CONCEPTUALIZATION OF MODULAR PRODUCTS FOR THE PROSUMER. A DESIGN WORKSHOP

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1.- INTRODUCTION

Consumption habits have evolved to give rise to the prosumers, users who partially produce the products they consume. The development of tools and communication channels has made it easier for prosumers to have resources to design, manufacture or assemble their own products [1, 2, 3]. New methods of product design must take this trend into account and meet its corresponding needs. In this regard, modular design is a tool that can provide numerous benefits to the prosumer field. Its ability to connect and exchange modules facilitates the intervention of the end user on the product [4, 5]. These characteristics have previously been used to partially cover the requirements of consumers through mass customization [6, 7]. However, its application has been focused from the point of view of the industry.

Previously, the link between modular design and prosumer users has been analyzed from theory [8, 9] with the aim of creating a new design method focused on prosumers that allows them to design modular products. This method will be applied in the conceptual phases to generate concepts that have modules that the prosumer can design and manufacture by their own means, as well as standard modules that they can buy. This seeks to take advantage of the benefits of modular design, such as customization and adaptability [10], in an area where it had hardly been previously exploited.

The relevance and novelty of this work lies in showing the results of a first application of modular design to create products for the prosumer. These users do not have product design knowledge but are familiar with manufacturing processes. For this, it is proposed and tested a new modular design method in a user-centered environment, and not in the industrial manufacture and development of the product as had been done until now [11,12]. The few antecedents that link modular design with prosumers do so from the theoretical field, so it is necessary to cover it from a practical perspective. This allows to check the theory and to verify the usefulness and real applicability of the method, which also follows the standard engineering design process [13]. This method is not based on previous methods due to the difficulty that it may pose for non-specialized users. Instead, a more accessible method that includes an evaluation metric is proposed to facilitate its applicability.

The paper presents the results of a design workshop in which the proposed method has been used by designers and prosumers to create modular products for the prosumer. The purpose is to analyze if the participants understand it correctly and how they apply it. This experience can serve as a precedent in the practical field to contribute to the creation of modular products for the prosumer. For this, a total of 22 design concepts generated in the workshop are shown. Each concept was evaluated with a metric that values the presence of modular design and prosumer features. The results allow detecting possible improvements in the creation of the design method and in the evaluation metric.

As a result, the participants learned a new method to design modular products for the prosumer and acquired knowledge about new design concepts and evaluation methods. Regarding the development of the proposed design method, the workshop offered results that made it possible to assess whether the process was satisfactory due to the participation of users and the concepts developed. It also allowed to know if there were differences between the results of prosumers and designers to value if the method is equally applicable to both profiles. Together, these conclusions enable refining the method, as well as enhancing its strengths.

2.- METHODOLOGICAL DESCRIPTION

The objective of the work is to test the application of modular design to create products focused on the prosumer through a design workshop. For it, two profiles were taken into account: designers (professionals) and makers (not specialized), who have a profile similar to the prosumer but with a collaborative philosophy. As a previous step to the workshop, a pilot test was carried out with an external user who fulfilled the maker and designer profiles. This allowed us to optimize the time of the workshop and the way of transmitting the method.

Subsequently, the workshop was held in two sessions of two hours each one. The format was online and they were developed in parallel with the *Google Meet* tool and the *Miro* collaborative work platform [14]. In both, three groups of four people between 25 and

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55 years were formed, led by a coordinator. The groups were created by parity of profiles (designers and makers) and gender. Due to the absence of two participants, a total of 22 design concepts were generated.

The product to be designed was a multifunction portable cart to cover personal needs that would be developed and manufactured by the maker procedure [15]. A series of components, materials and manufacturing methods were proposed to the participants, as well as some examples. However, other characteristics were not specified so as not to limit the participants. The workshop followed a structure according to the proposed design method that is illustrated in Figure 1.

