D printing offers precise replication of intricate designs while enabling material and design innovations that traditional methods cannot achieve., thereby contributing to the expansion of musical diversity and heritage.

According to Amit Zoran (2011), technologies like 3D printing provide a flexible way to create both mechanical and acoustic components for musical instruments (p. 382). Traditional acoustic instruments are frequently standardised and challenging to adapt, but digital instruments already have variable sound control. However, using Computer-Aided Design (CAD) and 3D printers offers a quick and simple technique for making design adjustments for Rebab Melayu. This creates opportunities for Rebab Melayu customisation and innovation. One of the primary discussions in this study is the potential use of 3D Printing to fabricate Rebab Melayu that defies creation through conventional manufacturing methods. Previous studies argue that although AM has been successful in creating traditional musical instruments with unique designs, the complete realisation of this technology in producing entirely novel sounds remains primarily untouched (Zoran, 2008; Cotrell & Howell, 2019).

Table 1: Examples of Musical Instruments Made Using Different Methods of Digital Fabrication.

Company/ Project	**Instrument**	**Technology/ Method Used**	**Innovation/Advantage**
RedEye RPM	Solid body guitar	3D printing	Customization and distinctive designs are made possible through digital manufacturing.
Blackbird Guitars	Blackbird Rider Acoustic guitar	Computer-aided milling machines	Utilisation of carbon fibre composite materials to reduce chamber size while preserving sound projection.
ReAcoustic eGuitar	Concept design	3D printing sound cells	Sound that can be modified by combining several 3D printed sound cells, enabling experimentation and new approaches to sound design.
Amit Zoran (2010)	3D Printed flute	CAD (Rhino4.0), 3D printing	Prior to manufacture, using a CAD model offers both functional and aesthetic simulations, which allow for the prediction of the final products' attributes.
Stephen Cottrell & Jocelyn Howell (2019)	B&H clarinet mouthpieces	Technical drawing, CAD (Solidworks), 3D printing	Recreating original instrument's part from historical documents.

As indicated in Table 1 above, there are instances of 3D-printed instruments in the past. Digital fabrication, using 3D printing technology, has revolutionised the creation of musical instruments, offering numerous advantages. One significant benefit is the ability to mend vintage musical instruments that have either gone extinct or have endured damage over time.

Duplicating the unique sounds and playability of many rare or historical musical instruments often proves to be an insurmountable task as they are either destroyed or significantly deteriorated. However, with 3D printing, accurate replicas can be manufactured using preserved historical records and documentation (Cotrell & Howell, 2019). Regarding the traditional Rebab Melayu, measurements and shapes can be carefully taken from practitioners like Che Mat Jusoh to ensure that critical components, such as the soundboard, are accurately replicated, thereby avoiding acoustic errors. This exercise preserves not just the cultural history but also enriches our understanding of musical traditions by allowing musicians, researchers, and enthusiasts to study and experience earlier epochs' music and performance styles. In addition to restoring antique instruments, instrument makers can wield 3D printing to fabricate brand-new instruments (Zoran, 2011). As 3D printing is digital, it can mould detailed and complex shapes of Rebab Melayu that were previously challenging to execute using conventional manufacturing techniques. This creative liberty paves the way for limitless opportunities to craft cutting-edge musical instruments with enhanced sound, playability, and aesthetics.

Moreover, digital fabrication caters to the benefit of customization. Musicians and instrument creators can collaborate closely to fabricate tailor-made instruments that cater to their individual needs and preferences (Kantaros & Diegel, 2018). With instrument performance optimization in mind, factors such as size, shape, weight, and material composition can be modified to elevate playing pleasure and better satiate the individual needs of musicians. Affordability, brought about by 3D printing technology, also presents an advantage in instrument creation. Traditional methods can prove to be time-consuming, labour-intensive and costly, particularly in the case of rare or historically significant instruments (Pedgley et al., 2009). Greater accessibility is a by-product of 3D printing streamlining the manufacturing process, curtailing material wastage, and reducing the need for specialised equipment and expertise. This accessibility benefits professional musicians, students, and hobbyists alike including Rebab Melayu makers by making top-tier instruments available to a broader audience.

Overall, 3D printing and digital fabrication have unfolded new avenues in creating and restoring musical instruments. It enables the construction of entirely new designs, provides customization opportunities, boosts affordability, and allows the preservation of Rebab Melayu. As technology advances, the advantages of using 3D printing in the music industry are likely to increase, fostering innovation and expanding opportunities for both artists and instrument makers.

