Analysing the prosumer opportunity. Prosumer products' success or failure.

Makerspaces and FabLabs have become prominent spaces in the prosumer and maker movements worldwide. Prosumers actively create products and services to meet their needs and wants. Availability of DIY manufacturing methods and digital fabrication tools are increasingly accessible; design and manufacturing knowledge, and reuse of parts and components, are also factors to consider. The prosumer system is influenced by economic factors and domestic fabrication costs. Emotional attachment and sustainability are also key components of the prosumer movement. Nevertheless, not everyone is inclined to become a prosumer for a variety of reasons. Prosumer design limitations need to be understood and evaluated, as do mechanisms and methods for identifying which concepts can be developed into successful products. A key objective of this work is to evaluate the transition from an idea to a fully functional product by identifying barriers and enabling factors, such as knowledge, resources and motivation. To assess the feasibility and success of prosumer-designed products, theoretical frameworks, metrics and evaluations are conducted.

Keywords: Prosumer movement, Maker culture, Design assessment, Prosumer metric, Evaluation tools, Needs and Wants

Introduction

The "prosumer" term was coined by Alvin Toffler to refer to mass consumers who would play the role of consumer producers (Toffler, 1980). He foresaw a DIY future in his book “The third wave”. However, the outcome did not turn out as he had expected. Prosumers are currently defined as users who actively participate in the creation of the products and services that they will ultimately use (Tapscott & Williams, 2008). It is their goal to satisfy a desire or need that market products are unable to meet, while simultaneously acquiring new knowledge (López-Forniés & Asión-Suñer, 2023). Depending on the level of involvement, prosumers can range from non-participation to low-level mass customisation, from DIY practices to complete self-production (Asión Suñer & López Forniés, 2022; Lang et al., 2021). Knott (2013) distinguishes three types of prosumers based on how they use their resources: rule-following prosumers, self-sufficient consumers, and DIY consumers who adapt tools and materials.

A growing movement of makers and prosumers is gaining momentum. The European Commission (JRC-EC) (Menichinelli & Schmidt, 2019; Rosa et al., 2017) reported that FabLabs (48%) and hackerspaces (40%) are the most prominent maker laboratories in Europe (Menichinelli & Schmidt, 2019). Globally, this movement encompasses individuals who are interested in designing and consuming their own products. Despite the fact that this is a small-scale initiative, it raises many questions, such as: What will happen if everyone becomes a prosumer? What are the motivations or barriers they will face?

As a result of the fourth industrial revolution, methodologies have been developed by focusing on the prosumer to shift from linear to circular economy (Bartodziej, 2017; Millard et al., 2018; Pavlopoulou, 2020). These methodologies also seek to provide individualised products that take into account prosumers' needs and wants (Bartodziej, 2017). One such example is mass customisation, which involves configuring a product by selecting several options, reducing development times and allowing for rapid adaptation to customer requirements (Wang et al., 2017). In this scenario, modular design is an excellent foundation to create editable and updatable products (Asión-Suñer & López-Forniés, 2021b; López-Forniés & Asión-Suñer, 2023).

From a social perspective, a shift in society and consumers is observed, and prosumerism is manifested as an emerging form of capitalism (Czuba, 2017), which has been reinforced by communities and networks (Kohtala et al., 2020; Lang et al., 2020; Millard et al., 2017). The reasons are lack of a desired product on the market or existing products differ from what they desire because they do not meet their requirements. Despite their activities, many of them are unaware of their status as prosumers, the existing communities that share knowledge, and are unfamiliar with certain resources. As a result, they do not disclose their results and other prosumers are deprived of valuable references to deal with similar situations (Asión-Suñer & López-Forniés, 2021a; Unterfrauner et al., 2017). Prosumer social communities share knowledge and experiences, including: systemic openness, widespread interactivity, community enabling, fractal organisation and social learning (Bianchini et al., 2014).

Economically, prosumers are unpaid for their work, but do not pay for their products (Ritzer & Jurgenson, 2010). Ritzer et al. (2012) stated that they are more concerned about the outcome than about the object itself. The decision whether to make or buy products is easier when the prosumer estimates their costs. However, it is not only the cost-to-price ratio that determines the economic impact, but so do logistics costs (Aronsson & Brodin, 2006), transportation (Arıkan et al., 2014), warehousing (Bartolini et al., 2019) and intermediaries because they affect the supply chain (Unterfrauner et al., 2017).

The maker movement contributes to circular economy by extending product life spans and fostering a consumer-to-prosumer mindset by enabling people to upgrade, repair and recycle (Metta & Bachus, 2020). The emotional component is also related to sustainability by extending the product life cycle and avoiding replacement and disposal (Nielsen et al., 2014). In addition, parts need to be recovered for reuse to reduce costs and environmental impacts (Bauer et al., 2021; Mollajan & Iranmanesh, 2021), which motivate some prosumers (Metta & Bachus, 2020). Strategies for product longevity, such as "Design for attachment and trust", "Design for adaptability and upgradability", "Design for ease of maintenance and repair" or "Design for durability and longevity", have technical and emotional components aligned with the prosumer’s nature (Haines-Gadd et al., 2018; Medkova & Fifield, 2016).

Prosumers need to have basic knowledge of design and manufacturing issues (Asión-Suñer & López-Forniés, 2021a), and level of satisfaction with outcome must be taken into account (Mugge et al., 2009). Some prefer a well-finished refined product that aligns with their tastes over a Frankenstein prototype. Do-it-yourself (DIY) equipment for fabrication with basic tools is widespread. Facilities for building prototypes and products are increasingly found, such as digital fabrication tools (3D printers, laser cutting, CNC, etc.), and access to FabLabs will be easier in the future (Blikstein, 2013) while prosumer tools are popularised (Asión-Suñer & López-Forniés, 2020). However, manufacturing loses meaning if the result fails, with consequent losses of time and resources, in addition to feeling frustrated about not enjoying the desired object. Therefore, it is necessary to implement evaluation tools to anticipate errors and to understand the difficulties or limitations of each design (Asión-Suñer & López-Forniés, 2023; Li et al., 2023; Maurya et al., 2021; Song et al., 2022).

Despite the growing scope of the prosumer movement, a significant part of the population is not ready to become a prosumer. Some reasons are: lack of resources (financial, time), lack of expertise (in design and manufacturing), the complexity of their needs (complex products), the convenience of marketed solutions, lack of customisation or autonomy needs and, finally, attachment or connection to a brand rather than a self-created object.

The objective of this work is to evaluate whether, in the prosumer or maker realm, the initial concepts can materialise into reality or remain as artifacts that do not meet users' needs and wants. Designs are validated with metrics that indicate success in the transition from the concept to the prosumer product in accordance with current trends in personalised, domestic and environment-friendly production. These metrics encourage the development of prosumer products through an evaluation that reports on the evolution of the best concepts and avoids user frustration when faced with possible failures. The evaluation analyses the reasons for success or failure, the influence of limitations, and the possibility of prior evaluations before reaching an advanced manufacturing stage. It is also important to identify what allows the transition from the concept to the materialised and functional product, what barriers exist, and how resources (materials and tools), knowledge (methods and skills) and emotional factors (satisfaction and attachment to the object) influence this process.

Theoretical framework

In the prosumer realm, needs and wants are delicate and complex (Liao et al., 2008), their motivations can range from simple aesthetic changes or solving a specific low-complexity problem to increasing product functionality or carrying out prototype tests to evaluate feasibility and performance. All these efforts share the objective of solving a specific and personal problem that is measured from the conceptual phase to the acceptance phase of the prototype as a product (Figure 1).