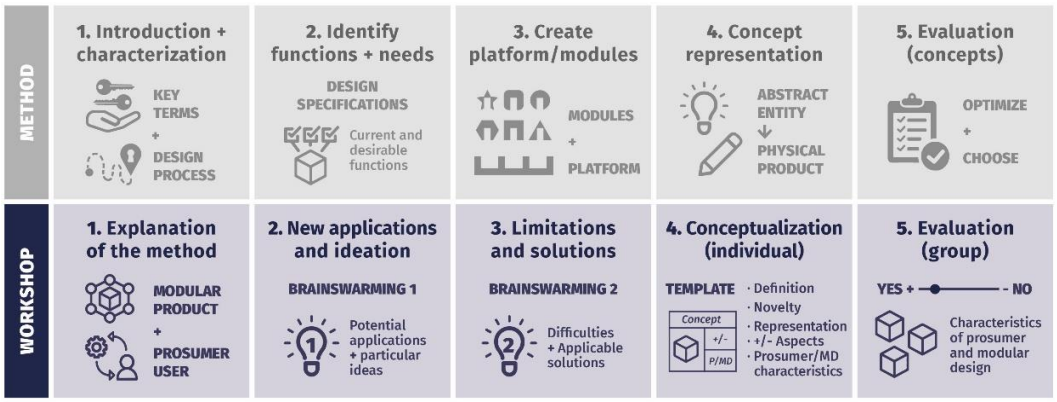

Fig. 1. Diagram of the proposed method and the structure of the workshop.

1. **Explanation of the method:** The key terms of the method were defined, as well as its objective. To define *modular design* and *prosumer*, real examples were shown and the differences with other similar terms were explained. The basic characteristics that all the concepts had to meet were also established: transformable, adaptable, customizable and updatable.
2. **New applications and ideation:** Through a brainswarming [16], the participants reflected on new applications for the product, taking into account the improvements that the modular design and the prosumer character can offer. First, they proposed potential applications and then they wrote ideas in each of them to finally select the application that they wanted to develop.
3. **Limitations and solutions:** In this second brainswarming, the difficulties and limitations of the new application were analyzed with respect to its modular and prosumer characteristics. The participants proposed a series of solutions that they would apply to the concept to be developed in the next phase.
4. **Conceptualization:** Each participant developed a concept following a template (Fig. 2) with its definition, novelty, graphic representation, positive aspects, aspects to be resolved, prosumer characteristics and modular design characteristics. Then, each one presented the concept to the rest and they put ideas in common.

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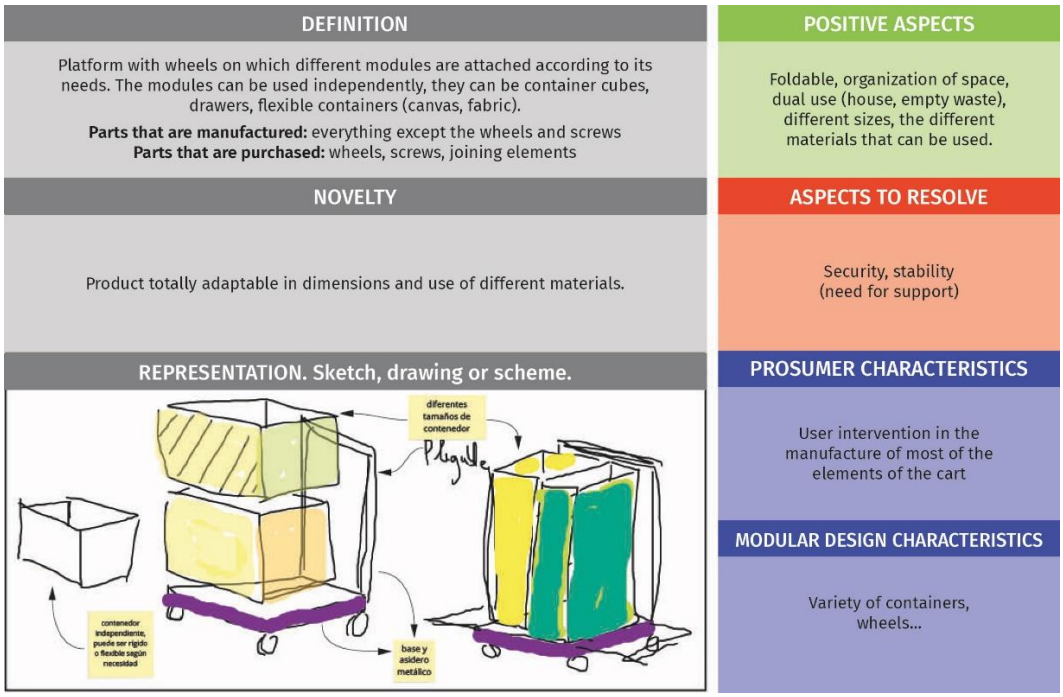

