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Post-Series Design: a tool for catalysing the diffusion of personalisable design

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Today a range of increasingly mainstream Digital Fabrication tools help designers not only in prototyping, but also in the production of final parts for consumer products. These hardware tools, while still have significant limitations, they already offer new levels of morphological freedom and logistical flexibility, which allows the efficient production of personalisable products – supposing advanced software tools of Parametric Design. However, since DF, PD and personalisation are still marginal, one may suspect that the Design profession has a shortage of adequate capabilities. Therefore, this contribution proposes a conceptual tool focused on valorising the previous hardware and software tools to achieve meaningfully personalisable products. The proposed canvas tool is structured specifically to facilitate opportunity identification and conceptual design, based on a set of key advantages (variabilities) derived from numerous case studies of existing personalisable products realised with DF. The new approach and tool have been experimented with a class of product design students, but it also aims to facilitate product development at enterprises, coherently with the emerging Industry 4.0 paradigm.

canvas; opportunity identification; concept design; personalisation

1 Introduction

Digital Fabrication tools were first used for their capacity of making small batches of precise special equipment, manufacturing tools, then for relatively cheap and fast prototypes, and later also for unique and complex one-off pieces of art and design. Today, there is the promise of a profound transformation of the relation between design, production and consumption through the emergence of a more 'on-demand' model of design (Di Lucchio, 2014). This shift is expected to be multi-faceted: the academic community, large enterprises, or the maker movement aim for a variety of objectives. From a Product Design perspective, this contribution is particularly interested in personalisable products: highly variable designs that follow individual user preferences. This seems to be a logical evolution of the design profession, that have turned its attention gradually from generic products for the masses to niche products for smaller and smaller communities.

As Digital Fabrication enables the efficient enough production of 'variable' series of products, emerges the need to produce the digital data for this differentiated digital production. Parametric Design (also called computational or generative) comes useful for this purpose: a carefully structured mathematical model of the geometry can allow differentiating the design according to the input of user preferences, supposing an adequate interface for the user to interact with. This approach is close to the industrial practice of Mass Customization, well-explored also in the academic literature. To synthetize findings, Salvador, de Holan and Piller (2009) identify 3 fundamental elements of the successful practice: a robust manufacturing process, a well-defined Solution Space, and an intuitive Choice Navigation system to let the user choose the best solution, possibly keeping to minimum the burden of choice. These 3 elements seem to be useful considerations whenever a personalisable product is the goal, also outside the conventional mass manufacturing setting. Reflecting on the changing role of the designer when designing variable products, De Mul (2011) emphasizes the importance of the virtuous handling of numerous variables:

> *The designer [...] should become a metadesigner who designs a multidimensional design space that provides a user-friendly interface, enabling the user to become a co-designer, even when this user has no designer experience or no time to gain such experience through trial and error.*

This implies that creating an unforeseeable multitude of products needs a different design approach compared to designing a single solution: user diversity should not be circumvented, but considered as a resource to create authentically personal artefacts. The trust in the user's creative contribution underpins design philosophies (and practices) such as Participatory Design or Open Design. However, as Cruickshank (2016) notes, providing adequate guidance is fundamental:

> *with too much structure the outcomes are controlled by the hidden hand of the designer and people are simply selecting from a range of options laid down by them. Too little support and many potential creative contributions are lost because starting from a blank page is difficult, even for experienced designers.*

1.1 User motivations and the need for new design tools

Today few of the everyday products allow a deep intervention of the user, which raises the question: How can we go beyond simple ornamental customization and enhance significantly the value of products by involving every single user in a collaborative design process?

Aiming to promote personalisable design, it's worth noting that the diffusion of personalised products might be withheld by the lack of demand: the users' desire to have 'deeply' personalised products cannot be taken for granted, especially considering the already extremely divergent offer in mature industrial economies. Actually, excessive choice can introduce uncertainty in the decision process, thus diminishing sales and even making consumers less gratified regarding their purchases, raising the 'paradox of choice', as Schwartz (2004) calls this kind of anxiety. Other studies found that such decrease of motivation is not universally true, but the large amount of options has a strongly variable effect on consumer behaviour according to the specific conditions of the choice to be made (Scheibehenne, Greifeneder, & Todd, 2010).

Hence, it seems that offering personalisable design requires a special attention, not only on the technical level (that can be addressed well with DF and PD), but also on the conceptual level. We start from the observation that the current knowledge and skills (and therefore practice) of the Product Design profession is not reliable enough for finding the product categories where personalization would be desired, and then develop well-balanced products that can cover unmet needs. Designing a product that is open to the user's modification (prior to the production) is an unconventional problem for a product designer, more used to identifying a dominant need and to satisfy it with a single solution.

The Design discipline includes a progressively widening range of activities and purposes, therefore it is difficult to identify a dominant design approach, but in general we can observe a major attention to the methods that revolve around the users. This attention is manifested in a variety tools, developed by both the academic community, enterprises and design consultancies.

However, both Digital Fabrication and Parametric Design are process innovations (rather than product innovations), suggesting the need for a 'technology push' approach: they are solutions in search of a problem, in contrast with the 'market pull' approach, which targets a problem looking for solution, to use a distinction of the business/marketing literature (Osterwalder, Pigneur, Bernarda, Smith, & Papadakos 2014). In the debate regarding the ideal starting point Osterwalder et al. note that, "Contrary to popular belief, great new value propositions don't always have to start with the customer. They do, however, always have to end with addressing jobs, pains, or gains that customers care about."

Considering personalisability as a design principle that can valorise DF and PD and create otherwise impossible value for the user, but recognising the difficulty of implementation, emerges the question: how would it be possible to catalyse the diffusion of personalisable products? Is it possible to amplify strategically the range of products that benefit from DF and PD? While technical knowledge regarding DF and PD is widely available, it is still challenging to identify commercially viable opportunities and to develop valid concepts, which are in general difficult to come up with.