Instruments

This research involved the production and comparative analysis of two versions of the Rebab Melayu: one crafted using traditional methods and materials, and the other produced using 3D printing technology. The instruments used in this study were as follows:

i. Traditional Rebab Melayu
- Documentation
    - All of the information on the production of traditional Rebab Melayu was taken from journals and books.
- Measurement

    The measurements for the instrument were taken from Che Mat Jusoh's Rebab. Che Mat Jusoh, a Resident Artist at the School of the Arts, Universiti Sains Malaysia, is a maestro in Makyung theatrical performance, specializing in both the crafting and playing of the Rebab Melayu.

ii. 3D-Printed Rebab Melayu
- Materials
    - PETG (Polyethylene Terephthalate Glycol): PETG was selected for its balance of strength, durability, and acoustic performance, making it suitable for replicating the structural and tonal qualities of the Rebab Melayu (Hsueh et al., 2021; Maurya et al., 2019).
    - Drumhead: A synthetic material used as an alternative to cow stomach's skin for the soundboard. The choice is made from the observation of a post made by Mohd Farid Bin Kamaruzaman's Facebook page on 19th of September 2021, another Rebab Melayu practitioner and maker who tested his Rebab Melayu using the drumhead.
- Production Process
    - Computer-Aided Design (CAD): The digital design phase where the Rebab Melayu was modelled using Rhino 4.0 software. This step allowed for precise control over the instrument's dimensions and structure.
    - 3D Printing: The CAD model was sliced using Cura software and printed using an FDM (Fused Deposition Modelling) 3D printer (Anycubic Predator). The printing process produced the components layer by layer.

- Post-Processing: Involved sanding, filing, and assembling the printed components. This step also included the application of a drumhead and the installation of nylon strings.
- Assembly: The final step is where all the 3D-printed components are assembled to form the complete instrument.

Methodology

The research methodology was designed to compare the traditional and 3D-printed Rebab Melayu in terms of cost, time, space, materials, and production processes. The methodology did not include acoustic testing, as the focus was on evaluating the production aspects.

i. Data Collection
   - Cost Analysis: The cost of materials and production for both the traditional and 3D-printed Rebab Melayu were recorded. For the traditional Rebab, costs were calculated based on market prices for materials and labor, while the cost of the 3D-printed Rebab was calculated based on the amount of PETG used and its cost per gram. The material costs were obtained from a top Shopee seller who provides 3D printing services, and used as an example to calculate the overall cost.
   - Time Analysis: The time required to produce each instrument was documented, with traditional crafting times based on artisan estimates and 3D printing times measured during the printing and post-processing stages.
   - Space Analysis: The space required for each production method was measured, considering the workspace needed for traditional crafting tools and the compact footprint of the 3D printer.
   - Materials Analysis: The materials used in each method were compared, focusing on their functional properties and cultural significance.
   - Process Analysis: The process used in each method were compared, focusing on

ii. Comparative Analysis
   - The collected data were analysed to identify the advantages and disadvantages of each production method. The analysis considered the efficiency, practicality, and potential cultural implications of using modern materials and methods versus traditional ones.
   - Limitations: The research acknowledged the limitation of not including acoustic analysis, which is crucial for determining the sound quality and cultural authenticity of the Rebab Melayu. This limitation was discussed in the context of future research needs.

iii. Results Interpretation
   - The findings were interpreted to assess whether 3D printing could serve as a viable alternative to traditional methods, particularly in the context of preserving the Rebab Melayu's cultural significance while modernizing its production process.

The methodology was designed to provide a clear comparison between the two production methods, highlighting the potential benefits and drawbacks of using 3D printing technology to modernize the Rebab Melayu. The study's findings are intended to contribute to ongoing discussions about the role of modern technology in cultural preservation and the sustainability of traditional crafts.