Fig. 2. Template used to present the concepts of each participant.

5. **Evaluation:** The workshop concludes with the evaluation by means of a checklist (Fig. 3) of each concept by all the participants. The characteristics of *modular design*, *modular design + prosumer* and *prosumer* were assessed through questions that could be answered gradually in a scale between "yes" and "no", locating a point between both extremes. All the participants made an individual and simultaneous evaluation on the same checklist, so that all the answers were visible during the evaluation of the concept, where each color represents a participant.

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Fig. 3. Evaluation method used on the workshop applied to a concept [17].

After finishing the workshop and analyzing the results, it was observed that the evaluation carried out by the participants was not decisive due to the lack of consensus of the answers, the time limit and the scarce experience of the evaluators in the area worked on. In addition, the fact of performing it simultaneously could have conditioned individual responses. For this reason, after the workshop the three coordinators carried out a second internal evaluation of all the concepts. The greater experience of the evaluators in modular design and prosumer, together with their external vision of the concepts, makes this second evaluation more objective and precise. On the other hand, a time limit was not established to carry it out, giving rise to a greater reflection and debate on the valued concepts.

The method used during the internal evaluation was the same as that used in the workshop (Fig. 3). However, this time the answers were private and hidden from the rest of the evaluators to ensure that they did not condition each other. The evaluations were only revealed at the end of the evaluation of all the concepts to discuss the answers and analyze the results between the evaluators.

Among all the evaluations, there were two concepts that stood out for their consensus evaluations and for their high level of modular design and prosumer. Both were partially evolved in order to assess the feasibility of their manufacture and subsequent development. Finally, one of them was chosen to work on and fully evolve it. The work ends with the development and manufacture of a multifunction portable cart focused on making purchases in supermarkets and department stores that can be manufactured by the end user.

3.- RESULTS

The results of the work are presented in two sections. The first shows the concepts generated during the development of the workshop and the second exposes how the selection process was. The section ends with the final result of the project after completely evolving and developing the chosen proposal.

3.1. DESIGN CONCEPTS

Table 1 lists the design concepts created during the workshop. Each work group has a specific application in which to develop their concepts individually. These are numbered and accompanied by a brief description, a simple graphic representation and identifying the participant's profile with M for makers and D for designers.

