DEVELOPMENT AND VALIDATION OF ADDED VALUE IDENTIFICATION METHOD AND DESIGN AID TOOL TO SUPPORT INDUSTRIAL DESIGNERS IN PRODUCING AN AM-ENABLED PERSONALISABLE PRODUCT DESIGNS

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ABSTRACT

Knowledge management and decision aid tools play an essential role in product development, and the selection of the presentation format is crucial to enable industrial designers to fully exploit the capabilities of Additive Manufacturing (AM) technology. This paper presents the development and validation of the Value-added AM-enabled Personalised Product (V+APP) Design Method, which was achieved by exposing the design workbook to expert designers and asking them to evaluate its usability, applicability and effectiveness. The aim of the validation is to determine the validity of the proposed method from industrial designers' opinions about its impact on professional design practice. Focus groups were identified with strategic samples of professional designers to gather an in-depth understanding of the issues. Based on the results, the study revealed that knowledge management and decision aid tools that are adapted to the specificities of AM play an essential role in creating value-adding design features in personalisable AM products. It is vital for industrial designers to adopt AM knowledge in the early stage design process so that they are able to fully exploit the unique and value-adding design characteristics enabled by AM.

KEYWORDS: *Product Value, Design Support Tool, Product Personalization, Additive Manufacturing, Industrial Design*

Received: Jun 08, 2020; **Accepted:** Jun 28, 2020; **Published:** Sep 14, 2020; **Paper Id.:** IJMPERDJUN20201214

1. INTRODUCTION

Additive Manufacturing (AM) technology is well known to have enormous potential for the personalisation of consumer product designs. This ability has generated public interest in using AM as a personal fabrication tool to produce personalised 3D-printed parts. Supported by suitable tools, AM can facilitate product personalisation, and it has shown promising capabilities as a means to assist end-users to achieve higher product value. Previous study shows that personalised consumer products using an AM-enabled design tool and printing system are able to provide higher end-users' perceived value when compared with standard mass-produced products [1–3]. This information was vital to support the subsequent development of this research. The opportunity to personalize products using AM will likely lead to further growth in the application of AM among end-users, provided they are aware of the added value they could acquire from the technology. In-depth training in design for AM is one way to enable end-users to adapt and innovate using AM [4]. However, another route is to enable professional designers to produce 'personalisable designs' that allow

end-users to participate and become co-designers to create their own personalized design.

Based on the previous study[1], it was important to identify the design strategies that could be used to present value-added personalised AM product information to industrial designers. According to Cross[5], design strategy can be described as “the general plan of action for a design project and the sequence of particular activities such as tactics or design methods which the designer expects to undertake to carry through the plan”. From an industrial design perspective, a simultaneous product and process design method is needed to assist expert designers in defining and exploring the design possibilities enabled by AM [6]. Establishing creative design decisions in the early stages of product development is one of the strategic approaches that enables efficient process-based design and provides better design direction for designers [7]. To date, there is still a lack of accepted AM-oriented value identification methods and tools for industrial design. The gap remains unexplored and therefore required further investigation.

To demonstrate an enhanced design for AM strategy, the development of design methods, tools, and activities has to be adapted to the specificities of AM [8]. Thus, a decision was made to explore a formal added value identification method and tool to assist designers in finding the best way to achieve high value for ‘personalisable’ product designs. The proposed design method and tool was aimed at helping designers generate ideas and solutions for identifying personalisable design attributes that best utilise the unique capabilities of AM. It also needed to provide guidance to designers on how to maximise the added value of the product through the amalgamations of shapes, forms, patterns, structures, and material compositions [9]. This paper is an extended version of work published in the 2nd Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER’18) [10]. We extend our previous work by adding further explanation on the development of added value identification method, development of design aid tool, measuring overall usability of the tool and in-depth discussion of the method and tool.

1.1. Development of Added Value Identification Method

The added value identification method was given the name Value-added AM-enabled Personalised Product (V+APP) Design Method. This ‘framework of action’ was then translated into a working design aid tool to enable designers to apply it to operational implementation. The V+APP Design Method adapts the knowledge, benefits and values of AM into the development of a ‘personalisable’ product. The design method aims to systematically integrate several design questions that need to be answered by designers when taking AM into account at every design phase. This would help designers to efficiently identify and generate possible design features that could enhance the value of the personalisable product being designed.