The initial 'problem finding' phase of the New Product Development (NPD) is considered a notoriously uncertain moment, also called the 'fuzzy front end of innovation'. Attempting to eliminate 'fuzziness', the often-cited Koen et al. (2001) have examined the development process in various enterprises, identifying a model composed of 5 interconnected activities: opportunity identification, opportunity analysis, idea genesis, idea selection, concept definition. The steps are rather generic, but nonetheless a useful division that is reflected in the elaborated tool. Regarding the practice of formal approaches, Keinonen and Takala (2006) note both their difficulty, and their potential usefulness, especially for hardly possible projects:

> *Within the industrial design community there is some mistrust of formal approaches that do not exactly match the designers' requirements. However, in the same team there may be individuals who can take comfort from well-defined approaches during the stressful concept creation process when the results are on the borderline of being achievable.*

Therefore, this contribution aims to provide a new tool/method/workflow for the conceptual development of meaningfully personalisable products, targeting designers, both students and professionals, considering the possibility of working for any kind of client (e.g. an artisan, a consumer brand, a DF service company or directly the end user). More specifically, in order to enhance the design practice and knowledge about personalisable products, the tool aims to facilitate discussion within a design team (and with the client, or instructor in academic settings), with a focus on the early conceptual development. A structured approach could lead more reliably to viable results, but it requires a clear, easy to replicate methodology with an (as much as possible) self-explanatory tool to guide the conceptual design process. A tool with these characteristics should minimize the instructor's workload regarding the discussion of recurring issues and facilitate the future implementation in a productive context, where professionals are not necessarily tutored to follow any specific method, unlike students.

To visualise the progress and allow rapid iteration, the proposed tool is a large format canvas optimised for print and group work with post-it notes; for individual use without post-its, an A4 printable format is provided. These are available from a dedicated website, along with a detailed user guide. The following sections will discuss briefly the principles behind the proposed tool, more in detail its structure and usage, then describe its first (experimental) didactic application within a BSc 3rd year atelier course titled 'Post Series Design'.

2 Tool background

2.1 Case studies on personalisable products: reasons for the variable design

A key element of the proposed Parametric Concept Canvas tool derives from the analysis of case studies, which lead to the understanding of the reasons why users would choose a personalisable product, usually more expensive and slower to acquire than similar mass-produced objects. We have examined a series of projects, mostly commercial products that use DF and PD, searching for the personalisable aspects that determine their competitive value from the users' viewpoint. It was possible to identify 6 types of variabilities, dividable in two groups between mechanical and cognitive variabilities (Figure 1):

Mechanical Variabilities: physiology/ergonomics; environment/objects; function/performance.
Cognitive Variabilities: aesthetic/emotional; social/cultural; narrative/experience.

Each case study could be categorized according to a dominant type of variability, but in many cases there were more than one potentially interesting aspects to be modified by the user, e.g. shoes are adapted both to the physiology and the aesthetic taste of the user. Therefore, the (often) multiple nature of personalize-ability has been recorded in a radar diagram for each case study, in order to make them easier to confront visually.

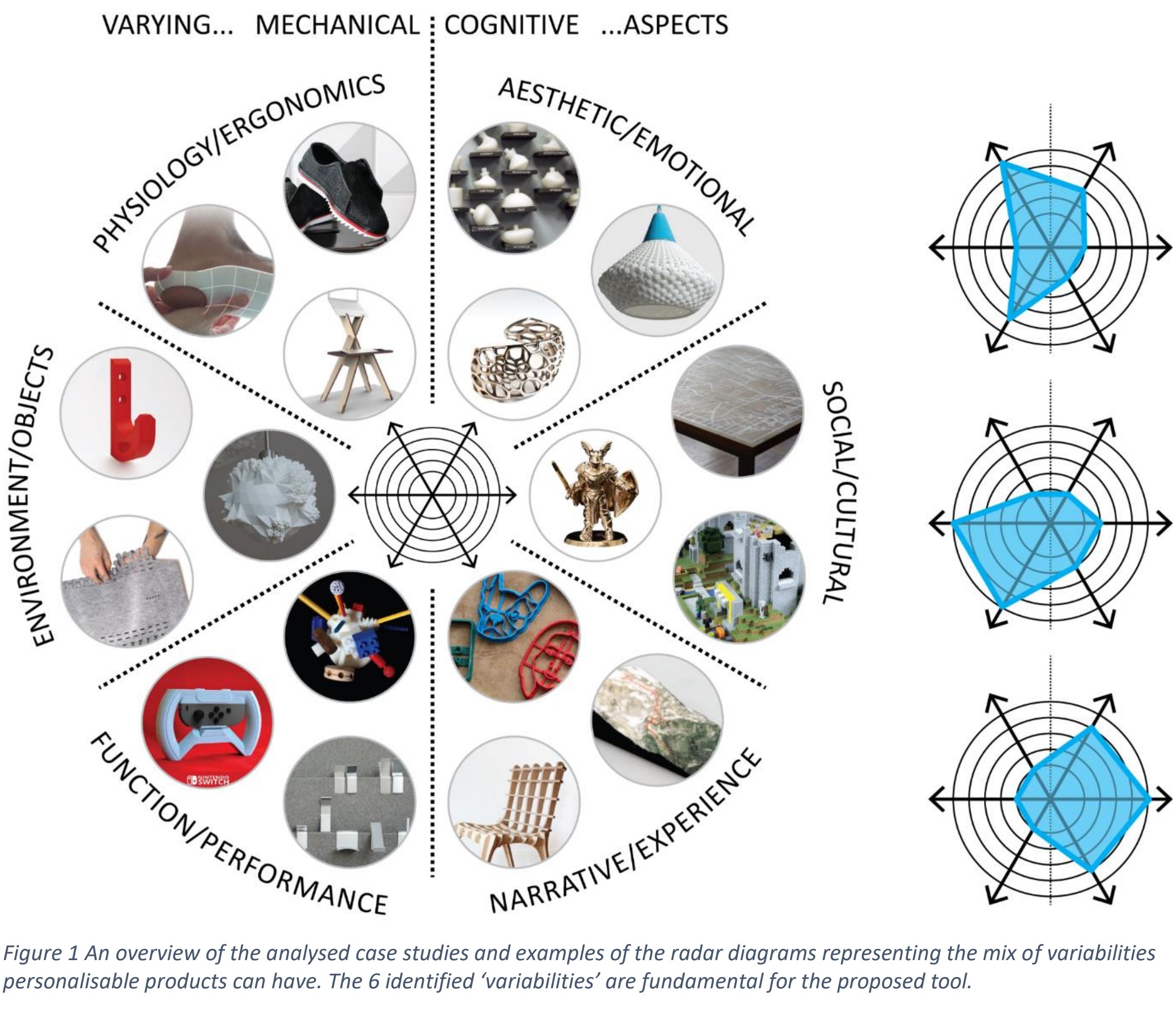

Figure 1 An overview of the analysed case studies and examples of the radar diagrams representing the mix of variabilities personalisable products can have. The 6 identified 'variabilities' are fundamental for the proposed tool.