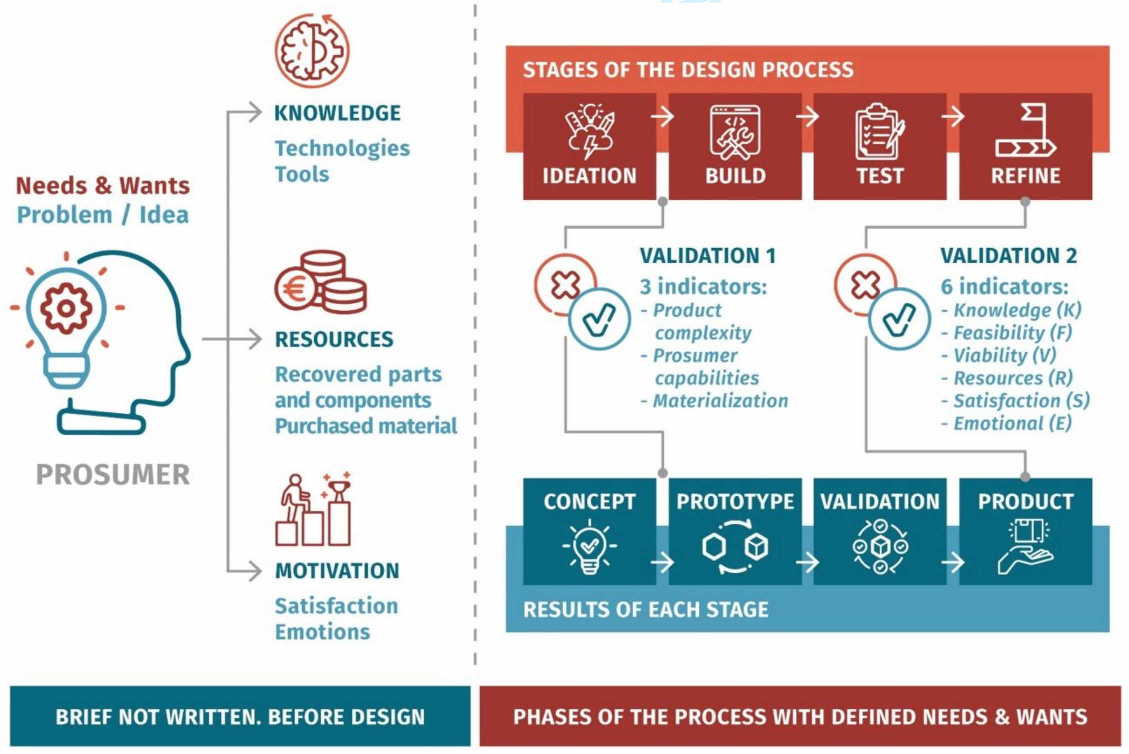


Figure 1. Prosumer product design phases.

Prosumers identify a personal need or want that they wish to reflect in an object. By taking into account three key items, the prosumer transforms the problem into an idea or a preliminary solution: (1) the necessary knowledge or technologies and the tools to be used (Von Hippel, 2017); (2) economic resources in terms of the cost of materials and tools to be purchased or the parts and components to be reused (Lehner, 2019); (3) motivation linked with meeting needs and requirements, as well as the emotional attachment this may generate (Haines-Gadd et al., 2018).

The prosumer makes a reflection between the problem and the solution from an unwritten briefing before starting the design phase. This reflection determines whether a project is to be started or abandoned. The design process proceeds through four stages: ideation, construction, testing and refinement. In the ideation phase, it is possible to imagine an object that meets the requirements of the problem and proposes conceptual alternatives for prototyping in the construction phase.

A first metric (M1) evaluates and takes into account the complexity of the object, the designer's skills and the manufacturing capacity to become a fully developed product. In the testing and refinement phase, errors and defects are detected and prototypes evolve. A second metric (M2) validates the solution by taking into account knowledge and manufacturing capacity, feasibility and resource considerations, such as economic factors and, finally, aspects like satisfaction and emotional attachment.

Research questions

RQ1. Do all the objects conceived and designed by prosumer designers have the potential to become fully developed products?

To answer this question, it is necessary to reach a definition level at which the prosumer considers the solution to be satisfactory and/or a company is willing to develop the product for commercialisation purposes. A consensus needs to be reached about what is meant by a prosumer product and the resolution level at which the result is accepted as a finished product. A prosumer product is a product designed, manufactured and used by a person who, faced with a need, is able to satisfy it by building a product that he/she uses and enjoys. An accepted prosumer product exceeds the prosumer's initial requirements and the resolution in relation to need, want and performance is accepted as valid by the prosumer, other prosumers or industry. On the one hand, and in a first situation, conceptual alternatives can be validated to be developed as a prosumer product. In a second situation, the object has a higher definition level and it is worth it being replicated by others or industry. On the other hand, failure or abandonment may occur in either the conceptual phase due to the inability to create/construct the object or the refinement phase due to lack of resources or specific knowledge.

At this point, a series of dimensions to be used in the evaluation are defined. We refer to a metric that evaluates prosumer characteristics in a checklist format using tiered questions and answers (Asión-Suñer & López-Forniés, 2022). It is necessary to define each question that defines the essential criteria (Table 1), such as prosumer knowledge, novelty on the market, technical and constructive feasibility, viability, resources required, satisfaction or emotional attachment.

Table 1. Indicators to be evaluated during the assessment of prosumer products.

Question	*Description*	*Indicator*
Is it a prosumer product?	It depends on the user, how it is built and the intended use. The complexity of the product, the capabilities of the prosumer and the materialisation of the solution should be considered	A, B, C and D
What is it?	Product description. Sets the initial problem	K1
What problem does it solve?	What need is being addressed? How is the product materialised? Design and Manufacturing	K2
Is it feasible?	Whether it can be manufactured in a prosumer manner. Object materialisation, functional prototype	F
Is it new?	Whether it exists on the market or not, and in what way	V1

Is it economically viable?	Whether it is economically worthwhile or not. (Prosumer fabrication cost/market price ratio)	V2
What resources are required?	How it is built, what materials are required, and whether components are recycled or purchased	R
Is it satisfactory?	It indicates the satisfaction of objectives based on the degree of solving the need, want and quality of the finish	S
Does it generate engagement?	It indicates whether the prosumer develops an emotional attachment or engagement to the object	E

RQ2. How can these designs be evaluated in terms of their success or failure? Is it possible to predict their performance in advance?

To answer these questions, metrics that evaluate prosumer products are used by defining their dimensions related to the design objectives. The definition of success or failure also has two phases. The first is more intuitive because the concept is a sketch of the product, while the detailed phase allows a thorough evaluation on all the dimensions. To validate the concept, it is necessary to achieve a valid and feasible functional unit after overcoming technological knowledge and desire satisfaction.

Two metrics are established (Table 2). M1 is used in the conceptual phase as a method for evaluating prosumer products, which is particularly important to help in the creation, improvement and selection of proposals. M2 is applied to evaluate already materialised products to assess satisfaction with a series of dimensions and design constraints.

Table 2. Metrics and dimensions for evaluating concepts and materialised products.

Metric	*Dimensions*	*Ind.*
Concepts (M1)	**Product complexity**. Related to technological feasibility (F). It indicates whether it can be manufactured in the prosumer context. It refers to the performance/functionality of the prototype. It is related to knowledge, skills, technical difficulties and instrumental requirements	**F**
	Prosumer capabilities. Knowledge of the need or want (K1). It indicates the level of understanding the problem. Knowledge to solve the problem (K2). It indicates the level of knowledge to materialise the product (design and manufacturing experience)	**K1, K2**
	Materialisation. Satisfaction (S), is the degree of solving the product in relation to the need.	**S**
Products (M2)	**Knowledge for defining the need or want** (K1). It indicates the level of understanding the problem to be solved (how clear the desired outcome is)	**K1**
	Knowledge for problem solving (K2). It indicates the level of knowledge required to materialise the product and refers to the prosumer's own knowledge (expertise in design and manufacturing)	**K2**

Feasibility (F). It indicates whether it can be manufactured in a prosumer context. It relates to the functional prototype's performance/functionality. It is related to knowledge, skills, technical difficulties and instrumental requirements	**F**
Viability (V1). It refers to innovation and indicates the degree of novelty that it represents compared to existing products on the market	**V1**
Value of novelty (V2). It refers to the final product's economic cost. It indicates the ratio of the final product's value to its commercial value if it exists (or a reference value)	**V2**
Resources (R). It refers to the use of material resources and processes to manufacture the object, and also to recycled or purchased materials and components	**R**
Satisfaction (S). It refers to the resolved need. It indicates the degree of resolution in relation to the initial need and the finished product quality	**S**
Emotional (E). It refers to emotional satisfaction and indicates the degree of surpassing expectations regarding the initial desire	**E**

The scores of the dimensions serve as indicators of barriers and constraints, as well as enablers for design and manufacturing. Establishing satisfaction or compliance levels for each indicator allows the validation of each design. Consequently, these dimensions establish the constraints for product success or failure.