There were four types of Product Value focused in the V+APP Design Method. They are (i) Functional Value - acquired from the increment in product utility derived from the 3D-printed personalised product compared to a standard mass-produced product, (ii) Unique Value - acquired from the creation of symbolic attributes that create an opportunity for drawing the attention of others, peculiar to the self-expression of the individual, (iii) Sensory Value - acquired from a product's ability to present a sense of emotional response, reflection in the form of sensation, sense of beauty, sensory pleasure or delight to enhance personal enjoyment, and (iv) Personal-expressive Value - acquired from the opportunity to reflect the image and personality of a person by representing one's self-image in the product.

In devising the V+APP Design Method, all design activities were constructed based on three key elements. They are (i) the structural aspect - served as the foundation of the design method and consisted of three major components, which are (a) generic industrial design process, (b) V+APP Strategic Area, and (c) V+APP Design Process, (ii) the

procedural aspect - combines all the main elements of the structural aspect and translated into ‘design process’ of the method, and (iii) design challenge—the core element of V+APP Design Method that contains lists of open-ended design questions posed to designers. These were aimed at stimulating designers’ cognitive thinking to efficiently identify the best solution to create an added value feature for the users to personalise using AM-enabled design tools. Figure 1 illustrates the operational approach of the V+APP Design Method.

In the design challenge, a total of 37 design questions were identified and clustered into eight categories according to the phases embodied in the V+APP Design Process. The contents of the design questions were determined based on the objectives and targets set out in each design phase. Table 1 shows the number of questions for each phase in the V+APP Design Process.

Figure 1: The Operational Approach of the V+APP Design Method.

Table 1: Number of Questions for Each Phase in the V+APP Design Process

Phase	Design Process	Number Of Questions
Phase 00	Identifying Opportunities	8
Phase 01	Key Value Components	3
Phase 02	Concept Generation	6
Phase 03	Concept Refinement	3
Phase 04	Concept Selection	7
Phase 05	Detail Design	4
Phase 06	Prototype Testing	5
Phase 07	Design Ready	1
Total		37

1.2. Development of Design Aid Tool

A decision was made to develop a paper-based tool in the form of a ‘design workbook’ that would provide visual inspiration to industrial designers. The nature of the design workbook would allow instant access to information and provide a practical approach for designers to apply the fundamental areas of the V+APP Design Method. Moreover, it could provide portability and the ability to provide page spaces to allow designers to record their input for future reference. The design workbook is referred to as the V+APP Design Method: Design Workbook. The main section of the workbook contains design questions and guidance that stimulate designers to adopt AM benefits and values at every design phase of product development. This would help designers to efficiently identify and generate possible design features that could enhance the value of the personalisable product. The content structure of the design workbook consisted of 12 sections.

The sections contained in the design workbook are listed in Table 2.

Table 2: List of Sections in the V+APP Design Method: Design Workbook

Section Number	Section Title
1	Cover page
2	Table of contents
3	Preface
4	Introduction
5	AM Technology: Enhancing Product Value
6	V+APP Design Method: Structural Aspects
7	V+APP Design Method: Procedural Aspects
8	Design Process
9	Design Challenge
10	V+APP Design Method
11	Reference
12	Design notes/sketches

2. METHODOLOGY

The study aimed to seek validity of the *V+APP Design Method*, which was achieved by exposing the design workbook to expert designers and asking them to evaluate its *usability* – the ease of use of the tool, *applicability* – the suitability of the proposed method for the development of high value AM-enabled personalised products, and *effectiveness* – the ability of the design aid tool to achieve the objectives of the proposed design method. Participants were selected based on non-probability, purposive sampling. Purposive sampling was used to access ‘knowledgeable people’; that is “those who have in-depth knowledge and experience in particular issues” [11].

Ten (n=10) expert industrial designers with AM-related expertise and experience in designing 3D-printed product designs that were suitable for personalisation participated in the study. The characteristics of the participants ranged in levels of expertise from novice to intermediate and advanced. These characteristics determined their exposure to the skills and understanding about AM in designing consumer products for personalisation. The participants were recruited from two sources. They were (i) institutions of higher learning within the UK and Europe - consisting of academics and research staff involved in the field of industrial and engineering design whose work was related to AM and 3D printing, and (ii) professional designers from online 3D printing community hubs - designers of 3D-printed products from around the world who have contributed various types of consumer product designs to the AM community including fashion products, functional components, household goods, and models. All the experts had at least 1 year of experience with the most experienced having worked in the area for 9 years.