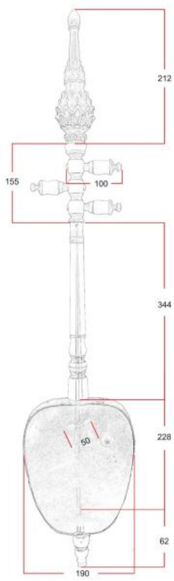
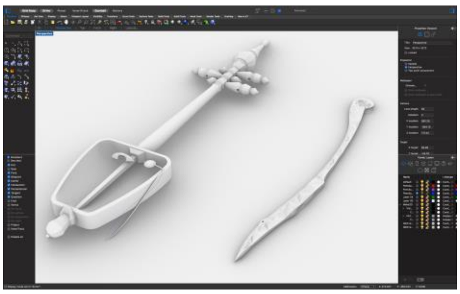
Case Studies: 3D Printing in Traditional Instrument Productions

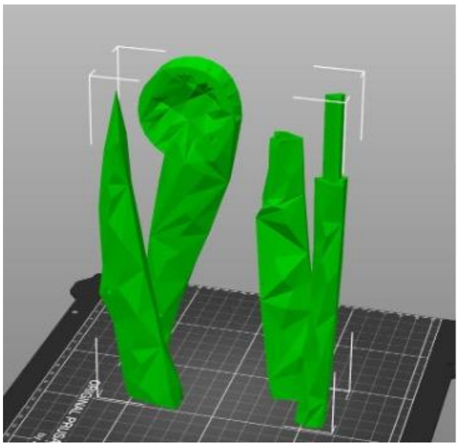
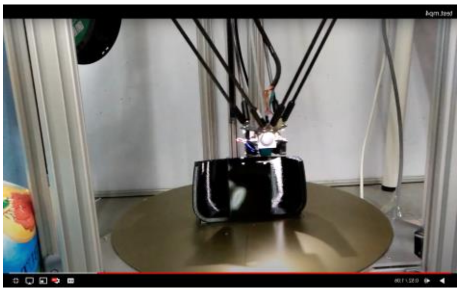
Based on the literature presented in Table 1, the researcher replicated and adapted previous methodologies to develop a modernized 3D-printed Rebab Melayu. Using the existing Rebab Melayu as a reference template, precise measurements were taken from the existing instrument, including all critical dimensions such as height, width, and depth (Savan & Simian, 2014). These exact measurements were necessary to ensure that the instrument would function properly without causing distortions in string tension or sound quality. Modifications were limited to non-acoustic components, allowing for changes in form only where they would not impact the instrument's sound.

Figure 1. Process of producing 3D-Printed Rebab Melayu adapted from Zoran (2008); Cotrell and Howell (2019)

In terms of material selection, PET-G was chosen based on the material research conducted by Zvoníček et al. (2023), which demonstrated its durability in the context of string instruments. Their research highlights PETG's significant advantages over ASA, particularly in the production of 3D-printed musical instruments. PETG's superior mechanical stiffness makes it particularly well-suited for components that must withstand mechanical stresses (Aabid et al., 2023). Additionally, PETG exhibits enhanced acoustic performance, especially in sound reflection at higher frequencies, which is crucial for preserving sound quality. The material's sound reflection properties are also less impacted by surface irregularities, allowing for greater flexibility in 3D printing without a significant loss in acoustic integrity. Moreover, PETG contributes to improved printing efficiency by reducing the time required for production without compromising acoustic quality, making it an optimal choice for the creation of high-quality 3D-printed musical instruments.

Table 2: 3D Printing Rebab Melayu

Steps	Figures	Process	Technology
Step 1		Measurement taken from Che Mat Jusoh's traditional Rebab	1. Measurement tape 2. Caliper
Step 2		Computer-Aided Design	1. Rhino 4.0

Step 3		Slicing	1. Cura
Step 4		Printing	1. Anycubic Predator FDM Printer
Step 5		Post- Processing	1. Sand papers 2. File tools

The process of creating a 3D-printed Rebab Melayu begins with detailed measurements of an existing instrument to ensure precision in the digital model. The initial step involves measuring a Rebab Melayu sample from Che Mat Jusoh's collection, which is crucial for accurate replication (Jusoh, 2011). This measurement data is then used to construct a 3D visual of the Rebab using Rhino 4.0, a software that allows for intricate design adjustments (Dabin et al., 2016). The design process focuses on modernising the instrument's form while preserving the traditional shaft (*Batang Rebab*) and soundbox (*Tempurung*) to maintain sound integrity. The conversion of this data into STL files for 3D printing ensures that the digital model accurately translates into a physical instrument (Iancu, et al., 2010). This step is essential for creating a precise and functional 3D-printed Rebab Melayu, reflecting the careful blending of traditional craftsmanship with modern technology.