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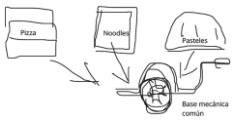
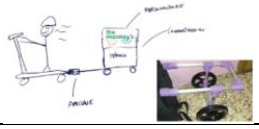
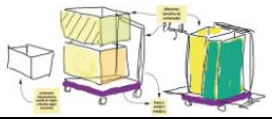
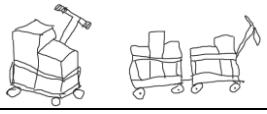
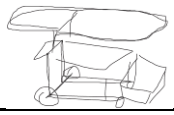
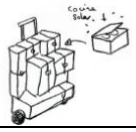
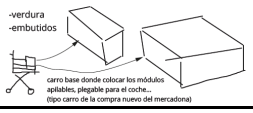
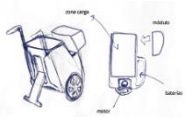
Application	*Nº*	*Brief description*	*Graphic representation*
Bring food home by bicycle or scooter. Use focused on food deliverers.	1	**D:** Personalized product for each type of restaurant. It is adapted to specific uses and can be designed by the buyer. It has a common base for all plugins.	
	2	**D:** Complement for riders as an alternative to the current backpacks. It has a larger capacity, can be customized by company, and is easily replaceable.	
	3	**M:** Trolley that can be connected to any electric vehicle with a universal anchor. It maintains the temperature of the product and facilitates its distribution.	
	4	**M:** Element that works with solar energy to carry delicate foods such as ice cream. It adapts to deliveries through interchangeable compartments.	*No graphical representation developed*
Collect and separate household waste to transport it to the container	5	**D:** Platform on which folding modules are attached that can be used independently as cubes, containers, etc.	
	6	**D:** Portable cart with a rigid base on which compartments of different sizes are placed. The product adapts according to the circumstances.	
	7	**M:** Animal-assisted traction vehicle for selective collection of waste on public roads and urban environments. Assembly focused on self-employment.	
Transport food to consume out of home. Possible environments: work, picnic, excursion, etc.	8	**D:** Carrier to eat outdoors. The modules, of different sizes, are joined and have a solar panel that gives them autonomy to preserve and prepare food.	
	9	**D:** Picnic suitcase made up of interlocking modules of standard sizes. It has wheels and attachable handles. Each module has a function.	
	10	**M:** Travel food backpack with modular extensions to transform the product into a resting station.	
	11	**D:** Stackable modules for different types of food that are stored in the fridge and are ready to go at any time. It helps the user to save time.	
Reduce efforts in moving and lifting weights. User: Elderly people or people with reduced mobility.	12	**D:** Walker that facilitates the loading and unloading of products. It has modules adapted to the user, such as first aid. It has also electric assistance.	

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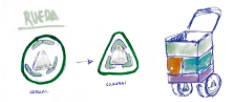
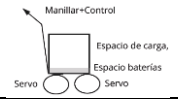
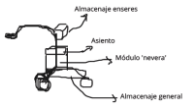
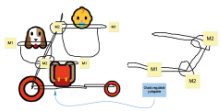
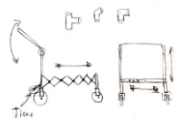
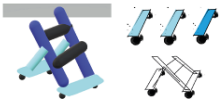
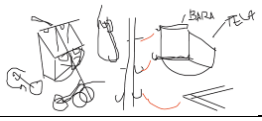
	13	**D:** Trolley with a motor to carry shopping in buildings without an elevator. Stackable and folding modules. Caterpillar wheels.	
	14	**M:** Conveyor for warehouses with an integrated motor capable of moving autonomously.	
	15	**M:** Multifunction cart for people with reduced mobility. It has geolocation and assistance button, as well as washable and reusable textile modules.	
Simultaneously transport the pet and the baby, as well as the objects that each of them requires	16	**D:** Carriage-flex transformable that adapts to everyday life. It has three modules (pet, child and objects) that can be used independently.	
	17	**D:** High trolley with removable backpack and a baby seat. It has hooks to attach the pet's leash.	
	18	**M:** Structure with a common base capable of adapting its measures. It has versatile structure and movement. The product is manufactured by the user.	
	19	**D:** Tube-based structure with universal joints. It is possible to add more horizontal tubes and resize it according to its application.	
Move the purchase inside the supermarket or department store and later transport it home	20	**D:** Folding and adjustable shopping cart. It fits bags, boxes and other products. It has a central axis with hooks at different heights.	
	21	**D:** Fabric basket with wheels. Modules are dockable boxes of different sizes. It is easy to store and the modules fold.	
	22	**M:** Trolley with compartments that can be added to other transport elements such as bicycles or baby strollers.	