Metrics development

There is a critical central question that arises throughout the literature: what are the criteria by which creative product design should be evaluated? There is no widely accepted or universally applicable criterion (O'Quin & Besemer, 1999). The prosumer domain lies in development and requires a special evaluation method. In the literature, we can find qualitative, quantitative and hybrid metrics.

Qualitative metrics commonly use Likert scales to evaluate the characteristics of concepts and products on generic dimensions, such as novelty, usefulness, feasibility, among others. (Chulvi et al., 2012; Cropley, 2023; Dean et al., 2006; Horn & Salvendy, 2006; Kudrowitz & Wallace, 2013; O'Quin & Besemer, 2006; Shah et al., 2003). In spite of their subjectivity, there are quick application metrics, such as SWOT, QFD, Pugh Matrix (Guler & Petrisor, 2021), Weighted Decision Matrix, etc., that allow decisions to be made in early design stages. Some qualitative metrics (Cropley, 2023), such as CPSS (O'Quin & Besemer, 2006), RIBS (Runco et al., 2014), CSDS (Cropley & Kaufman, 2013), KEYS (Amabile et al., 1995), SPAF (Horn & Salvendy, 2006)or PCMI (Horn & Salvendy, 2009), increase the number of dimensions to better define the creative product.

Quantitative metrics designed to measure and assess dimensions based on goal achievement (i.e., time, weight, speed, etc. or number of ideas, valid solutions, etc.) are more precise in terms of their indicators, but leave some intangible characteristics not assessed (López-Forniés, 2022; Oman et al., 2013). Assessment based on evidence-centred design (Riconscente et al., 2015) serves to validate both functionality and operability by means of prototypes or functional models. Additionally, there are metrics based on data and mathematical function, used to solve complex problems, which are applicable when the product has reached a mature stage and numerical data for each dimension can be obtained. These metrics are based on Multi-Criteria Decision Making (MCDM) methods and there is a wide selection applicable to the diversity of problems encountered in any knowledge area.

Hybrid metrics mix qualitative and quantitative dimensions to cover a wider range of dimensions. These metrics analyse product-specific dimensions, such as novelty, utility and feasibility, in addition to measurable factors, such as cost, environmental impact, among others (López-Forniés et al., 2017). Qualitative aspects include creativity like originality, flexibility and usefulness, together with numerical values like number of ideas or number of idea clusters, as in the Creative Engineering Design assessment (CEDA) (Charyton, 2013). There are metrics that replace Likert scales with levels of satisfaction for a criterion. The objective of each criterion is defined by a question and answers are established by marking the levels of satisfaction of the criterion to, thus, not make a subjective assessment between two extremes with intermediate points, but to choose the answer that comes qualitatively closer to the evaluated product (López-Forniés et al., 2023; Sierra-Pérez et al., 2016, 2021).

The metrics in this document work based on the satisfaction of criteria according to a series of responses related to five levels ranging from 0 to 4 for each indicator. This evaluation has been previously tested in the design of prosumer products (Asión-Suñer and López-Forniés, 2023). Table 3 establishes the concept evaluation metric (M1) that is used after the ideation phase. Table 4 does the same for the evaluation metric (M2) of fully developed concepts.

Table 3. Dimensions and levels for the metric M1 assessing the product concept metrics.

Product complexity	
4	A unique piece made of a single material with limited functionality
3	A few components that are easy to integrate with low functionality
2	The product is simple in components and integration terms, but requires instrumental and/or technical skills
1	High difficulty level due to the number of components and technologies to be integrated
0	The product is extremely complex and requires high skill levels, knowledge and overcoming instrumental difficulties
Prosumer capabilities	
4	Both levels are high. It has profound knowledge of the problem or need, and possesses exceptional manufacturing skills. It can apply a creative and disruptive approach to develop unique and ground-breaking solutions
3	One level is high and the other is medium. It can tackle highly complex projects that require completely mastering many disciplines and using cutting-edge technologies
2	Both levels are medium. It can combine different disciplines and use more sophisticated tools and technologies to develop more complex solutions
1	One level is normal and the other is low. It can research and understand available options, and apply more advanced techniques in its manufacturing
0	Both levels are low. It may have a general idea of what it wants to achieve and some practical skills to create simple objects
Materialisation	
4	The product redefines the market or industry by generating a significant impact and changing how the problem is addressed
3	The product stands out for its originality and provides users with added value
2	The product achieves a high level of functionality, quality and user satisfaction
1	The product effectively meets the need and exceeds basic expectations
0	The product meets the basic need, but may have limitations as regards performance or finish

Table 4. Dimension and levels for the metric M2 assessment of the materialised product.

Knowledge (K1, K2)	
4	It has successfully addressed the problem or need with profound knowledge and exceptional manufacturing skills. The prosumer designer has applied a creative and disruptive approach to develop a unique solution
3	The prosumer designer has tackled a project that requires completely mastering many disciplines and using cutting-edge technologies
2	The prosumer designer has combined different disciplines, and utilised sophisticated tools and technologies to develop the solution
1	The prosumer designer has researched and understood the available options, and applied the most appropriate techniques in its fabrication
0	The prosumer designer has a general idea of what achievement is wanted and possesses skills to fabricate objects, but has been unable to fully solve the problem
Feasibility (F)	
4	The product can be entirely manufactured in a prosumer environment and is also easy to disseminate for others to copy or even scale up for industrial production
3	The product can be manufactured in a prosumer environment and is also easy to disseminate for others to copy, but it is not interesting for industrial scale production
2	The product can be partially manufactured in a prosumer environment, but not every prosumer can achieve it, and it requires redesign for industrial scale production
1	The product can only be partially manufactured in a prosumer environment
0	It cannot be manufactured in a prosumer environment
Viability (V1/V2)	
4/V2	The product does not exist on the market, it is completely novel, and there are no similar references
3/V2	The product does not exist on the market, but there are similar references
2/V2	The product exists on the market, but it involves differentiation or customisation (functional, formal, aesthetic, etc.)
1/V2	The product exists on the market, but the differentiation is very basic
0	The product exists on the market and does not present any differentiation
Resources (R)	
4	The material and technological resources are easily accessible, and the technology is of everyday use
3	The material and technological resources are accessible
2	The material resources are accessible, but some technological resources need to be externally used
1	The material and technological resources are not easily accessible, the materials are special and the technology is not household
0	Not all the material and technological resources are easily accessible because either the material resources or the technological resources need to be externally acquired and with difficulties
Satisfaction (S)	
4	The materialised product fully satisfies the prosumer's objectives/requirements, needs and wants, and the product quality is excellent
3	The product fully satisfies the main objective/requirement, needs, and partially fulfils some desires. The product is well finished
2	The product satisfies the main objective, but not all objectives/requirements, needs and wants. The product finish is acceptable
1	The product partially satisfies the main objective or is poorly finished
0	It does not satisfy the needs or wants at all, and is poorly finished
Emotional (E)	
4	It has been designed and generates attachment. Even after its life cycle, it still functions and is kept for sentimental reasons, adaptability updates, and documentation for dissemination

3	Yes, partially, once its life cycle is completed, emotional attachment exists and the object is kept. Although it may be functionally outdated, it serves as documentation
2	Emotional attachment and bond persist, even if there is no functional or documentary contribution
1	The emotional bond is basic (a basic memory remains, archived photo, PDF, blueprints, etc.). It is shown to others. The object is discarded
0	No, it does not generate any emotional attachment. The object is discarded

For judges, Kaufman (2013) found evidence to suggest that a sufficiently detailed and explicit rubric may enable quasi-experts and non-experts to make judgements of product creativity that come close to those made by experts. The judges for M1 and M2 are experts in product design with ample experience in creativity and prosumer design, but can be used by prosumers themselves.