The outlined system of 6 variabilities can be applied to a variety of product typologies, attempting to identify which aspects of these products are personalisable in a desirable way. Hence, the key principle for the development of the proposed method/tool was the systematic attempt of connecting the possible variabilities with the divergent needs of possible users.

2.2 Further principles of the 'Parametric Concept Canvas' tool

The main expectation from the proposed method/tool was to facilitate the process of transformation from a (today) static product category to a dynamic, mutable geometry, according to the possibilities of PD and DF and the principle of personalization. The literature review of various collections of design tools (e.g. Hanington & Martin, 2012; Visocky O 'Grady, 2006; Tassi, 2008; Kuma, 2012 and online collections such as designkit.org) have not found any tool focused on our objectives, but there were some potentially useful strategies that were considered as inspiration.

One tool in particular demonstrates well how helpful a conceptual tool can be: the Business Model Canvas of Osterwalder and Pigneur (2010), widely used in the entrepreneurial community, provides a well-defined structure for developing and evaluating entrepreneurial ideas, reminding the user to consider a series of factors that are fundamental for developing a profitable product or service (Figure 2). The canvas format offers a logical layout of communicating fields to be filled with post-it notes, an approach that is effective in a wide range of contexts from the conceptual development of new products for start-up companies, to the verification and improvement of the offer of large corporations. An interesting offshoot (or complement) of the Business Model Canvas is the Value Proposition Canvas (Osterwalder et al., 2014), an even simpler format that stimulates the articulated discussion of the perceived value of products, also beyond their trivial functionality (jobs), explicating the pains it alleviates and the gains it provides to the user, also on the 'abstract', social level. This threefold discussion of values has been integrated directly into the proposed canvas.

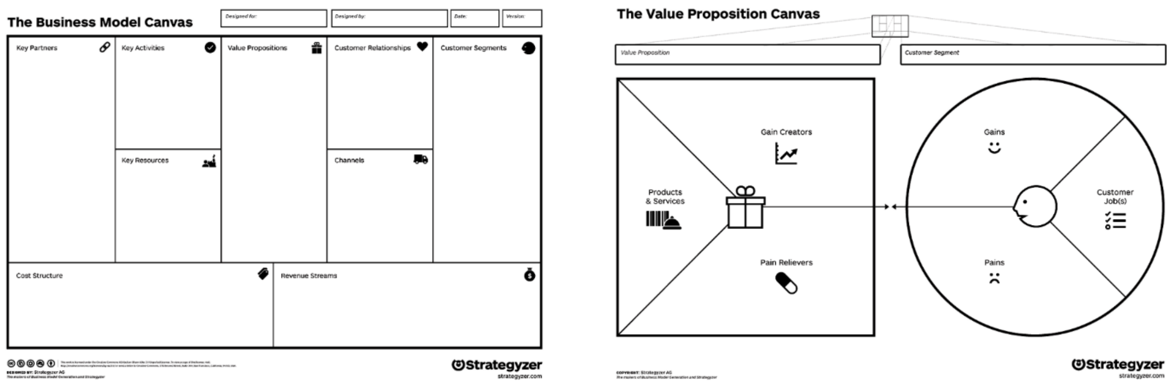

Figure 2 Business Model Canvas and Value Proposition Canvas, widespread examples of paper tools that facilitate the comprehensive conceptual development of business ideas. source: https://strategyzer.com/platform/resources

Similarly to the BMC, the proposed tool aims to provide a flexible but uniform structure to the analytical observations and to the design ideas, helping a comprehensive development by reminding the designer to consider a range of important factors that could underpin the success of a personalisable product, as well as the possibilities of PD and DF. In order to promote the 'courageous' compilation of the tool, it suggests the use of post-it notes (as opposed to direct writing on the canvas), maintaining the possibility of later corrections. It is worth noting that there are risks associated with the (mockingly) so-called "post-it design", which, in its attempt to objectivise an otherwise subjective design process, fragments decisions and degrades the designer into an administrative role (Manzini, 2015). However, systemizing the flow of thought can lead to a more complete understanding of the design problem at hand, especially important in case of a relatively unusual process of designing.

3 Parametric Concept Canvas

3.1 Central elements

The logical structure of the 'Parametric Concept Canvas' (PCC) tool has been derived from its objective of guiding the design process from the choice of a product typology to the concept of a variable product. To do so, the canvas offers a series of fields for the analysis according to numerous aspects. The most relevant of these has been derived from the already discussed case studies, which were categorized according to the variabilities that determine the perceived value of the products. Based on these, the backbone of the work on the canvas is the examination of the chosen typology according to the 6 variabilities that could make the personalization desirable. In addition, the designer analyses 3 more factors that determine the feasibility of the personalization using the available PD and DF tools. To each of these 9 factors, there is a corresponding quantitative question, that asks to evaluate approximately how much the relative user requirements can vary; current diversity within the given product typology can strongly indicate whether there are divergent requirements, but designers should consider also the possibility of currently unmet needs. High evaluations indicate greater probability of developing concepts that are personalisable according to the given parameters.

While this system of criteria is the backbone of the analytical work on the PCC, it is completed with already existing frameworks and visual tools, such as the mentioned jobs-pains-gains analysis derived from the Value Proposition Canvas, the widespread *personas* technique, or storyboarding of the customers journey.