Following the creation of the 3D model, the next step involves using Cura slicing software to prepare the STL files for printing. Cura is critical for defining the material thickness, volume, and size, which are vital for achieving high-quality prints (Cottrell & Howell, 2019). The researcher organised the files based on the printer's capacity, grouping the soundbox, feet, and axis together separately for one print job and other components. The bow was printed independently due to its size limitations and was designed separately to fit the print area on the FDM 3D printer. This step highlights the importance of precise software and printer management in ensuring that each component of the Rebab Melayu is accurately reproduced, demonstrating the efficiency of 3D printing in handling complex designs.

In the final step, post-processing is performed to refine the 3D-printed parts of the Rebab Melayu. This includes cleaning the surfaces of the printed components to achieve the necessary smoothness and applying drum skin for the soundbox and nylon strings for the bow (Cottrell & Howell, 2019). The drum skin is crucial for replicating the instrument's traditional sound, while the nylon strings are essential for the bow's functionality (Dabin et al., 2016). This stage of the process underscores the significance of integrating traditional materials and techniques with modern printing methods to ensure the final product maintains its cultural value and meets functional requirements.

(a)

(b)

Figure 2. Side by side 3D-Printed Rebab Melayu (a) and Traditional Rebab Melayu (b) comparison.

As illustrated in Figure 2, the researchers preserved the overall shape of the Rebab Melayu to maintain its cultural identity. The only modifications were made to the shape and form of the *Kepala Rebab* and *Pemulas*. While the traditional Rebab Melayu (b) features an organic shape, the 3D-printed version adopts a more geometric design to give it a modern and contemporary appearance. One significant advantage of the 3D printing process is its ability to combine two parts, the Celi and Kaki Rebab, which were traditionally made from different materials and through separate processes. This approach effectively addresses the cost and time constraints associated with the traditional production of the Rebab Melayu.

Ultimately, the 3D printing process for the Rebab Melayu demonstrates how modern technology can be applied to preserve and innovate traditional craftsmanship. By meticulously measuring, designing, and printing, this approach ensures that the Rebab Melayu maintains its cultural integrity while embracing contemporary methods. The use of 3D printing not only modernises the production process but also helps preserve the instrument's unique heritage, showcasing a successful integration of tradition and technology (Dabin et al., 2016; Cottrell & Howell, 2019).

Comparative Analysis: Traditional and 3D-Printed Rebab Melayu

Table 3 presents a comparative analysis of the cost, time, and space requirements for producing a traditional Rebab Melayu versus a 3D-printed Rebab Melayu. This comparison highlights the efficiency and potential advantages of using 3D printing technology in the production of this culturally significant instrument.

Table 3: Comparison on Cost, Time, Space

	Traditional Rebab Melayu	**3D-Printed Rebab Melayu**
Cost	RM 1000 – RM 1500	540gram X RM 0.49 = RM 264.60
Time	56hrs	20hrs
Space	15ft X 15ft	5ft X 5ft

Cost Analysis

The cost of producing a traditional Rebab Melayu ranges from RM 1000 to RM 1500, reflecting the expenses associated with high-quality materials, skilled labour, and the intricate craftsmanship involved. In contrast, the cost of producing a 3D-printed Rebab Melayu is significantly lower, calculated at RM 264.60. This figure is based on the material cost of 540 grams of filament, priced at RM 0.49 per gram. The substantial cost reduction offered by 3D printing can make the Rebab Melayu more accessible to a broader audience, particularly in communities where traditional craftsmanship is becoming scarce and expensive.

Time Analysis

The traditional method of crafting a Rebab Melayu takes approximately 56 hours, which includes the time-intensive processes of selecting and preparing materials, hand-carving, and assembling the instrument. In contrast, 3D printing the Rebab Melayu requires only 20 hours, representing a significant time saving. This reduction in production time is a key advantage of 3D printing, allowing for faster production cycles and the ability to produce multiple instruments within a shorter timeframe. The reduced time requirement also implies that more instruments can be produced in response to demand, potentially revitalizing interest in the Rebab Melayu.