Participants were involved in a session containing two parts of the study: (i) performing the test on the V+APP Design Method: Design Workbook, and (ii) assessment and evaluation through a set of questionnaires. They were asked to go through the design workbook and follow the flow of the workbook step-by-step. They were encouraged to go through all the design questions in the workbook as if they were answering them for a product they had previously designed and were now trying to make personalisable. They could use the design guidance provided in the workbook as ‘design hints’ as well as their experience and knowledge in designing 3D-printed products to answer the design questions. Participants were also asked to use design notes and the additional empty pages provided to record any design decisions they made. Therefore, they could document their decisions and choices as they progressed. Once they had completed the design workbook, they were then asked to evaluate the workbook by completing a questionnaire to gain their feedback.

Participants were asked to express their opinion on the usability, applicability and effectiveness of the proposed method and tool.

3. RESULTS AND DISCUSSIONS

3.1. Assessing the Usability of the Design Aid Tool

This section aimed to assess the usability of the design aid tool, where the measurement was based on five statements. Participants were asked to indicate their agreement or disagreement on a Likert scale. The responses were collated for all five statements and the results are shown in Table 3.

Overall, the results in Table3 reveal that the participants mostly agreed with the statements given in the questionnaire, with 33 out of 50 responses indicating Agree or Strongly Agree (66 %). This result shows that most participants regarded the design workbook as both usable and easy to use. Based on the results, the statement ‘the presentation of the Design Workbook is attractive to the user’ received the highest responses of 8 (Agree and Strongly Agree), closely followed by ‘the textual and graphic information provided in the design workbook is easy to understand’ with the total number of 7 agreeing. Apart from several neutral responses and 1 strongly disagree, most of the participants thought that the overall content of the workbook was well integrated and able to be learned very quickly. Most participants also agreed that the workbook is useful for recording their outputs, despite some participants indicating disagree and neutral responses. These results suggest that the key feature needed to allow the design workbook to be usable is that it should provide instant access to information. Furthermore, the presentation of the workbook should also be simple, attractive and visually inspiring because the graphic representation of process-enabled information is one of the most effective ways to transfer knowledge to industrial designers.

Table 3: Participants’ Responses on the Usability of V+APP Design Method: Design Workbook[10]

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
S1: The textual and graphic information provided in the design workbook is easy to understand.	0	0	3	4	3
S2: Overall contents provided in the V+APP Design Method was well integrated.	0	0	4	2	4
S3: I would imagine that most designers would learn to use this method very quickly.	1	0	3	2	4
S4: The presentation of the Design Workbook is attractive to the user.	0	0	2	4	4
S5: The Design Workbook is useful for recording my design outputs.	0	2	2	3	3
Total Responses Out of 50 (N10 X 5 Questions)	1	2	14	15	18
Total Responses (%)	2	4	28	30	36

3.2. Assessing the Applicability of the Design Aid Tool

This section aimed to assess the applicability of the design aid tool. Participants were asked to indicate their agreement or disagreement using a Likert based on four attributes. The responses to all four statements were collated and presented in the Table 4.

Table 4 shows that most of the participants considered that all the measured attributes are important, with 27 out of 40 responses being Agree or Strongly Agree (67.5%). These results indicated that the V+APP Design Method: Design Workbook is applicable and suitable for practical implementation. As seen in Table 4, most of the participants indicated that they agreed or strongly agreed that the content provided in the workbook is relevant to the development of

personalisable AM products (8 responses). This is followed by the statement ‘the V+APP Design Method: Design Workbook was able to assist me in preparing design inputs and interpreting design outputs in a more organised way’, which received a total number of 7 responses for agree or strongly agree. Despite some participants indicating disagree (1 response) and 3 neutral responses, most participants agreed with the statements ‘the organisation of information in the workbook is suitable for practical implementation’, as well as ‘I felt confident in applying the V+APP Design Method to my selected design task’. Overall, the results suggest that the workbook provides a practical approach for applying AM knowledge in the development of personalisable product designs.

Table 4: Participants’ Responses on the Applicability of V+APP Design Method: Design Workbook[10]

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
S1: I felt confident in applying the V+APP Design Method to my selected design task.	0	1	3	3	3
S2: The contents provided in the V+APP Design Method is relevant to the personalisable product design.	0	0	2	2	6
S3: The organization of information in the V+APP Design Method is suitable for practical implementation.	0	1	3	2	4
S4: The V+APP Design Method was able to assist me in preparing design inputs and interpreting design outputs in a more organised way.	0	0	3	3	4
Total Responses Out of 40 (N10 X 4 Questions)	0	2	11	10	17
Total Responses (%)	0	5	27.5	25	42.5

3.3. Assessing the Effectiveness of the Design Aid Tool

This section aimed to assess the effectiveness of the design aid tool. Participants were asked to indicate their agreement or disagreement using a Likert scale and Table 5 shows a collation of all the results.