The workflow on the canvas follows the approximate reading order, from left to right, from top to down. It was not possible to establish a strictly linear order of execution, but interacting elements were kept in proximity.

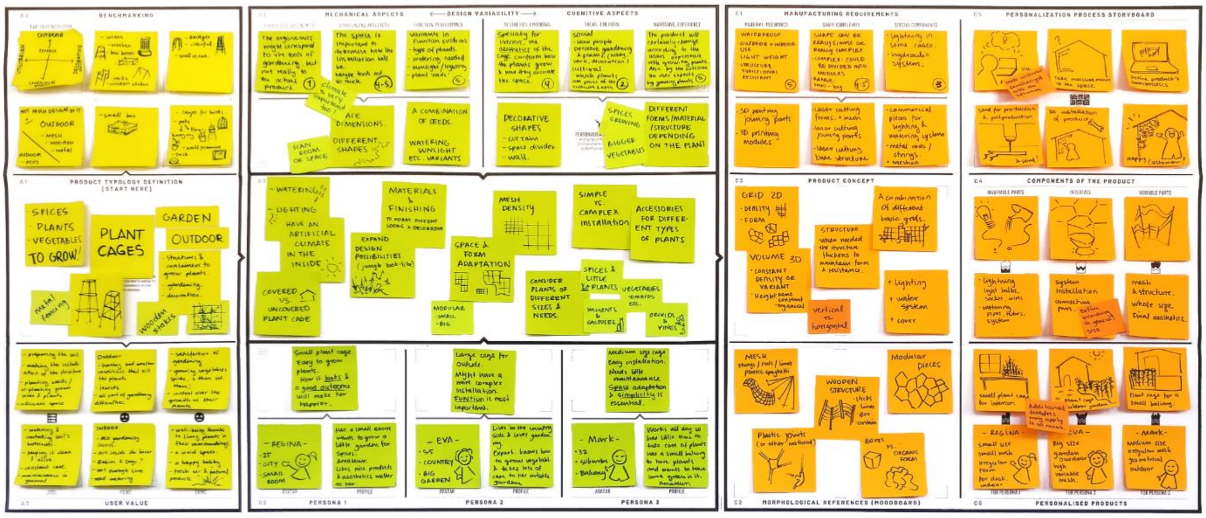

Figure 3 Parametric Concept Canvas, completed. Different colour post-its show the three main blocks of the canvas, better explained on the next page. Note that also various smaller versions have been elaborated, as explained later.

3.2 *Canvas structure*

The 15 fields of the canvas are grouped in three modules, which should be completed sequentially: even if fields within the module A and B are not compiled in strict order, the designers should fill in at least a hypothesis of them before moving on the next module.

Module A. Product typology definition:

- A1. deciding the adequate scope of the design activity;
- A2. analysing existing products within the chosen product typology (benchmarking);
- A3. clarifying the possible user values through jobs-pains-gains analysis.

Module B. Personalisation principle definition:

- B1 evaluating the relevance of the previously mentioned six personalisation principles and understanding the personalisable features of the product;
- B2 constructing personas that represent potential users and their personalisation need;
- B3. identifying design opportunities between the previous elements of the module.

Module C. Detailed concept definition:

- C1. analysing manufacturing requirements and identifying digital fabrication options;
- C2. collecting morphological references (moodboard);
- C3. crystallising the product concept based on previous opportunities;
- C4. distinguishing between variable and invariable elements of the design;
- C5. defining the personalisation process through storyboarding;
- C6. hypothesising possible outcomes of the personalisation based on the needs of the tree previously constructed personas.

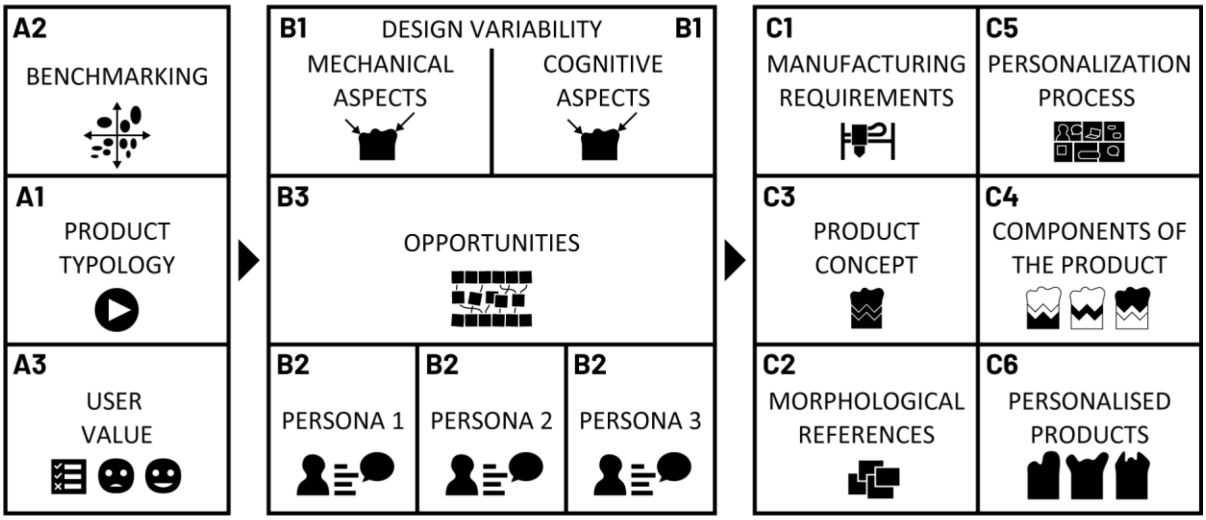

Figure 4 The structure of the canvas, as detailed above. Figure 5 shows the actual canvas graphics.

3.3 Workflow

Module A. Product typology definition

A1. Product typology definition. The starting area where the designers enter the product typology that they want to redesign for DF, aiming for a personalisation as a key competitive advantage.
A2. Benchmarking. Exploration of the current variety within the chosen product typology, through a set of examples organised according to observable tendencies. The benchmarking should highlight how much divergence is there among currently existing products in the category, hence indicating the already existing need for personalisation.
A3. User value. The third square in the bottom with the title 'Usage' helps to clarify the product typology's *raison d'être* (reason for being) by analysing the jobs users want to carry out with the product, the pains (difficulties) they might experience during the usage and the gains they hope to obtain as a result.