Product Selection

We selected four objects designed by novice designers. All the works are academic in nature and are intended to solve a specific and personal issue. As products differ in function and complexity terms, metrics are tested with a wide range of options.

Two factors were considered in the selection of products. Firstly, each one has a conceptual phase in their design process, which allows them to create initial prototypes suitable for evaluation purposes. Secondly, these products can be constructed using traditional tools (DIY) or those available in a FabLab by sharing a similar level of difficulty when it comes fabricating them.

The four products selected for evaluation are: (A) an autonomous bicycle flashlight; (B) a multifunctional cart; (C) a multiuse washbasin tray; (D) a manual sink dishwasher. They were all developed by the students enrolled for a Degree in Industrial Design and Product Development Engineering. Students are trained and must act as prosumers at the time they are assigned to the project: two as part of a subject work, who are referred to as a "prosumer", and two as part of final degree works. All four students have a similar level of knowledge and ability to learn to create and test prototypes in order to assess the functionality of the developed product.

All the products followed the same creation process and were fully comparable during the evaluation because they are all based on the prosumer's needs. Firstly, the prosumer defines a personal problem that is his/her own, which must be solved throughout its project. Secondly, during ideation, a constructive, functional and formal exploration is done. Finally, the solution is completed, and a prototype is developed to evaluate functionality and its formal and aesthetic aspects with near-final finishes.

Results

An overview of each product is presented in the form of a datasheet, which includes not only images, but also a description of its prosumer nature. It also explains how each design scores for indicators. These designs were selected from dozens of examples to show optimal, acceptable and rejectable results. This sample provides objective sampling that allows the type of projects being undertaken in the prosumer field to be interpreted, which reveals the drivers and barriers for designs that facilitate open discussion.

Concept A. Autonomous bicycle flashlight

Table 5. Datasheet A. Description according to each indicator of the autonomous flashlight.

P	The 3D printing process allows for customization, updates, and improvements to be made to the product at any time. Prosumers participate in the entire development process, from material retrieval to design, manufacturing, fitting, and editing. The product's performance is enhanced through iterative trial and error inspired by

	biomimicry. The development involves 3D printing, electrical circuit calculations, optimization of bio-inspired blades, and the use of a wind tunnel. Manufacturing issues are minimal, and the electronic components are not complex. The innovation lies in an autonomous accumulator that charges during the day and operates independently from the wheel. Overall, this concept is within the prosumer scope and worth pursuing
K1	A generator driven by bio-inspired blades generates its own energy. When in motion, it generates electric current that charges the battery and powers the LED
K2	There are flashlights that mount and dismount on the bike, but their batteries need to be recharged. This design charges the battery with movement. During the day it generates and accumulates energy, at night it generates and consumes energy
S	The object meets the performance specifications. Finding a more suitable motor to improve battery charging may improve the object's performance. Meets all other functions. The prototype evidences satisfactory use, functions and characteristics. The quality of the product is excellent
V1	There are no comparable products on the market, compared to the cost of replacing batteries or recharging them over time. For the time being, bicycle flashlights cannot illuminate autonomously without changing or recharging batteries, except by means of dynamos connected to the wheel. Only flashlights with solar panels can be compared
V2	Prosumer manufacturing cost = €21 Market price = €15 V2 = 21/15= 1,4
F	To manufacture, it is necessary to have basic knowledge of 3D printing, simple electrical assembly for power generation circuits and batteries, and finally, very basic assembly tools available in any home or basic workshop. It has to be made with FabLab tools
E	It can be customized, and new designs can be 3D printed to vary the aesthetics
R	The motor is recycled from a hair dryer, the LED lens is recycled from an old flashlight and the batteries are AAA rechargeable. The 3D printed housings and blades were attached to the bike's handlebars with screws. FabLab tools used

Concept B. Multifunctional adaptable cart

Table 6. Datasheet B. Description according to each indicator of the multifunction cart.

P	This product can be customized and upgraded as a bag or platform by varying the elements that hold the bags. Prosumers play a vital role in the development process and it can be designed, developed, and manufactured with 3D printing and assembly techniques. Despite its simplicity, it has various applications and adaptations have been made in the prosumer field. Despite its simplicity, it has a wide variety of applications. Adaptations, transformations, or new designs have already been implemented in the prosumer realm
K1	It is a trolley that can be used for domestic or professional purposes. The trolley is foldable and extendable
K2	Many carts are available on the market that can be adapted to various functions and changed. Nevertheless, this design is unique in that each user can decide how to use, update, and configure by its modules

S	It fulfils the initial design objectives and includes some new features such as folding. The modular functions of replacing and changing bags, etc., are satisfactory. The prototype demonstrates satisfactory use, functions, and features of the object. The product is well finished
V1	It meets the original design objectives and includes new features like folding. Bag replacement and changing functions are satisfactory. An acceptable prototype demonstrates the product's functions, features, and uses
V2	Prosumer manufacturing cost = €57.70 Market price = €30 V2 = 0.52
F	Design and 3D printing knowledge are required to manufacture this product. Every home or basic workshop should have some assembly tools. PVC pipes and wheels need to be acquired or recovered. It can be made with FabLab tools and/or DIY process.
E	Since it is highly functional and does not stand out in terms of aesthetics, it is unlikely to create attachment
R	The connecting parts are made with 3D printing, the tubes are standard PVC purchased or reused. The wheels were purchased because of the difficulty of 3D printing. Other elements are recycled screws or purchased from hardware stores. Finally, FabLab and DIY making process are used

Concept C. Multiuse washbasin tray

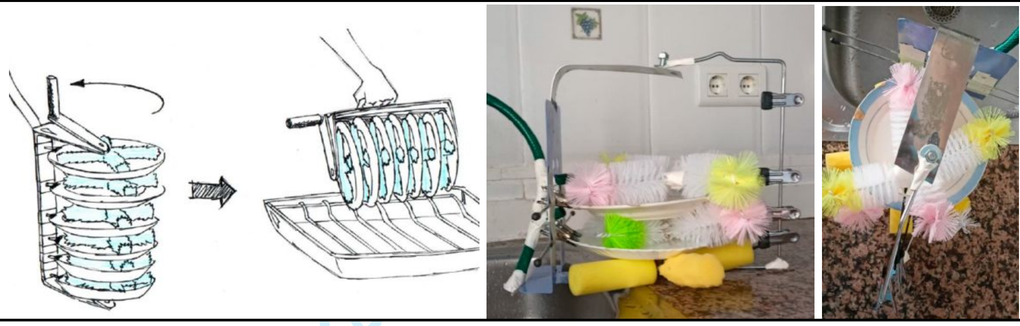
Table 7. Datasheet C. Description according to each indicator of the washbasin tray.