Space Analysis

The space required for the traditional production of a Rebab Melayu is 15ft x 15ft, which accounts for the workshop area needed for various tools, materials, and workspace for the artisan. On the other hand, the space needed for 3D printing the Rebab Melayu is considerably smaller, at just 5ft x 5ft. This reduction in space requirements is due to the compact nature of 3D printers and the reduced need for large-scale materials and tools. The smaller footprint of 3D printing setups makes it feasible to produce the Rebab Melayu in various environments, including urban settings with limited space, further expanding the production potential.

Table 4: Comparison on Materials and Process

	Traditional Rebab Melayu	**3D-Printed Rebab Melayu**
Materials	1. Jack-fruit wood 2. Cow stomach’s skin 3. Stingless bees’ wax 4. Metal plate 5. Tubeless metal	1. PETG 2. Drumhead

Jurai Sembah 5(1) (23-36)
e-ISSN 2716-5523

Process	1. Lathe 2. Forming 3. Drilling 4. Sanding 5. Painting 6. Carving 7. Assembly	1. CAD 2. 3D Printing 3. Post-Processing 4. Assembly

The table above provides a comparative analysis of the materials and processes involved in the production of a traditional Rebab Melayu versus a 3D-printed Rebab Melayu. The analysis highlights the differences in material selection and manufacturing techniques, shedding light on the implications for the instrument's production, cultural significance, and practical applications.

Materials Analysis

i. Traditional Rebab Melayu: The materials used in the traditional production of the Rebab Melayu are deeply rooted in the cultural practices and natural resources available in the Malay world. Key materials include:

- Jack-fruit wood: Known for its durability and resonant properties, this wood is integral to the body of the Rebab.
- Cow stomach's skin: Used for the soundboard, this material is critical for producing the instrument's unique acoustic qualities.
- Stingless bees' wax: Applied as an adhesive or protective layer, contributing to the instrument's longevity and sound quality.
- Metal plate and tubeless metal: These components provide structural integrity and are essential for certain parts of the instrument.

These materials are not only functional but also carry cultural significance, reflecting traditional knowledge and craftsmanship passed down through generations.

ii. 3D-Printed Rebab Melayu: In contrast, the 3D-printed Rebab Melayu utilizes modern materials such as:

- PETG (Polyethylene Terephthalate Glycol): A versatile plastic known for its strength, durability, and ease of printing. While PETG is a practical choice for 3D printing, it lacks the natural resonance and cultural connection of traditional materials like wood.
- Drumhead: Used to replicate the soundboard, this synthetic material mimics the function of the cow stomach's skin but may not fully replicate its acoustic properties.

The shift to synthetic materials in 3D printing reflects a trade-off between practicality and the preservation of traditional acoustic and cultural qualities.

Process Analysis

i. Traditional Rebab Melayu: The traditional production process involves a series of skilled, labour-intensive steps, including:

- Lathe, forming, and drilling: These processes shape the wood for *Kepala Rebab, Batang Serunai*, *Pemulas*, *Batang Rebab*, and *Kaki Rebab* into the precise forms required for the instrument.
- Sanding and painting: These steps ensure a smooth finish and apply decorative elements that contribute to the instrument's aesthetic appeal.

- Carving and assembly: Intricate carving is often done by hand, adding personalized artistic touches that reflect the artisan’s skill and cultural heritage. The carving process involves only the *Kepala Rebab* and *Penggesek.* (Abd. Latif, 2010; Jusoh, 2011 & 2017)

This process is time-consuming and requires a high level of expertise, but it results in an instrument that is both a work of art and a cultural artefact.

ii. 3D-Printed Rebab Melayu: The 3D printing process is more streamlined and relies heavily on modern technology:

- CAD (Computer-Aided Design): The design phase where the instrument is digitally modelled. This allows for precise control over the shape and dimensions of the Rebab.
- 3D Printing: The core manufacturing process where the digital model is printed layer by layer, transforming the design into a physical object. This step is efficient and consistent but lacks the organic variations of handcrafting.

- Post-Processing and Assembly: Post-processing involves cleaning, smoothing, and sometimes painting the printed parts before assembly. While this process is quicker and less labour-intensive, it may not achieve the same level of detail and craftsmanship as traditional methods.

The 3D printing process reduces the need for skilled labor and speeds up production, but it also removes the artisanal aspect that is integral to the traditional Rebab Melayu.