Module B. Personalisation principle definition

B1.1 Design Variability. Area of key importance, where the designer analyses how much the previously mentioned 6 variable aspects (derived from case studies) determine the shape, usage and perceived value of the product. Each of these aspects are evaluated on a 1 to 5 scale according to a specific question, and the motivations are registered on a post-it note. This field relies on the capacity of the designer to critically assess the design of existing products, building on the observations in the previously filled fields of the canvas (A2. Benchmarking and A3. User value).
B1.2 Personalisable features. In this field the designer should clarify how the most interesting variable aspects (evaluated in B1.1) might influence the design of the features of the product, respecting the given typology's functional requirements. This field should clarify which part(s) of the product can be personalised while satisfying the requirements of the given product typology. According to the previous evaluation (on the 1 to 5 star scale), the most interesting aspect(s) should be considered, while dropping those with low ratings.

B2.1 Personas Profile and avatar. In order to comprehend whether user needs are sufficiently divergent to justify a personalisable product, in this area the designer constructs 3 'imaginary' user profiles according to the widespread *personas* technique. To create empathy and allow quantitative work, fictional personal details and an evocative avatar (drawing or photo) are added, making the persona a realistic character for whom to design. The constructed personas should have markedly different expectations from the chosen product typology.
B2.2 Personalisation need. After constructing the personas, in these fields the designer should insert ideas regarding their most particular needs, which would motivate them to engage in a personalization process.

B3. Opportunities. In this area the designer should connect the possibly personalisable features (B1.2) with the identified personalisation needs (B2.2). The ample and unstructured space is open for idea generation, allowing to dedicate the necessary number of post-its for ideas, ideally connected to previous observations; connections should be marked e.g. with sticky paper tape. The designer should try to identify which personalisable features have the strongest connections to the identified personalisation needs, resulting in more defined ideas about the desirable configuration and morphology of the final product. However, in this phase it is not yet necessary to define precisely the product concept, it is more important to map out many opportunities and focus on connections.

Module C. Detailed concept definition

C1.1 Manufacturing requirements. Approaching the final concept, the designer analyses the requirements that determine the feasibility of the previously identified product/feature opportunities, trying to find the ideal Digital Fabrication strategy. For the ease of discussion, the manufacturing requirements are divided according to three aspects; similarly to the nearby B1.1 fields, beyond the verbal assessment the feasibility of these aspects should be rated on a 1 to 5 scale, where lower ratings indicate harder to satisfy requirements, which need extra attention.

C1.2 Technology candidates. In this field, the designer should identify which digital fabrication technologies could match the above requirements. Beyond the digitally manufactured components, the product might include parts which must be realized with conventional, serial manufacturing technologies; these requirements should be listed as well.

C2. Morphological references (moodboard). This field illustrates the expected visual qualities of the final object through a collection of images and/or text description. The morphological references (moodboard) should be coherent with the range of previously constructed personas (see the neighbouring B2 fields).

C3. Product concept. This field contains the morphological concept of the product, considering an 'average' personalisation. Based on the previous analytical work and ideation, the overall design should be illustrated, as detailed and precise as possible, providing a preview of the final product.

C4. Components of the product. Further illustrating the concept outlined in the C3 field, here the designer should distinguish between the variable and invariable parts of the design, highlighting also the interface where they meet. 'Variable' parts are those which can be personalised through parametric design, to be manufactured with digital fabrication. 'Invariable' parts are those which cannot be personalised, either because they need to have a given geometry in order to function properly, or because personalisation would not change the object's perceived value. Invariable parts can be produced by either digital fabrication or serial production. Finally, under 'interface' the designer should describe where/how variable and invariable parts meet.

C5. Personalisation Process Storyboard. This field contains an illustration and description of the main steps necessary to obtain the custom product. Based on one of the previously constructed personas, the storyboard should begin with the emergence of the personalisation need and proceed with the persona entering in interaction with the system of personalisation, e.g. webpage or physical shop.

C6. Personalised Products. This field should illustrate and describe briefly three hypotheses of the product, personalised for the three previously constructed personas (B2). Noteworthy differences in the creative input should be described.

3.4 Workflow conclusion

Considering the previous experience, it is advisable to dedicate 3-5 days for a full and accurate compilation of the full canvas with a working group. Naturally, growing experience can decrease the time necessary for arriving to a valuable conclusion. However, let's note that the process is not necessarily linear, because emerging ideas could stimulate revisiting previous steps. In fact, when the canvas is completed, it is advisable to review it in order to confirm whether the previous statements are still valid and whether they are coherent and supportive of the elaborated concept. The review might result in the rebuttal of the original hypothesis of working on the chosen product typology, especially in an entrepreneurial environment, where working on sub-optimal (non-profitable) ideas can have substantial cost, unlike in didactic settings.

As the output of the canvas, the designer can expect a concept that is mature enough for the rather onerous phase of parametric modelling, with a good comprehension and confidence about the potential utility of the personalization.