As can be seen in Table 5, most participants gave positive responses to the measured attributes. Overall, 72.5% (29 out of 40) of the responses indicated that participants agreed or strongly agreed that the design workbook was effective to aid designers developing personalisable AM products. Based on the table, most participants indicated that the workbook has clear objectives that can be easily achieved, which gained 6 responses on Strongly Agree. The statement ‘the questions in the *design challenge* were able to assist me in identifying potential design features that could enhance the value of personalisable AM products’ achieved a high number of positive responses (8 Agree or Strongly Agree). Participants also gave positive responses on the statement ‘the V+APP Design Method was able to assist designers to develop specialised design skills by applying AM value and knowledge in designing personalisable product designs’, which gained a total number of 7 Agree or Strongly Agree. With the exception of 1 Disagree and 2 Neutral responses, the majority of the participants felt that the workbook was able to assist designers in developing a personalisable 3D-printed product design in a more systematic way, when compared to a generic design process. These results indicate that the AM design aid tool should be effective in supporting designers when adapting the knowledge and benefits of AM into the design process. Such a design aid tool should also integrate systematic design hints to stimulate the designer’s cognitive thinking to efficiently identify high-value design features in a product.

Table 5: Participants’ Responses on the Effectiveness of V+APP Design Method: Design Workbook[10]

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
S1: The V+APP Design Method has a clear objective that can be easily achieved.	0	0	3	1	6

S2: The V+APP Design Method was able to help me develop a personalisable 3D-printed product design in a more systematic way than a generic design process.	0	1	2	3	4
S3: The questions in the design challenge were able to assist me in identifying potential design features that could enhance the value of personalisable AM products.	0	0	2	3	5
S4: The V+APP Design Method can assist designers to develop specialised design skills by applying AM value and knowledge in designing personalisable product designs.	0	0	3	3	4
Total Responses Out of 40 (N10 X 4 Questions)	0	1	10	10	19
Total Responses (%)	0	2.5	25	25	47.5

3.4. Measuring Overall Usability

To analyse the overall goal of the proposed method and tool, a modified System Usability Scale (SUS) [12] was implemented, and a singular result was used to manifest the overall usability of the proposed design aid tool. *Usability* can be defined as “the extent to which a product can be used by specified users to achieve specified goals” [13]. In order for the measured qualities to be considered singular, the results must be considered homogenous with the overall data being converted into a single item [14]. To calculate the score, the scores of each participant were multiplied by 1.5384 and summed to obtain an overall value of SUS score out of a maximum of 100, for each participant. The scores for the SUS could range from 0 to 100, where higher scores indicated better usability. The SUS scores were then added up to determine an overall SUS score (out of 1000). The Likert responses and usability scores from each participant are shown in Table 6.

To determine a single score from the result, the average score was then calculated by dividing the total SUS score of 809.2 by the number of participants of 10. This determined the average SUS score of 80.92. The details of the results are shown in Table 7.

To determine whether the average SUS score is acceptable, a grading scale developed by Bangor et al.[15] was used (see Figure 2). The grading scale was used to help the author to measure and interpret the average SUS scores [12]. The grading scale contains three types of scale: Quartile Ranges, Acceptability Ranges, and Adjective Ratings.

Based on the SUS grading scale in Figure 2, the overall usability result was determined (see Table 8).

Based on Table 8, it can be seen that the overall usability result could be categorized in the high grading scale. The result shows that the average SUS score of the supporting tool was placed in the 4th quartile in the Quartile Ranges, acceptable in Acceptability Ranges, and positioned between Good and Excellent in Adjective Ratings. Based on the result, it can be said that the *V+APP Design Method: Design Workbook* is a usable support tool and is able to aid expert designers in preparing AM-enabled personalisable product designs to provide value-adding personalisation features.