P	It can be customized and upgraded at any time to fit different sizes. Prosumer involvement is integral to the entire development process, from design to product fit. Conceptually, it is easy to design and manufacture. It can be manufactured with traditional tooling or laser cutting technology for better finishes. Being simple, it effectively solves a particular problem not addressed by the market. The user's own experience generates knowledge. Conceptually, it meets the objectives set in advance. Because of its simplicity and development possibilities, it has great potential and little risk of failure.
K1	It is a product that sits on the sink to offer a stable surface with various functionalities. Its function can be likened to a washbasin tray or a bathroom auxiliary cart
K2	College dorms and small student apartments have limited space, especially in bathrooms, which lack support surfaces. It is used as a drainer, support surface, etc., increasing the functionality of the sink
S	Meets the initial objectives. Worktop replacement and exchange are fully satisfactory. There is no storage function for the unused worktop (neither smooth nor perforated). The prototype shows satisfactory use, functions and features. The quality of the product is excellent
V1	Affordable materials and simple fabrication reduce costs. Costs depend on choice of materials and finishes. Upgrades, maintenance and replacement are easy. Solves a very specific problem, not widely available on the market. Only one similar product exists
V2	Prosumer manufacturing cost = €14.60 Market price = €25 (free laser cutting at a public FabLab/city council) V2 = 0,6

F	Prosumers can make it with hand tools (saw and drill). As a first test, the cardboard worked well. Laser or CNC cutting can be used to obtain more precise finishes. It can be made with FabLab tools and/or DIY process
E	It can create attachment as it is customizable and the aesthetics can be varied
R	This product is made from recycled or acquired plastic sheets of 4 or 5 mm, in transparent or opaque colours as needed. Lasers are used to cut, although a jigsaw can also be used and then the edges need to be sanded and refined. FabLab tools used

Concept D. Manual sink dishwasher

Table 8. Datasheet D. Description according to each indicator of the manual dishwasher.



P	It can be customized, updated, and repaired to fit different dishes. From design to manufacturing, the prosumer is involved at every step. As a modular element, modules can be implemented for different tableware pieces. A complex system involves many undeveloped parts moving together. Results will be determined during the conceptual phase by testing and resources dedicated to design and prototyping. It is more complex functionally and structurally than it appears, so having a clear vision is crucial. The product could be exemplary if the desired results are achieved, but manufacturing is an issue. Unless it provides significant functional, economic, or emotional benefits, it should not be developed
K1	Water-saving dishwashing device that cleans small dishes in the sink
K2	Dishwashing dissatisfies. One by one, washing and draining is tedious. Dishwashers require space, electricity, and excessive water consumption, designed for families, not for singles. Dishes must be rinsed before washing, as they do not clean well
S	Operation is rough and imprecise; design specifications are not met. Dimensions, finishes, and details make the operation inadequate. There are design and manufacturing problems in the prototype. The product is poorly finished
V1	Economical due to the number of dishes to wash. Construction, maintenance, and repairability must be taken into account, but dishwashers, electricity, and water savings make it feasible. Sink dishwashers with drainers and manual operation are unavailable. Couples or singles can use small appliances. The only reference found is a conceptual design by a student [https://inhabitat.com/hand-powered-circo-independent-dishwasher-saves-time-space-money-and-water/], and there are motorized washers, but they are conceptually different
V2	Prosumer manufacturing cost = approx. €15.00 Market price = No market reference V2 = 1.72 (lowest of the other concepts)
F	It is a complex and challenging device to build; initial assembly and fitting issues exist. The first design lacks robustness and durability. It is necessary to test direct water use at different pressures and to ensure that there are no leaks. It can be made with FabLab tools and/or DIY process
E	High functionality makes it unlikely to generate attachment. It performs an undesirable function, and it must perform well to generate an emotional connection
R	Materials used for construction include hangers, flexible water tubes, adhesives, etc. Washing sponges, brushes, and scouring pads have been acquired. DIY making process

Metric assessment

Table 9 provides a summary of the results obtained by applying both metrics. Figure 2 shows the scores for each dimension in all the concepts.

Table 9. Summarized results of both metrics for the selected products.

M1 Prosumer concepts				
Dimension/Product	A	B	C	D
Product complexity	3	3	4	0
Prosumer capabilities	2	2	3	1
Materialization	3	2	2	0
	8	**7**	**9**	**1**
M2 Prosumer materialized products				
Dimension/Product	A	B	C	D
Knowledge (K1, K2)	2	2	3	0
Feasibility (F)	4	3	4	1
Viability (V1)	3	1	3	4
Cost ratio (V2)	1,4	1,9	0,6	0,6
Viability (V1/V2)	2,1	0,5	5,1	6,8
Resources (R)	3	4	4	2
Satisfaction (S)	4	3	4	1
Emotional (E)	4	2	3	1
	23,5	17,4	26,7	16,4

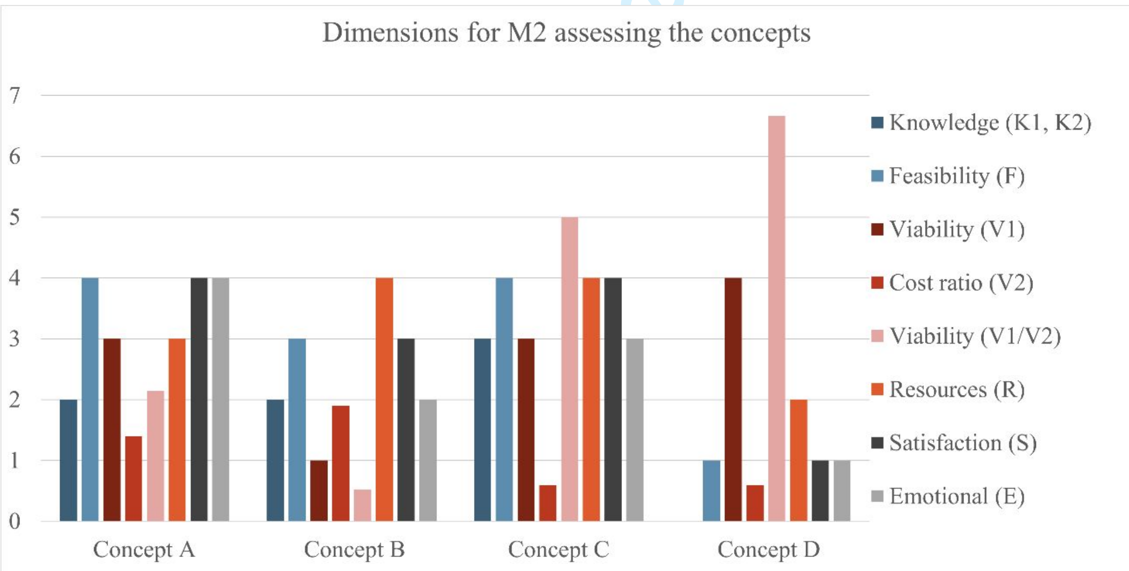


Figure 2. Results for concept assessment with metric M2.

For the concept evaluation phase, Table 9 reveals that Concepts A and C clearly meet the expectations to be developed as fully prosumer products given their high scores. M1 shows that Concept D should not be further developed due to its low score, and given its complexity and the difficulty of materialisation. Concepts A, B and C move to the next design phase without hesitation. M2 scores and Figure 2 show the differences in Concepts A and C compared to Concepts B and D, and Concept B does not satisfactorily meet the initial expectations.

As concepts move into the development and prototyping phase, the evaluation of the remaining dimensions provides scores for meeting the initial expectations. The analysis of the individual indicators shows clear differences between evaluated the concepts (Figure 2). The importance of knowledge (K) indicators K1 and K2 decreases not only because of the lower weight assigned to them in the evaluations, but also because, if the concept passes the first evaluation with M1, knowledge is assumed in the next stage.

The feasibility (F) and resource (R) indicators are instrumental and may depend on the prosumer's geographic location, access to material and technological resources, the tools utilised, etc. The scores are similar for M1, but Concept D scores very low.

In value contribution (V) terms, Concept D obtains the highest score in V2 due to the presented innovation and the good price-to-cost ratio. For satisfaction (S), which indicates acceptance, the product D scores are very low due to the difficulty of developing a functional prototype and the poor quality of the construction finishes.