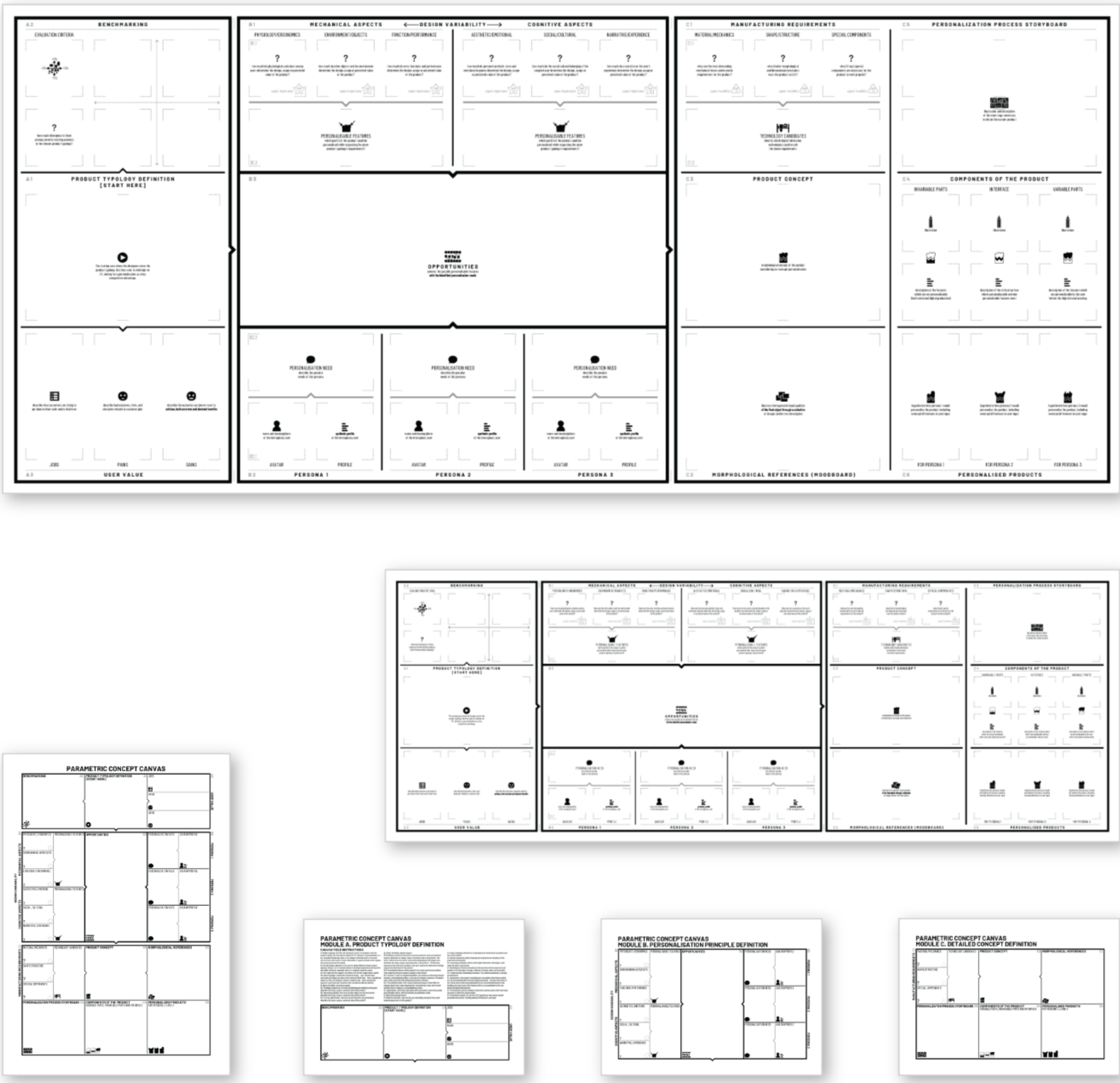

Figure 5 All formats of the canvas as described below, depicted proportionally (bottom row: standard A3 and A4 sheets). For readable (and printable) PDF versions of the canvas, please visit http://www.malakuczi.it/canvas.html

3.5 Canvas formats

In order to maximize the utility of the proposed tool in a variety of contexts, several versions have been elaborated in different dimensions, for individual or group use, with or without post-it notes, allowing both continuous development (post-its on big canvas) or rapid iteration (direct writing on small canvas). The following formats are offered:

- **Normal canvas**: canvas for working in groups, using standard post-its (3x3” or 76x76 mm). Canvas dimensions: 1500x630 mm, foldable to A4 format for portability.
- **Small canvas**: canvas for individual work or small groups, using small post-its (2x1.5” or 52x39 mm). Canvas dimensions: 1000x360 mm, foldable to 200x360mm.
- **Compact sheet**: mini-size canvas for individual work, for direct writing on the sheet. Dimensions: printable both A4 or A3, for cheap printing to stimulate iterations. For convenient writing in the restricted space, the small sheet contains a vertical (rotated) version of the canvas with simplified graphics.

- **Triple sheet**: mini-size canvas for individual work, cut in three pieces for convenient handling. Dimensions: printable on A4 or A3 sheets (3x), suitable also for A3 sheets. Offers slightly more space than the compact sheet and instructions for all fields are included on the first sheet.

Regardless the format, all versions of the canvas share the same fields, which are identified with the same icons and letter-number combination (e.g. C5).

4 Didactic experiment

So far, an early version of the proposed tool has been experimented in an academic context, with students of product design, anticipating also future uses with industrial partners, for whom we aim to create a useful knowledge. Experimenting with personal fabrication with university students is not new; the course “How to make almost anything” at MIT since 2001 show examples of how empowering Digital Fabrication can be for creating unique objects (Gershenfeld, 2005). A recent interesting didactic/research program example is Beyond Prototyping, carried out at Technische Universität Berlin and Berlin University of the Arts. This project was more focused on designing feasible products that are easily personalisable through online services, yet offering the aesthetic quality that one would expect in design-oriented shops (rather than technological demos); after the teaching experience, some projects were further developed in commercially available products (Ängeslevä et al.,2016). In the past, also the Authors have carried out similar teaching experiences, e.g. an international workshop for personalisable souvenirs to enhance the tourist experience in the city of Rome.

Even considering the many related examples, there seems to be no strong attempt to guide and visualise the conceptual design process of personalisable products, nonetheless the apparent difficulty; this was part of the motivation for developing the Parametric Concept Canvas. This development relied on a course with Product Design students in the third year of their bachelor studies in Product Design, who helped to test the first version of the canvas; the PCC described above is, actually, the revised final version.

4.1 Post-Series Design course

The ‘Post Series Design’ aimed to prepare the students to the contemporary cultural and productive environment, characterized by a strongly segmented market, saturated with a wide offer of alternative products. In order to promote competitivity in such environment, the course was focused on personalisable products, and in order enable designing them, the aim was to provide both conceptual and technical skills. Beyond the didactic objectives, the course had the research objectives of A.) verifying the proposed method/tool of conceptual development, and B.) demonstrating that DF and PD are applicable to a wide variety of products.