Table 6: SUS Scores Obtained for Each Participant

Participant	Likert responses													SUS Score
	Usability					Applicability				Effectiveness				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S1	S2	S3	S4	
P1	4	3	3	4	2	3	4	3	3	3	4	3	3	64.61
P2	5	5	5	5	5	4	5	5	5	5	5	5	5	98.46
P3	5	5	5	5	5	5	5	5	5	5	5	5	5	100.00
P4	4	5	5	5	4	5	5	5	5	5	4	5	5	95.38
P5	3	3	3	3	3	3	4	3	3	3	4	4	3	66.15
P6	4	4	4	4	3	4	3	4	4	4	3	3	4	72.30

P7	4	3	1	4	5	3	5	3	5	5	3	5	4	75.38
P8	3	3	4	3	4	4	5	4	5	5	5	4	4	80.00
P9	3	4	3	4	2	2	3	2	3	3	2	4	3	58.46
P10	5	5	5	5	4	5	5	5	5	5	5	5	5	98.46
Total														809.2

Table 7: SUS Score of Overall Usability

N	Total SUS Score	Average score	Min	Max	SD
10	809.20	80.92	58.46	100.00	15.92

Figure 2: SUS Grading Scale.

Table 8: Overall Usability Result

Scale	Result
Quartile Ranges:	4th
Acceptability Ranges:	Acceptable
Adjective Ratings:	Good-Excellent

4. DISCUSSIONS

Based on the results obtained, it can be concluded that the *V+APP Design Method: Design Workbook* has the potential to support expert designers in preparing AM-enabled personalisable product designs that provides value-adding 'personalisable features' to the product. The feedback and opinions gathered in study also provided valuable insights into the implementation of the design workbook. From a usability aspect, one participant stated that using the design workbook was a relatively straightforward process that was easy to follow. Another useful comment from a different participant was that the methodology used in the workbook is similar to the one used in the software development process. In that case, authors feel that the framework used in this design method could also be used to facilitate new research opportunities to develop a new added value identification method and personalisation design tool that focuses on the Experiential Value standpoint. However, the participant stated further, it is just a short handbook and some use of real cases would help to understand more about it. One participant stated that the writing used in the workbook was very academic and should not have used acronyms, if it wants to draw designer's attention to using it.

From an applicability aspect, a participant pointed out that the design hints and the check lists provided in the workbook are very useful and build confidence that most designers can benefit from them. Furthermore, the structure of the method can be used to test a design and to describe the product when completed. There was also one critical feedback pointed out by another participant. The participant stated that the workbook has provided a conceptual framework, but does not go far enough to be practically applicable due to certain details that might have been overlooked. Those are (i) personalisable designs where the user opens the model in CAD and edits it, (ii) systems like Thingiverse Customizer where users have specific inputs which the design incorporates, and (iii) consideration on 'design-for-printability', so that the resulting model is printable for all ranges of consumer

inputs. Without this level of detail, the design method is merely a conceptual tool that has value but is not functional. From the effectiveness viewpoint, one participant stated that the questions in the design challenge should be revised as 'suggestions' or to make them guidelines rather than make the user think they need to answer them. Positive feedback received from one of the participants was that the design questions posed in the design challenge are beneficial to designers as they provide well-focused interrogation questions that significantly assist them in identifying potential value-added features in personalisable AM products.

A major limitation found in the study was that the test did not involve in-depth user trials where participants could work through the workbook on an actual design project. The test only involved short-term evaluation of the support tool where the Design Workbook was presented to expert designers and feedback obtained based on their knowledge, expertise, and experience in designing consumer products for AM. To implement the support tool in a real design project would have been preferable. However, it would be challenging to undertake this due to time, cost, and professional commitment constraints of professional designers. At present, the support tool would seem to provide a useful framework, but its effectiveness has not yet been fully proven. It is recommended that future studies should be performed in a more realistic design setting by recruiting participants involved in actual personalised product design projects. The design workbook could also be converted into an online web tool. This could reduce the printing cost of a paper-based tool, reduce the time taken to distribute, and enable a wider and larger population of designers to access it.

5. CONCLUSIONS

The lessons learnt from the previous study paved the way for the development of an added value identification method for industrial designers. This novel method provides a 'framework of action' to help industrial designers to efficiently identify and generate possible design features in a product that would potentially add value to an AM-enabled personalised product. It would therefore act as a design support tool to aid designers in providing value-adding 'personalisation features' in order to satisfy end-users' individual needs. This paper has described the development process of an added value identification method and the validation of the proposed design aid tool. The findings of the implementation have been discussed in a way that is appropriate to the context of the paper. Based on the findings, the study has revealed the critical role of a formal added value identification method in aiding expert designers in identifying the potential value-adding personalisation features in personalisable AM products. It is crucial for designers to adopt AM knowledge in the early stage design process so that they are able to fully exploit the unique characteristics and design possibilities enabled by AM. This study has also shown that the graphic representation of the design aid tool is useful in assisting designers in producing AM-enabled personalisable product designs. A well-focused interrogative design question posed to designers at every design phase is the most suitable way to stimulate a designer's creative thinking to identify good solutions for creating high-value personalisable AM products. Therefore, it can be concluded that the design workbook is applicable for practical implementation and is an effective instrument that enables value-added personalised AM product information to be presented to industrial designers.