It is impossible to accurately evaluate the emotional (E) and attachment indicators until a certain time period has elapsed. So it is necessary to directly inquire with the prosumer to determine if any emotional connection has been established with the designed and constructed object.

Discussion

Metrics are used to evaluate the performance of new products, including whether they increasingly focus on external issues, such as end users' needs and satisfaction (Sun et al., 2023), or providing internal issues like establishing goals, assisting with the planning, decision making, and execution of new product development, and for assessing or reviewing design process performance (Tatikonda, 2007). One external aspect, such as social impact and an internal one like finished product quality can, despite their importance, hardly be evaluated by the application of both metrics. So these aspects are to be studied by future work in more mature commercialisation and use phases. This paper evaluates dimensions like satisfaction (S) and emotion (E) by the performance and product finish, and dimensions likes viability and feasibility (V1, V2 and F), to evaluate the social impact and market potential in a limited way.

Hybrid metrics based on criteria satisfaction are useful for evaluating concepts and products, and can help to convert qualitative indicators into quantitative ones. However, these metrics lack precision when concepts can fall between two values. Its use does not completely eliminate subjectivity, but positions the concept at a level that improves evaluators' decision making (López-Forniés, 2021). These metrics are more useful for expert evaluators than for beginners who may need the help of an expert, a professional or an educator. As prosumers do not usually apply evaluation metrics and make decisions intuitively, it is necessary to adapt the metrics to their knowledge. The quantitative metrics used in engineering design are too complex to be used by non specialized users. Thus score-based metrics are more understandable and easier to execute.

In the concept evaluation phase, some concepts should not be further developed because they do not meet the minimum requirements for potential success. M1 can be valuable for assessing future design and development challenges, and for the answers RQ1 on the potential for product ideas to become fully developed products. Furthermore, M1 can anticipate failure or success depending on the complexity level by answering RQ2. The complexity indicator is crucial because it affects the need to acquire or develop specific knowledge related to the problem to be solved and to the product design and manufacture. The "prosumer capabilities" and "materialisation" indicators provide informative value because they warn about what may occur during development. The M1 value lies in screening ideas before embarking on a prototyping process that can consume time, material and financial resources, and can potentially lead to frustration. Based on the obtained product D scores, the decision is to abandon and continue the ideation process to explore less complex concepts. Beforehand, we do not assume complexity as a pass-fail filter or whether it should be weighted above the other dimensions to further emphasise the results, but it should be considered a condition to continue or abandon. The "knowledge" dimension plays an important role in concept evaluation given the uncertainty surrounding complexity and the ability to effectively solve the concept. However, K1 and K2 are not as important in product evaluation because development places the product at a different level. When the concept moves beyond the conceptual phase, the prosumer is familiar with the problem, knows its performance or has access to necessary knowledge and technology. If the "prosumer capability" factor in the conceptualisation phase obtains intermediate values, it indicates the possibility of successfully solving the design, but highlights feasibility challenges due to lack of knowledge, experience or tools for home manufacturing. The prototyping and product refinement phase reflects the ease or difficulty of achieving satisfactory results and the possibility of reproducing the design at the industrial level with the necessary adjustments by allowing the prosumer's individual innovation results to be transferred to the industrial environment (Ziemba & Eisenbardt, 2015).

The M2 metric focuses on outcomes that affect the prosumer's own experience as a producer and acceptance as a consumer. It is essential to use ex-post metrics to assess the prosumer's achievement of design objectives and performance, as well as the feasibility, and the material, economic and emotional aspects, of the design itself. The M2 scores are indicators of success or failure as a response to RQ2. It is important to analyse the M2 scores because they can influence acceptance or rejection based on their functionality, performance, resources and quality of finish. M2 indicates positive and negative aspects to be improved in the next design. Although M2 does not serve as a formal decision-making tool resoundingly, it generates knowledge through the experience of creating a product, and reflects on whether its performance is optimal, acceptable or unacceptable.

The indicator of product value and innovation on the market, which initially does not seem crucial, becomes prominent when positioning each product. When the novelty level (V1) is high, there may be industry interest in replicating this concept (Seran & Izvercian, 2014). Prosumers do not disseminate their results even if they do not mind others using them as long as they serve their purpose. Consequently, prosumer projects are not sufficiently widespread and visible. So their impact on society cannot be measured because they are only accessible in a very limited context. By applying the V2 factor, interesting ideas are better defined. For Concept A, a higher cost compared to the market price is not an obstacle for the prosumer or for others who copy it, while cost-saving cases increase the feasibility for industrial-scale production. Costs are calculated for a handcrafted production of a few units, which can be exponentially reduced in industrial scale production by making them more profitable to acquire. An interesting example is Concept D which, despite its difficulty, if a functional unit is tested and improved iteratively to give satisfactory results, it could respond to a market niche that has not yet been exploited.

Material and technological resources are unlikely to be a limitation in the future, unless very exclusive materials or industrial technologies are used that are not accessible due to economic barriers in investments, industrial scale or the technological exclusivity of companies (Richardson & Haylock, 2012).

Prosumer users tend to acquire, transform or build their own tools. With access to home fabrication or by frequenting digital fabrication labs, they can obtain high-quality results for their designs at a very affordable cost. In Concept C, it is noted that the material is easy to obtain and cutting is possible by various technologies, but laser cutting provides a quality level that makes the object appealing and clean with high-quality finishes. The same is true for Concept A that, thanks to it having its own printer and hand tools, the prosumer is able to manufacture several prototypes for various tests run in the wind tunnel.

Prosumer satisfaction (S) depends on how well or how poor the product performs its function (Farmer, 2018), and the perceived quality of the finish can be decisive for future projects. Attachment is difficult to assess and has a personal bias. As this is an indicator that cannot be objectively measured externally, it is necessary to consult those prosumers who have developed and used products for a long period and obtained individual responses.

It is important to acknowledge and address imitations. We discuss three key limitations that researchers often encounter and need to consider. One common limitation is the challenge of effectively handling metrics. Metrics, which are used to measure particular dimensions, can be complex and difficult to define, and imprecise on a 5-point Likert scale that can be subjective. Introducing responses that gradually respond to the satisfaction of a condition orients and simplifies the judge's evaluation. When dimensions are properly defined and levelled against an objective criterion, they help to qualitatively assess whether subjectivity can become a problem. By establishing their key dimensions, researchers can better identify and address potential biases in advance to avoid subjective interpretations, which could form part of future work.

Another limitation is a bias in the selection of dimensions, researchers' previous experience and their familiarity with specific metrics all affect their choice. It is essential to be aware of this bias and to attempt to minimise it by a careful selection and definition of the employed dimensions. Abstract dimensions, such as emotional attachment, may be imprecise given their personal nature, and must be assessed both specifically and independently.

The third limitation is the few analysed products. Within the framework of this research, four objects with differences in complexity and degrees of definition are selected as a sample to obtain diverse results. In future work, other researchers will be able to increase sample size and to compare similar products in functionality and complexity terms.

Conclusions

Evaluating prosumers' ideas and concepts is essential to anticipate their success or failure when they are fully developed. Needs and wants motivate prosumers to iteratively create and improve products that address their own problems, and evaluating compliance with their requirements is necessary.

The M1 metric evaluates the initial ideas, and it is crucial to validate concepts due to its complexity, which is presented as a critical dimension. Capabilities and resource availability have less influence on the development of success or failure.

The M2 metric evaluates products developed ex-post by indicating which factors are critical and those that most influence product performance.

Material and technological resources, including access to manufacturing tools and techniques, influence the realisation of prosumers' designs. Performance, functionality and satisfaction with the final product are essential for determining its acceptance and potential for future development. Emotional attachment to self-created objects is a subjective factor that requires individual evaluation and further research.

These results highlight the importance of evaluating prosumers' ideas by taking into account several factors that influence their success, and the need to define dimensions and indicators to improve a subsequent development process.