While it would have been desirable to work on product categories as divergent as possible, starting from a blank page or assigning a wide range of predefined product typologies would not have been adequate for the syllabus. Therefore, the 55 students organized in 21 groups were divided in 6 macro-groups, each receiving a keyword that left a wide possibility of interpretation. These keywords were derived from the exhibition “Neo Preistoria: 100 Verbi”, held at La Triennale of Milan (Branzi, 2016), showcasing how 100 actions (verbs) were manifested in mass produced objects of the twentieth century. While the 6 randomly assigned verb were interpreted freely by the students, their thinking was channelled towards established product typologies that are already mass manufactured, therefore ‘needed’ by many people. Moreover, experimenting with the (parametric) re-design of an existing product stimulates the conscious thinking about the relative advantages that DF and PD can offer, important for gaining a more solid understanding of the future role of these technologies. Therefore, based on the assigned action, each group have analysed a set of objects they collected in their homes, and then they choose a product type to work on for the rest of the semester.

4.2 Workshop of analysis and opportunity identification

The described choice of product typology has provided the input for the work on the 'Parametric Concept Canvas', the tool that this paper is focused on. Each of the 18 groups had a canvas to work on during the 3 intense days of a workshop, divided in the following way:

- day 1: analysis of the product category through examples, the jobs-pains-gains framework (left column) and the system of variabilities derived from the case studies (top-centre row).
- day 2: construction of personas and analysis of their needs, connecting them to the possibility of variation, i.e. feature ideation (bottom row, central field)
- day 3: establishment of the product concept and user journey through a storyboard, presentation of findings in front of the entire class (right column).

As usual in the design atelier courses, the abilities of the students have determined the pace of the process, and so did the product category they choose to work on. However, nonetheless the clearly visible differences of quality, the level of completeness at the end of the three-day workshop was quite uniform among the groups: less than 20% of the groups have shown significant disadvantages compared to the aimed level. This is considered a progress compared to a similar workshop organized a few months before, and the difference can be associated to the presence of the Parametric Concept Canvas tool. During the previous workshop, the absence of a strictly defined process (tool) resulted not particularly fruitful, wandering discussions in some of the groups. In the latter workshop, however, the defined format has helped many groups to identify autonomously their own mental blocks, as these caused a visible blocking in the compilation of the canvas, therefore these students could turn to the tutors for clarifications. For the same reason, from the instructor's points of view, it was relatively easy to identify the groups to help, simply by observing their advance of the canvas. The specific questions that guide the work on the canvas also create a platform of discussion, which helps professors to switch rapidly between completely different topics, particularly important when the attention must be divided between numerous students, as this is an increasingly typical issue also in the higher education of design.

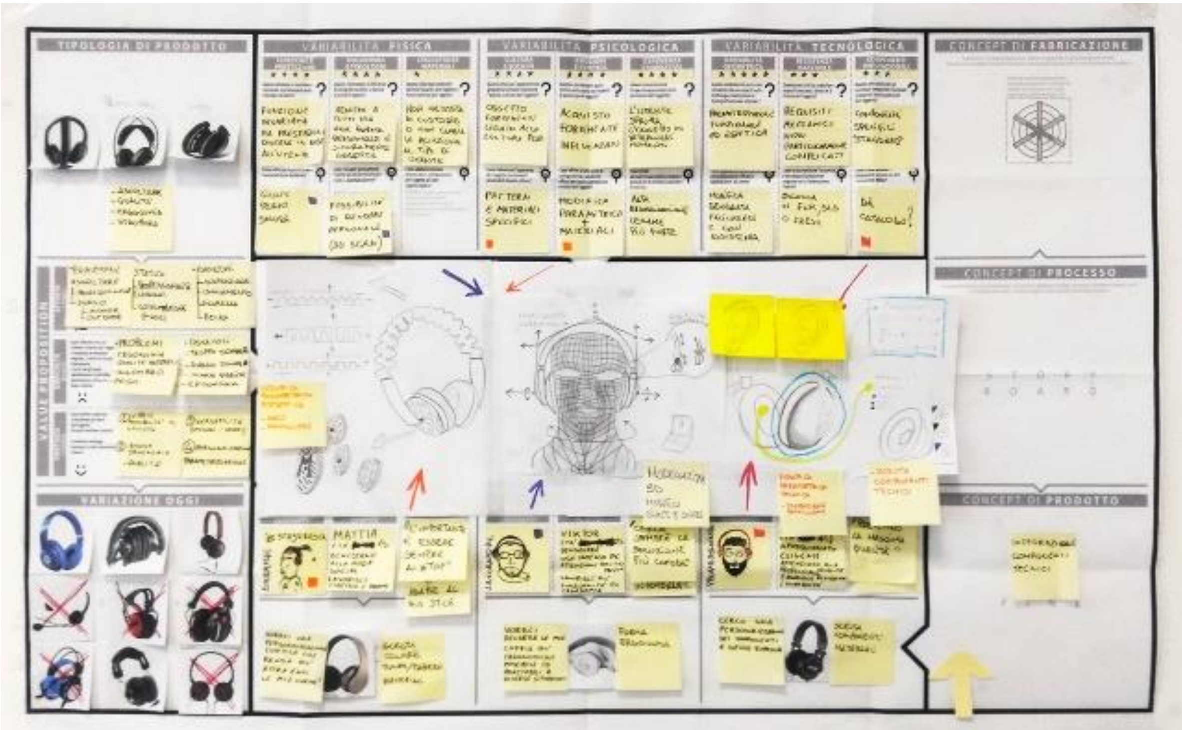

Figure 6 An example of the first version of the canvas, which was refined subsequently, arriving to the previously described final version of the Parametric Concept Canvas tool (Figure 5).

On the other hand, the workshop has helped to surface some (precious) negative observations, to consider for the future development of the tool.