Table 1. Complete list of concepts generated during the design workshop.

All these are conceptual proposals developed in a workshop with limited time. They all have a similar level of definition and require further evolution and development. The concepts belonging to the same work group and application show similarities between them, because the two previous brainswarming exercises are focused on presenting ideas and solutions as a group, so their individual application makes many of the concepts coincide at a functional and even formal level.

The workshop concluded with the evaluation of the concepts by the participants of each group. This first test of the evaluation method reveals that the evaluation is still complex and not precise to be applied by external evaluators due to the lack of consensus in the answers. Therefore, it requires a detailed review by the coordinators to assess it and detect possible improvements.

3.2 EVALUATION AND FINAL RESULT

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The evaluation carried out by the coordinators was done individually and separately, putting the results in common only at the end. The questions and the response scale remained the same as in the workshop. Table 2 summarizes the results obtained in this internal evaluation. The columns represent each concept according to the numbering in Table 1, while the rows establish the characteristics to be assessed in each field: modular design (*independent*, *connectable* and *variable*), modular design + prosumer (*transformable*, *adaptable*, *customizable* and *upgradable*) and prosumer (*own modules*, *participation* and *intervention phase*).

The results are presented by colors according to the following criteria:

- Green: Positive assessment of the characteristic, if the three assessments were between the maximum (*Yes*) and the center of the scale.
- Yellow: Intermediate rating, if the three ratings are close to the center.
- Red: Negative assessment, if the three assessments are located between the center and the minimum (*No*).
- Grey: Invalid evaluation due to lack of consensus, if the three evaluations were outside the previous ranges.

Finally, Table 2 highlights in its last row eight of the most outstanding products of the valuation. These correspond to two for each aspect to be highlighted: positive rating in everything (*All*), higher ratings in modular design (*M*), higher ratings for prosumer (*P*) and lower ratings in everything without having any positive evaluation (*No*). The rest of the products did not have outstanding ratings or, if they did, they were lower than the products indicated. This selection contributes to knowing the strengths and weaknesses of the most outstanding concepts with the aim of learning from each other and even exchanging design solutions.

Characteristic		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
Modular design	Independent																						
	Connectable																						
	Variable																						
Modular design + Prosumer	Transformable																						
	Adaptable																						
	Customizable																						
	Upgradeable																						
Prosumer	Own modules																						
	Participation																						
	Intervention phase																						
Total		M	-	M	-	All	-	-	-	-	P	-	-	-	No	No	P	-	-	-	All	-	-

Table 2. Internal evaluation carried out by the three workshop coordinators.

The final choice was made between the two concepts with the highest ratings across the board: the platform for collecting and separating waste (Nº5), and the folding shopping cart for supermarkets and department stores (Nº20). After partially evolving them, it was decided to develop concept number 20. One of the reasons for this choice was its high capacity to be built and assembled using ordinary manufacturing processes, such as 3D printing, and standardized materials, such as PVC pipes. In addition, another of the advantages that this proposal presented over the others was the ease of using it with everyday products such as bags, baskets and boxes. Finally, it can be adapted to more environments and functions than Nº5, which is focused only on transporting household waste.

Regarding the evolution of the concept, the structure of one axis was replaced by another of two to provide more stability to the product at rest. A folding system was also developed whose joints were designed and modeled to be manufactured later by 3D printing. To conclude, the product was assembled and tested in order to implement possible improvements. Figure 4 shows four visualizations of the final result of the project in which its potential use can be seen with different elements that are joined by supports located at different heights. After this development, the three coordinators reapplied the evaluation method to the final result to verify that the specifications required as a starting point were still met. The evaluation resulted in a positive assessment with an improvement of the features *upgradeable* and *own modules*, although the *independence* dropped one point.