It is difficult to separate the different dimensions of a prosumer domain: the human, the object, the process or the project management itself. The human dimension of a prosumer designer is inseparable from the other dimensions due to experience and knowledge in design and manufacturing. For the prosumer designer, who usually works alone and is self-taught, establishing a good process, manufacturing the best object and managing the project's resources are intrinsically related to the creation of his/her best design.

References

Amabile, T. M., Burnside, R., & Gryskiewicz, S. S. (1995). *User's guide for KEYS: Assessing the climate for creativity*.

Arıkan, E., Fichtinger, J., & Ries, J. M. (2014). Impact of transportation lead-time variability on the economic and environmental performance of inventory systems. *International Journal of Production Economics*, *157*, 279–288.

Aronsson, H., & Brodin, M. H. (2006). The environmental impact of changing logistics structures. *International Journal of Logistics Management*, *17*(3), 394–415. https://doi.org/https://doi.org/10.1108/09574090610717545

Asión Suñer, L., & López Forniés, I. (2022). *El diseño modular en la creación de productos para prosumer*. Universidad de Zaragoza.

Asión-Suñer, L., & López-Forniés, I. (2020). Prosumer and Product Design Through Digital Tools. In *Lecture Notes in Mechanical Engineering* (pp. 23–30). Springer International Publishing. https://doi.org/10.1007/978-3-030-41200-5_3

Asión-Suñer, L., & López-Forniés, I. (2021a). Adoption of modular design by makers and prosumers. A survey. *Proceedings of the Design Society*, *1*, 355–364.

Asión-Suñer, L., & López-Forniés, I. (2021b). Analysis of Modular Design Applicable in Prosumer Scope. Guideline in the Creation of a New Modular Design Model. In *Applied Sciences* (Vol. 11, Issue 22). https://doi.org/10.3390/app112210620

Asión-Suñer, L., & López-Forniés, I. (2022). Validation of a New Evaluation Method of Modular Design Focused on the Prosumer. *Proceedings of the Design Society*, *2*, 313–322. https://doi.org/10.1017/pds.2022.33

Asión-Suñer, L., & López-Forniés, I. (2023). Evaluation Method of Modular Products for the Prosumer. Proposal and Improvement. *Lecture Notes in Mechanical Engineering*. https://doi.org/10.1007/978-3-031-15928-2_29

Bartodziej, C. J. (2017). The concept industry 4.0. In *The concept industry 4.0* (pp. 27–50). Springer.

Bartolini, M., Bottani, E., & Grosse, E. H. (2019). Green warehousing: Systematic literature review and bibliometric analysis. *Journal of Cleaner Production*, *226*, 242–258. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.04.055

Bauer, T., Mandil, G., Monnier, É., & Zwolinski, P. (2021). Design for cascading applications reuse–understandings of an emerging end-of-use strategy and propositions for its implementation. *Journal of Engineering Design*, *32*(3). https://doi.org/10.1080/09544828.2020.1871470

Blikstein, P. (2013). Digital fabrication and 'making'in education: The democratization of invention. *FabLabs: Of Machines, Makers and Inventors*, *4*(1), 1–21.

Charyton, C. (2013). *Creative engineering design assessment: background, directions, manual, scoring guide and uses*. Springer Science & Business Media.

Chulvi, V., Mulet, E., & González-Cruz, M. C. (2012). Measure of product creativity: Metrics and objectivity. *Dyna*, *87*(1), 80–89. http://www.scopus.com/inward/record.url?eid=2-s2.0-84858259010&partnerID=40&md5=57fd6c6bcf53b236809f19c8354d90f3

Cropley, D. H. (2023). *A Review of Approaches to the Assessment of Product Creativity*.

Cropley, D. H., & Kaufman, J. C. (2013). Rating the creativity of products. In *Handbook of research on creativity*. Edward Elgar Publishing.

Czuba, M. (2017). Prosumption as a factor of sustainable development. *Problemy Ekorozwoju*, *12*(1), 55–61. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85007564195&partnerID=40&md5=e22c204fed709431d16b3ee1183827fb

Dean, D. L., Hender, J. M., Rodgers, T. L., & Santanen, E. L. (2006). Identifying Quality, Novel, and Creative Ideas: Constructs and Scales for Idea Evaluation. *Journal of the Association for Information Systems*, *7*(10), 646–698. https://doi.org/Article

Farmer, N. M. (2018). *Maker meaning: An exploration of the maker movement, career adaptability, and life satisfaction* [Thesis Dissertation, University of Kansas].

https://kuscholarworks.ku.edu/bitstream/handle/1808/27552/Farmer_ku_0099D_15836_DATA_1.pdf?sequence=1

Guler, K., & Petrisor, D. M. (2021). A Pugh Matrix based product development model for increased small design team efficiency. *Cogent Engineering*, *8*(1), 1923383.

Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., & Aliakseyeu, D. (2018). Emotional durability design nine—A tool for product longevity. *Sustainability*, *10*(6), 1948.

Horn, D., & Salvendy, G. (2006). Product creativity: conceptual model, measurement and characteristics. *Theoretical Issues in Ergonomics Science*, *7*(4), 395–412.

Horn, D., & Salvendy, G. (2009). Measuring consumer perception of product creativity: Impact on satisfaction and purchasability. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *19*(3), 223–240.

Kaufman, J. C., Baer, J., Cropley, D. H., Reiter-Palmon, R., & Sinnett, S. (2013). Furious activity vs. understanding: How much expertise is needed to evaluate creative work? *Psychology of Aesthetics, Creativity, and the Arts*, *7*(4), 332.

Knott, S. (2013). Design in the Age of Prosumption: The Craft of Design after the Object. *Design and Culture*, *5*(1), 45–67. https://doi.org/10.2752/175470813X13491105785587

Kohtala, C., Hyysalo, S., & Whalen, J. (2020). A taxonomy of users' active design engagement in the 21st century. *Design Studies*, *67*, 27–54.

Kudrowitz, B. M., & Wallace, D. (2013). Assessing the quality of ideas from prolific, early-stage product ideation. *Journal of Engineering Design*, *24*(2), 120–139. https://doi.org/10.1080/09544828.2012.676633

Lang, B., Botha, E., Robertson, J., Kemper, J. A., Dolan, R., & Kietzmann, J. (2020). How to grow the sharing economy? Create Prosumers! *Australasian Marketing Journal*, *28*(3), 58–66. https://doi.org/10.1016/j.ausmj.2020.06.012

Lang, B., Dolan, R., Kemper, J., & Northey, G. (2021). Prosumers in times of crisis: definition, archetypes and implications. *Journal of Service Management*, *32*(2), 176–189. https://doi.org/10.1108/JOSM-05-2020-0155

Lehner, M. (2019). Prosumption for sustainable consumption and its implications for sustainable consumption governance. *A Research Agenda for Sustainable Consumption Governance*, 105–120.

Li, S., Hou, L., Chen, Z., Wang, S., & Bu, X. (2023). Uncertainty modeling and applications for operating data-driven inverse design. *Journal of Engineering Design*, *34*(2). https://doi.org/10.1080/09544828.2023.2180846

Liao, S.-H., Hsieh, C.-L., & Huang, S.-P. (2008). Mining product maps for new product development. *Expert Systems with Applications*, *34*(1), 50–62. https://doi.org/https://doi.org/10.1016/j.eswa.2006.08.027

López-Forniés, I. (2021). Game-Based Learning and Assessment of Creative Challenges Through Artefact Development. In *Smart Pedagogy of Game-based Learning* (pp. 1–20). Springer International Publishing. https://doi.org/10.1007/978-3-030-76986-4_1

López-Forniés, I. (2022). Concept Assessment Using Objective-Based Metrics on Functional Models. *Design Tools and Methods in Industrial Engineering II: Proceedings of the Second International Conference on Design Tools and Methods in Industrial Engineering, ADM 2021, September 9–10, 2021, Rome, Italy*, 320–327.