Discussions

This research paper focuses on comparing the traditional and 3D printing methods involved in producing the Rebab Melayu, to identify the advantages and disadvantages of each approach. While this study provides valuable insights into the production processes, it is important to acknowledge that the analysis is limited to the manufacturing aspects, and does not include a comprehensive acoustic analysis of the instruments produced by these methods. This limitation should be taken into account when interpreting the findings, as the sound quality and acoustic performance are essential elements of any musical instrument.

Comparative Analysis of Materials

The materials used in the traditional crafting of the Rebab Melayu, such as jack-fruit wood, cow stomach’s skin, and stingless bees’ wax, are not only functional but also deeply rooted in the cultural heritage of the instrument. These natural materials contribute significantly to the Rebab’s unique acoustic properties, providing a resonant, warm sound that is difficult to replicate with synthetic alternatives. The selection of these materials is guided by centuries of cultural practices, ensuring that the instrument maintains its traditional sound and cultural identity.

In contrast, the 3D-printed Rebab Melayu utilizes modern materials like PETG and synthetic drumheads. While these materials are cost-effective, durable, and suitable for 3D printing, they may not offer the same acoustic qualities as their traditional counterparts. For instance, PETG provides strength and ease of manufacturing but lacks the natural resonance found in wood. This transition from natural to synthetic materials represents a trade-off between preserving the traditional acoustic characteristics of the Rebab and adopting modern, more sustainable materials that are better suited for mass production.

Comparative Analysis of Processes

The traditional production process of the Rebab Melayu is highly skilled, labour-intensive, and time-consuming. It involves a series of intricate steps, including lathing, forming, drilling, sanding, painting, carving, and assembly, all of which are performed by hand. This method not only ensures the functionality and aesthetic appeal of the instrument but also preserves and transmits the cultural knowledge embedded in the craftsmanship. However, the traditional approach is expensive, requires a significant amount of space, and is increasingly difficult to sustain due to the declining number of skilled artisans.

On the other hand, the 3D printing process is more streamlined and efficient. It begins with a digital design using CAD software, followed by the printing of parts, post-processing, and assembly. This method reduces the time and space required for production, making it more accessible and less reliant on specialized skills. However, the standardized nature of 3D printing may lead to a loss of the unique, artisanal qualities that are intrinsic to the traditional Rebab Melayu. The result is a more uniform product that, while practical, may not fully capture the cultural and aesthetic nuances of the handcrafted instrument.

Limitations of the Study

A key limitation of this study is the absence of a comprehensive acoustic analysis. While the research effectively compares the materials and processes involved in traditional and 3D-printed Rebab Melayu production, it does not evaluate the acoustic performance of the instruments. The sound quality of the Rebab is a crucial aspect of its cultural and functional significance, and without testing this aspect, the study cannot fully assess whether the 3D-printed version can serve as a viable alternative to the traditionally crafted instrument. This limitation highlights the need for further research that includes detailed acoustic testing. Such analysis would provide a more complete understanding of how 3D printing impacts the sound quality of the Rebab Melayu and whether it can truly replicate the acoustic properties that are essential to its role as a traditional musical instrument.

Challenges and Ethical Considerations

The use of 3D printing in producing traditional instruments like the Rebab Melayu introduces several challenges and ethical considerations that need careful evaluation. One major concern is the potential loss of traditional artisanal skills. As Kim (2016) points out, if 3D printing replaces traditional craftsmanship entirely, the invaluable cultural knowledge embedded in the artisanal process may be lost. The artisan’s expertise goes beyond mere construction, encompassing the transmission of cultural values and historical practices that are integral to the Rebab Melayu’s identity. Moreover, there is a risk of cultural commodification, where mass production could dilute the instrument’s cultural significance, reducing it to a mere product rather than a symbol of heritage (Kim, 2015). This process could undermine the Rebab Melayu’s role in cultural practices and ceremonies, where its historical and symbolic meanings are paramount.

To mitigate these concerns, it is essential to adopt a hybrid approach that integrates 3D printing with traditional crafting methods (Simian, 2023) This approach would allow artisans to continue playing a central role in the production process, thereby preserving their skills and ensuring that the instrument’s cultural integrity remains intact. By involving traditional artisans in the design and production phases, the benefits of 3D printing—such as precision and efficiency—can be harnessed without displacing the artisanal craftsmanship that contributes to the Rebab Melayu’s cultural value. This balanced approach not only respects traditional knowledge but also leverages modern technology to enhance the production process.