6. ACKNOWLEDGEMENT

Authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) for funding this research (PJP/2019/FKM (6A)/S01677).

REFERENCES

1. S. I. Abdul Kudus, R. I. Campbell, and R. Bibb, "Customer Perceived Value for Self-designed Personalised Products Made Using Additive Manufacturing," *International Journal of Industrial Engineering and Management (IJIEM)*, vol. 7, no. 4, pp.

- 183–193, 2016.
2. R. Bernabei and J. Power, "Personalisation From A Design Practice Perspective," in *Product Lifetimes And The Environment*, pp. 37–40, 2017.
 3. R. I. Campbell and R. Bernabei, "Increasing product attachment through personalised design of additively manufactured products," in *21st International Conference On Engineering Design (ICED 17)*, pp. 71–79, 2017.
 4. Chitte, Pritish, et al. "Design and Fabrication of Automated Pneumatic Shearing Machine to Cut Aluminium Sheet". *International Journal of Mechanical and Production Engineering Research and Development*, p-ISSN (2018): 2249 6890 (2018).
 5. W. Gao et al., "The Status, Challenges, and Future of Additive Manufacturing in Engineering," *Computer-Aided Design*, vol. 69, pp. 65–89, 2015.
 6. N. Cross, *Engineering Design Methods: Strategies for Product Design*, 4th ed. West Sussex: John Wiley & Sons, 2008.
 7. D. L. Bourell, M. C. Leu, and D. W. Rosen, *Identifying the Future of Freeform Processing*. Austin: The University of Texas at Austin, 2009.
 8. M. J. Burton, "Design For Rapid Manufacture: Developing An Appropriate Knowledge Transfer Tool For Industrial Designers," Loughborough University, 2005.
 9. Gaikwad, Nikita, Yogita Mistry, and Kiran Inamdar. "Design and Implementation of Energy Efficient Environment Monitoring System." *International Journal of Electronics, Communication & Instrumentation Engineering Research and Development (IJECIERD) ISSN (P) (2016)*.
 10. M. K. Thompson et al., "Design for Additive Manufacturing: Trends, Opportunities, Considerations, and Constraints," *CIRP Annals - Manufacturing Technology*, vol. 65, no. 2, pp. 737–760, 2016.
 11. D. W. Rosen, "Design For Additive Manufacturing: A Method To Explore Unexplored Regions of the Design Space," in *Eighteenth Solid Freeform Fabrication Symposium SFF 2007*, 2007, pp. 402–415.
 12. S. I. Abdul Kudus, R. I. Campbell, and R. J. Bibb, "Validation of design support tool to aid industrial designers in the development of an AM-enabled personalisable product designs," in *2nd Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER'18)*, pp. 110–112, 2018.
 13. Kumar, Rajeev. "Prospects of Sustainable Fashion Design Innovation." *International Journal of Textile and Fashion Technology (IJTFT)*, 7 (6), 5 14 (2017).
 14. L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*, 7th ed. Oxon: Routledge, 2011.
 15. J. Brooke, "SUS : A Retrospective," *Journal of Usability Studies*, vol. 8, no. 2, pp. 29–40, 2013.
 16. M. Speicher, "What is Usability? A Characterization Based on ISO 9241-11 and ISO/IEC 25010," 2015.
 - A. Bangor, P. Kortum, and J. Miller, "Determining What Individual SUS Scores Mean: Adding An Adjective Rating Scale," *Journal of usability studies*, vol. 4, no. 3, pp. 114–123, 2009.
 17. Malladi, A. V. I. N. A. S. H., and S. I. R. I. S. H. A. Potluri. "A study on technologies in cloud-based design and manufacturing." *Int. J. Mech. Prod. Eng. Res. Dev* 6.8 (2018): 187–192.
 - A. Bangor, P. T. Kortum, and J. T. Miller, "An Empirical Evaluation of the System Usability Scale," *International Journal of Human-Computer Interaction*, vol. 24, no. 6, pp. 574–594, 2008.