López-Forniés, I., Aguerri Galindo, Á., & Sierra-Pérez, J. (2023). Circular Strategies to Improve Ephemeral Products Sustainability Through Co-creation and Its Metrics. In *Lecture Notes in Mechanical Engineering*. https://doi.org/10.1007/978-3-031-15928-2_5

López-Forniés, I., & Asión-Suñer, L. (2023). Self-commissioning, Intuition and Prosumer. *Proyecta56, an Industrial Design Journal*, *3*, 109–137. https://doi.org/https://doi.org/10.25267/P56-IDJ.2023.i3.07

López-Forniés, I., Sierra-Pérez, J., Boschmonart-Rives, J., & Gabarrell, X. (2017). Metric for measuring the effectiveness of an eco-ideation process. *Journal of Cleaner Production*, *162*, 865–874. https://doi.org/10.1016/j.jclepro.2017.06.138

Maurya, S., Mougenot, C., & Takeda, Y. (2021). Impact of mixed reality implementation on early-stage interactive product design process. *Journal of Engineering Design*, *32*(1). https://doi.org/10.1080/09544828.2020.1851662

Medkova, K., & Fifield, B. (2016). Circular design-design for circular economy. *Lahti Cleantech Annual Review*, *32*.

Menichinelli, M., & Schmidt, A. G. S. (2019). First exploratory geographical and social maps of the maker movement. *European Journal of Creative Practices in Cities and Landscapes*, *2*(2), 35–62.

Metta, J., & Bachus, K. (2020). Mapping the circular maker movement: from a literature review to a circular maker passport. *Deliverable*, *2*, 68.

Millard, J., Sorivelle, M. N., Katsikis, O. K., Unterfrauner, E., & Voigt, C. (2017). The maker movement in Europe: empirical and practitioner insights into sustainability. *EPiC Ser. Comput*, *52*, 227–242.

Millard, J., Sorivelle, M. N., Katsikis, O. K., Unterfrauner, E., & Voigt, C. (2018). The maker movement in Europe: empirical and practitioner insights into sustainability. *ICT4S2018 (EPiC Series in Computing)*, *52*, 227–242.

Mollajan, A., & Iranmanesh, S. H. (2021). Modularisation of system architecture to improve system recoverability: a unique application of design structure matrix. *Journal of Engineering Design*, *32*(12). https://doi.org/10.1080/09544828.2021.1971634

Mugge, R., Schoormans, J. P. L., & Schifferstein, H. N. J. (2009). Emotional bonding with personalised products. *Journal of Engineering Design*, *20*(5), 467–476. https://doi.org/10.1080/09544820802698550

Nielsen, K. R., Reisch, L. A., & Thøgersen, J. (2014). *Users, Innovation and Sustainability: The role of end-users and policy makers in sustainable innovation*.

Oman, S. K., Tumer, I. Y., Wood, K., & Seepersad, C. (2013). A comparison of creativity and innovation metrics and sample validation through in-class design projects. *Research in Engineering Design*, *24*, 65–92.

O'Quin, K., & Besemer, S. P. (1999). *Creative Products. I: Runco, MA & SR Pritzker (eds.) Encyclopedia of Creativity*. San Diego: Academic Press.

O'Quin, K., & Besemer, S. P. (2006). Using the Creative Product Semantic Scale as a Metric for Results-Oriented Business. *Creativity and Innovation Management*, *15*(1), 34–44. https://doi.org/10.1111/j.1467-8691.2006.00367.x

Pavlopoulou, Y. (2020). European framework conditions of the Circular Collaborative Production. *Pop-Machina, D*, *2*.

Richardson, M., & Haylock, B. (2012). Designer/maker: the rise of additive manufacturing, domestic-scale production and the possible implications for the automotive industry. *Computer-Aided Design & Applications PACE*, *2*, 33–48.

Riconscente, M. M., Mislevy, R. J., & Corrigan, S. (2015). Evidence-centered design. In *Handbook of test development* (pp. 40–63). Routledge.

Ritzer, G., Dean, P., & Jurgenson, N. (2012). The coming of age of the prosumer. *American Behavioral Scientist*, *56*(4), 379–398.

Ritzer, G., & Jurgenson, N. (2010). Production, Consumption, Prosumption: The Nature of Capitalism in the Age of the Digital `Prosumer'. In *JOURNAL OF CONSUMER CULTURE* (Vol. 10, Issue 1, pp. 13–36). http://explore.bl.uk/primo_library/libweb/action/display.do?tabs=detailsTab&gathStatTab=true&ct=display&fn=search&doc=ETOCRN267985647&indx=1&recIds=ETOCRN267985647

Rosa, P., Ferretti, F., Pereira, Â. G., Panella, F., & Wanner, M. (2017). Overview of the maker movement in the European Union. *Publications Office of the European Union, Luxembourg*.

Runco, M. A., Walczyk, J. J., Acar, S., Cowger, E. L., Simundson, M., & Tripp, S. (2014). The incremental validity of a short form of the ideational behavior scale and usefulness of distractor, contraindicative, and lie scales. *Journal of Creative Behavior*, *48*(3). https://doi.org/10.1002/jocb.47

Seran, S., & Izvercian, M. (2014). Prosumer engagement in innovation strategies: The prosumer creativity and focus model. *Management Decision*, *52*(10), 1968–1980.

Shah, J. J., Smith, S. M., & Vargas-Hernandez, N. (2003). Metrics for measuring ideation effectiveness. *Design Studies*, *24*(2), 111–134. https://doi.org/10.1016/S0142-694X(02)00034-0

Sierra-Pérez, J., López-Forniés, I., Boschmonart-Rives, J., & Gabarrell, X. (2016). Introducing eco-ideation and creativity techniques to increase and diversify the applications of eco-materials: The case of cork in the building sector. *Journal of Cleaner Production*, *137*, 606–616. https://doi.org/10.1016/j.jclepro.2016.07.121

Sierra-Pérez, J., Vallés, M. A., & López-Forniés, I. (2021). Conceptualization in the circular economy: Analysing the influence of thinking profiles in creative groups. *Journal of Cleaner Production*, *316*. https://doi.org/10.1016/j.jclepro.2021.128287

Song, D., Yuan, W., Chao, M. A., & Han, T. (2022). A modular visuo-haptic mixed reality (VHMR) aided prototype technique for in-vehicle human-machine interaction (HMI) evaluations. *Journal of Engineering Design*, *33*(12). https://doi.org/10.1080/09544828.2022.2158556

Sun, H., Ong, S. K., Nee, A. Y. C., & Guo, W. (2023). A customer requirements analysis method of considering product scenarios for improving product design. *Journal of Engineering Design*, *34*(5–6). https://doi.org/10.1080/09544828.2023.2225843

Tapscott, D., & Williams, A. D. (2008). *Wikinomics: How mass collaboration changes everything*. Penguin.

Tatikonda, M. V. (2007). Product development performance measurement. In *Handbook of new product development management* (pp. 199–216). Routledge.

Toffler, A. (1980). The Third Wave. In *The Ultimate Business Library, Wiley*. Wiley. https://search.credoreference.com/content/entry/wileyultbuslib/alvin_toffler_the_third_wave_1980/0

Unterfrauner, E., Voigt, C., Schrammel, M., & Menichinelli, M. (2017). The Maker Movement and the disruption of the producer-consumer relation. *International Conference on Internet Science*, 113–125.

Von Hippel, E. (2017). Free innovation by consumers—how producers can benefit. In *Research Technology Management* (Vol. 60, Issue 1). https://doi.org/10.1080/08956308.2017.1255055

Wang, Y., Ma, H.-S., Yang, J.-H., & Wang, K.-S. (2017). Industry 4.0: a way from mass customization to mass personalization production. *Advances in Manufacturing*, *5*, 311–320.

Ziemba, E., & Eisenbardt, M. (2015). Prosumers' participation in business processes. *Online Journal of Applied Knowledge Management*, *3*(1).