There are also challenges such as material limitations, surface finish and dimensional accuracy, structural integrity and durability, post-processing challenges, material and acoustic properties, and health and safety concerns when using the 3D printing technology as stated by Damodaran et al. (2021). AM materials, such as PLA, ABS, and nylon, often lack the required hardness, stiffness, and durability needed for high-quality musical instruments (Zvoníček et al., 2023). These materials may also absorb acoustic waves, leading to a loss of harmonics and compromised sound quality. AM processes result in poor surface finishes, which can affect the airtightness and acoustic performance of wind instruments. Additional post-processing steps are often required to achieve the necessary surface quality, which can be labour-intensive and may lead to slight distortions. AM-produced parts may suffer from issues like anisotropy, low mechanical strength, and material degradation over time, which can compromise the instrument’s performance, especially in terms of airtightness and resonance. The need for specific tools and skilled labour to perform post-processing operations, such as sealing and polishing, poses a significant challenge. The relationship between surface finish and sound characteristics is not well understood and requires further investigation.

The variability in materials and AM methods can lead to minor differences in the printed parts, which are particularly problematic for wind instruments that require precise acoustic properties. The ability to combine acoustic and mechanical properties in AM materials is still under development. The chemical composition and biocompatibility of AM materials are critical, especially for mouthpieces and other components that come into direct contact with musicians. Ensuring that these materials do not pose health risks remains a challenge. The environmental sustainability of AM processes and materials, including the potential for material degradation and waste, is an area that requires further research.

Conclusion

In conclusion, the integration of 3D printing technology into the production of the Rebab Melayu offers a promising pathway for preserving this culturally significant instrument while adapting to the challenges of modern manufacturing. The lessons learned from other 3D-printed musical instruments demonstrate that while the technology can replicate the intricate designs and functional aspects of traditional instruments, careful attention must be paid to maintaining the acoustic qualities and cultural authenticity that define their identity.

The application of additive manufacturing (AM) to the Rebab Melayu can potentially address the decline in skilled artisanship and the rising costs associated with traditional methods, ensuring that this iconic instrument remains accessible to future generations. However, the success of this approach hinges on a balanced integration of modern technology with traditional craftsmanship. As demonstrated by the case studies, such as those involving the cornett and shakuhachi, the acceptance of AM-produced instruments by the musical community and broader society depends on their ability to match or even enhance the performance and aesthetic qualities of their traditionally-made counterparts.

Ultimately, the modernization of the Rebab Melayu through 3D printing should not aim to replace traditional methods but rather to complement them, creating a hybrid model that preserves the instrument's cultural heritage while embracing the possibilities offered by new technologies. By harmonizing tradition with innovation, the Rebab Melayu can continue to thrive in the contemporary world, serving as both a symbol of Malay identity and a testament to the resilience of cultural practices in the face of technological advancement. This research contributes to the broader dialogue on the preservation and evolution of traditional crafts, offering insights that may apply to other cultural artefacts facing similar challenges in the modern era.

Acknowledgement

I would like to express my sincere gratitude to my supervisors, Dr. Mohammad Kamal Sabran and Dr. Hasnul Azwan Azizan, for their continuous support, expert guidance, and invaluable insights throughout this research. Their encouragement and constructive feedback have been instrumental in shaping the direction and quality of this work. I would also like to acknowledge the support provided by the School of the Arts at Universiti Sains Malaysia, particularly for granting access to the laboratory facilities and resources essential to this research and the Malaysian Ministry of Higher Education for the scholarships. Special thanks go to my Rebab community in particular Mr. Che Mat Jusoh, for their collaboration and assistance during the data collection and analysis phases. Their expertise and willingness to help were invaluable. Finally, I would like to extend my deepest appreciation to my family. Their unwavering support, patience, and encouragement have been my source of strength throughout this process. To mama and bapak, forgive me. Allahummaghfirlahum warhamhum wa'afihim wa'fu'anhum.

References

Aabid, A., Amir, A., & Baig, M. (2023). Advancements and limitations in 3d printing materials and technologies: A critical review. *Polymers, 15*(11).

Abd. Latif, A. (2010). *Identiti rebab di alam Melayu.* Retrieved from https://www.scribd.com/doc/39638983/Identiti-Rebab-Di-Dalam-Melayu.