- difficulty of applying some of the analytical questions to some of the product categories
- difficulty of reasoning in terms of ‘variabilities’ (rather than in terms of ‘simple’ improvement)
- sometimes misinterpreted suggestions, as limitations rather than stimuli
- sometimes mechanical compilation of the fields, rather than critical discussion

Therefore, on a general level we can assert that the canvas has fulfilled its main function of guiding the discussion in the desired direction, however we can also note the difficulty of the students to change their approach from developing single solutions (that respond specific problems) to wide solutions spaces (that respond variable requirements). Since the research (of which the course is a part of) was started with an awareness of this difficulty, it was not surprising to observe it on the field. However, this also indicates that tackling with the problem of variable design would need a higher level of professional preparation of what third year bachelor students have, who are still in the process of solidifying their skills for a simpler, ‘univariable’ kind of design. More specifically, more past experience would have been helpful with conceptual tools such as personas and user journey storyboarding, as well as with the technical tools such as parametric modelling software.

As far as the ‘Parametric Concept Canvas’ concerned, the previous critical feedback has stimulated its simplification and partial restructuring, which lead to the final version of the canvas, already discussed.

4.3 Next steps

The proposed ‘Parametric Concept Canvas’ tool provide a framework only for the first steps of a design project. After the ideation workshop, the ‘Post Series Design’ course continued with a more conventional process of weekly meetings, during which students have elaborated firstly a ‘static’ 3D model simulating the personalisable product, then a parametric (personalisable) model. In order to facilitate the discussion, students were asked to document each step of the development with a standard style of visualisation (figure 7), that distinguishes with colours the variable parts (cyan) from the invariable parts (grey), and the interface where these two meet (magenta).

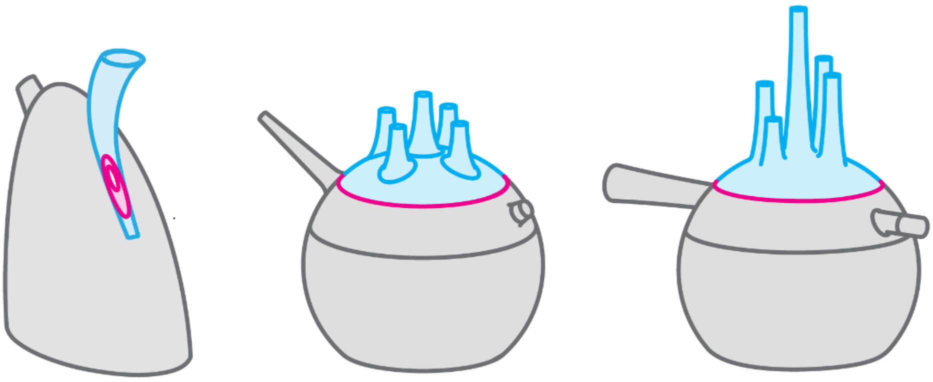

Figure 7 Development process of a student project, following the provided colour scheme to distinguish variable parts (cyan) from invariables (grey) and to show the interface between them (magenta).

While the technology to use for the parametric modelling can vary according to the business model suggested by the concept, in case of the ‘Post Series Design’ course, the parametric modelling was done with Grasshopper for Rhinoceros 3D.

This simple but powerful approach to parametric modelling allowed most students to create a variable geometry that is readily personalisable using the online platform ShapeDiver. This implies that with the currently available software tools one product designer plus one web designer can easily design and market a personalisable product for Digital Fabrication.

Figure 8 A selection of the 21 personalisable products developed by the students.

Since the use and teaching of parametric modelling tools (as well as DF machines) is already a well-established practice, discussing in detail these aspects of the 'Post Series Design' course is out of the scope of this paper. Yet, it is worth noting that today the parametric approach is largely facilitated by evolution of software tools also beyond those used during the course. In a previous work, the authors (Di Lucchio and Malakuczi, 2016) have examined them according to their level of abstraction, which determines the effort needed for the acquisition and practice of the necessary knowledge, ranging from simple parametric solid modelling (e.g. Solidworks, Fusion) to visual programming of generative geometries (e.g. Grasshopper) until demanding but versatile direct code writing (e.g. Processing, Javascript, Unity). According to the tools used, the designers' role and business model can range from digital tailormade through the offline use of parametric solid modellers, to an enterprise collaborator who helps to redefine an entire range of products according to the contemporary creative and productive possibilities.

5 Conclusion

While this paper was focused on the development and educational experimentation of the 'Parametric Concept Canvas' tool, it also aims to help professional designers to develop successful personalisable products, hopefully more fulfilling for the end users, thus providing competitive advantage to the designers' organisations. Moreover, the structured approach to concept development could help researchers to understand better the possible scope of Digital Fabrication, Parametric Design and personalisable design in general. While the proposed method is based on a set of variabilities extracted from case studies, future research could extend or refine this set of key characteristics. In fact, a limitation that must be acknowledged is that the tool is not promoting actively the discovery of entirely new meanings of personalisation, neither does is promote the exploration of entirely new morphological qualities.

However, it is worth remembering that:

> *methodology should not be a fixed track to a fixed destination, but a conversation about everything that could be made to happen. The language of the conversation must bridge the logical gap between past and future, but in doing so it should not limit the variety of*

possible futures that are discussed nor should it force the choice of a future that is unfree. (Jones, 1970)

It is also important, though, to acknowledge that there is a large undiscovered territory to be explored, if we intend to maximise the positive impact and move towards a strategic use of new technologies, that benefits economic and social progress, as well as the design profession. Future research and innovation actions should verify whether and how the proposed tool can be applied in entrepreneurial settings at different scales, from artisanal micro-enterprises to large international brands. This would be particularly timely because the concept of technology driven personalisation falls under the Industry 4.0 paradigm, which currently enjoys a strong governmental support across Europe. In order to facilitate the diffusion, the elaborated toolkit (containing both the canvas and a more detailed user guide) was made available at http://www.malakuczi.it/canvas.html with Creative Commons license.

Whether and how the design profession can accommodate the new approach of designing wide solution spaces for parametrically variable products is not yet clear. The necessary new technical and conceptual skills might require a further branching of the discipline, which would be a natural and welcome sign of maturation. In any case, we hope to contribute to raising the profession's capacity to adequately valorise emerging technological possibilities.

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