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Fig. 4. 3D modeling and prototype of concept Nº20 developed in the design workshop.

4.- DISCUSSION

User profile shows differences in the application of the design method. While makers focus on manufacturing and developing their own modules with a medium-low level of innovation, designers work on the new applications and the incorporation of modular design. Both visions have their benefits and it would be optimal if they were applied together. However, this can be a challenge when generalizing the method for any kind of profile. It is complex to know the previous experience of the user, especially in the case of non-specialized users.

The results of the evaluation carried out in the workshop show the need to evolve the metric to make it more objective and applicable. In its application, there were a series of conditions that could affect its operation. This raises certain questions: Would the result of the evaluation be the same in a blind evaluation? Did the short time affect to the evaluation? Is it necessary to provide more information about the product or the key terms? It is possible that the dynamics generated in the group during the session also affected the objectivity of the evaluations. For greater precision, it can be helpful to create levels that replace the current scale. It is also important to promote individual thinking to gain greater objectivity, as has been shown in the evaluation of the coordinators.

It has been identified some difficulty in understanding and evaluating the *transformable* characteristic both in the evaluation of the workshop and in the evaluation carried out by the coordinators. Some participants stated that its definition was similar to other characteristics, such as *adaptable*, and therefore it was difficult to differentiate between them. In a subsequent development, it will be necessary to assess whether the *transformable* characteristic is necessary in the application of the evaluation method or if, on the contrary, it should be dispensed with and only three characteristics to be evaluated per area (*modular design*, *modular design + prosumer* and *prosumer*).

The use of modular design still generates confusion in some users, results of parametric design and modules design are wrong even that the difference with modular design was explained. This fact raises questions about how to improve this application. Providing more information can lead to misunderstanding in sessions with a time limit, while the presence of examples facilitates their understanding, but also conditions the concepts. An intermediate point could be to expand the information with neutral pictograms and visual elements that support the explanation of the terms in an objective way.

5.- CONCLUSIONS

The workshop has obtained the expected results, both in the definition of concepts and in the understanding of the modular design method. The simplicity of its application makes the workshop easy to reproduce by the participants. In general terms, participation was high, voluntary and active, leading to quality results despite the short time available. The concepts fit to the objectives of the workshop. On the other hand, the fact that the workshop was online had a positive impact on the number of attendees. The use of *Miro* with its templates facilitates the transmission of the method. However, the graphic representation of the concepts could have been affected by the tool.

Although differences are detected in the application of the method between designers and prosumers, both obtain valid results. All the participants easily empathized with the user to whom the product is directed. This aspect should be strengthened in future work to equate the application of the method in both profiles. To do this, an introduction to the conceptual design will be added and the information on manufacturing methods will be expanded. Moreover, to bring the method closer to non-specialized users, it is proposed to develop a self-guide and disseminate it through the usual channels of these users, such as video tutorials.

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The tested method is in a process of evolution that requires refining the errors identified in this workshop. The factors that have affected the evaluation method must be considered in order to optimize it, such as its collective application or the *transformable* term. This may result in the method being used independently of the general method [18, 19].

It is identified that the most applied characteristics of modular design in the generated concepts coincide with the most common interventions of the prosumer on their products: customization and adaptation to different environments and situations. As for the most common tools and methods to modify the product, we find 3D printing, FabLab tools, DIY and the assembly of components, whether purchased or self-made. Among the pieces to be built, stands out the supports, fixings, decorations, handles and casings. While in the parts to buy we find tubes, wheels, screws, electrical components and fabrics.

There are groups of elementary functions that modularity can assume. Between the modules developed in the concepts, we find common functions such as the ability to fold/extend, the variation in the order of elements and the ease of storing or transporting them. As secondary characteristics, the multifunctionality, the update and the reuse of components stand out. Although the participants did not apply them intentionally, the presence of the modular design means that all the concepts have these characteristics, which translates into the extension of the product's life cycle and improving its sustainability.

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