Cottrell, S., & Howell, J. (2019). Reproducing musical instrument components from manufacturers' technical drawings using 3D printing: Boosey & Hawkes as a case study, *Journal of New Music Research*, (*48*)5, 449-457, https://doi.org/10.1080/09298215.2019.1642362

Dabin, M., Narushima, T., Beirne, S.T., Ritz, C.H. & Grady, K. (2016). *3D modelling and printing of microtonal flutes*, Proceedings of the 16th International Conference on New Interfaces for Musical Expression (NIME 2016), Queensland Conservatorium Griffith University, Brisbane, pp. 286-290.

Damodaran, A., Sugavaneswaran, M., & Lessard, L. (2021). An overview of additive manufacturing technologies for musical wind instruments. *SN Applied Sciences*, *3*, 1-12.

e-ISSN 2716-5523

Hsueh, M. H., Lai, C. J., Wang, S. H., Zeng, Y. S., Hsieh, C. H., Pan, C. Y., & Huang, W. C. (2021). Effect of printing parameters on the thermal and mechanical properties of 3d-printed pla and petg, using fused deposition modeling. *Polymers*, *13*(11), 1758.

Iancu, C., Iancu, D., & Stăncioiu, A. (2010). From CAD model to 3D print via" STL" file format. *Fiability & Durability/Fiabilitate si Durabilitate*, (1).

Jusoh, C. M. (2011). Lampiran I-Rebab Makyung. In R. Z. S. U. RS (Ed.), *Makyung warisan mistik Malaysia*. Institut Terjemahan Negara Malaysia Berhad.

Jusoh, C. M., & Bidin, M. O. (2017). Permainan dan pembuatan rebab dalam persembahan tradisional Melayu. In Nazarudin, Z., Bidin, M. O. (Eds.). *Dinamisme etnik dan sosiobudaya Melayu.* Penerbit USM.

Kantaros, A., & Diegel, O. (2018). 3D printing technology in musical instrument research: Reviewing the potential. *Rapid Prototyping Journal*, *24*(9), 1511-1523.

Kechot, A.S., Daeng Jamal, D. H., Abdullah, H., & Nawi, M. Z. (2015). Pembuatan alat musik rebab Melayu. In Mariyam, J. G. (Ed.), *Ensiklopedia Alam Melayu* (323). Aras Mega.

Kim, J. T. (2016). *Combining 3D printing with traditional crafts: Why is it needed and what is the role of the designer* (Masters thesis, Ulsan National Institute of Science and Technology).

Magnusson, T. (2021). The migration of musical instruments: On the socio-technological conditions of musical evolution. *Journal of New Music Research, 50*(2), 176-183. https://doi.org/10.1080/09298215.2021.1907420

Mat Zain, Z. (2015). *Pengenalan asas rebab Kelantan* (Doctoral dissertation, Universiti Pendidikan Sultan Idris).

Matusky, P., & Tan, S. B. (2017). *The music of Malaysia: The classical, folk, and syncretic traditions* (2nd ed.). Taylor and Francis.

Maurya, N. K., Rastogi, V., & Singh, P. (2019). Experimental and computational investigation on mechanical properties of reinforced additive manufactured component. http://dx.doi.org/10.5109/2349296

Nasuruddin, G, M. (2018). *Traditional anthropological performance healing in Malaysia.* Universiti Putra Malaysia Press.

Nik Salleh, N. M. (1995). *Alat musik tradisional dalam masyarakat Melayu di Malaysia.* Perpustakaan Negara Malaysia Data Pengkatalogan dalam Penerbitan.

Pedgley, O., Norman, E., Armstrong, R. (2009). Materials-Inspired innovation for acoustic guitar design. *METU Journal of the Faculty of Architecture, 26*(1), 157-175.

Savan, J., & Simian, R. (2014). CAD modelling and 3D printing for musical instrument research: The cornett case study. *Early Music*. *42*(4).

Simian, R. (2023). 3D-Printed musical instruments: Lessons learned from five case studies. *Music and Science, 6*, 1-16. https://doi.org/10.1177/20592043231210653

Zoran, A. (2011). The 3D printed flute: Digital fabrication and design of musical instruments. *Journal of New Music Research. 40*(4). 379-387.

Zvoníček, T., Vašina, M., Pata, V., & Smolka, P. (2023). Three-Dimensional printing process for musical instruments: Sound reflection properties of polymeric materials for enhanced acoustical performance. *Polymers*, *15*(9), 2025.